PN-ABF-345

INTERNATIONAL WORKSHOP ON EARTHQUAKE INJURY EPIDEMIOLOGY FOR MITIGATION AND RESPONSE

The Johns Hopkins University
Baltimore, Maryland, U.S.A.

July 10-12, 1989

Workshop Organizing Committee:

Dr. Nick Jones, The Johns Hopkins University
Dr. Eric Noji, The Johns Hopkins University
Dr. Gordon Smith, The Johns Hopkins University
Dr. Fred Krimgold, Virginia Polytechnic Institute and State University

Workshop Funded By:

National Science Foundation
National Center for Earthquake Engineering Research
Office of U.S. Foreign Disaster Assistance, Dept. of State
The Hoechst Company

Session Transcriptions Prepared by:

Technical Resources, Inc.
3202 Tower Oaks Boulevard
Rockville, Maryland 20852

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International Workshop on
Earthquake Injury Epidemiology for
Mitigation and Response

The Johns Hopkins University
Baltimore, Maryland, U.S.A.

July 10-12, 1989

Overview and General Introduction

Contained herein are the proceedings of a workshop entitled "Earthquake Injury Epidemiology for Mitigation and Response" held at The Johns Hopkins University, Baltimore, Maryland on July 10–12, 1989. The workshop was organized by Dr. Nicholas P. Jones, Department of Civil Engineering at The Johns Hopkins University, Dr. Fred Krimgold, Institute for Policy Studies, Virginia Polytechnic Institute and State University, Dr. Eric Noji, Department of Emergency Medicine, The Johns Hopkins University, and Dr. Gordon Smith, Injury Prevention Center, The Johns Hopkins University. Principal funding for the workshop was provided by the National Science Foundation (NSF) through Dr. William A. Anderson of the Division of Critical Engineering Systems. Additional support was provided by the National Center for Earthquake Engineering Research in Buffalo, the Office of Foreign Disaster Assistance of the U.S. Department of State Agency for International Development, and the Hoechst Company.

The aims of the workshop are summarized on the announcement distributed with the invitations which is included following this introduction. Participation was by invitation only. The total workshop attendance was around 50, with an average daily attendance of about 45.

The workshop was split into two major components: The first one and a half days were devoted to plenary sessions, where a number of participants presented papers outlining the state-of-the-art in their particular field, as related to earthquake injury epidemiology. The remainder of the second day and the third day were organized into breakout sessions covering various specific aspects of the rather broad and new field of earthquake injury epidemiology. A plenary wrap-up session was held at the conclusion of the breakouts.

Organization of this Document

Contained in these proceedings are:

- Transcriptions of the plenary and breakout sessions.
- The papers presented in the plenary sessions, in order of presentation.
- The material distributed at the breakout sessions.

- An address list of all participants.
- Biosketches of (most of) the participants.
- The organization of the breakout groups.

The transcriptions were performed by Technical Resources Inc. of Rockville, Maryland.

Caveats and Warnings

It was considered a very high priority by the workshop organizers that the proceedings from this workshop be compiled and distributed to all participants and other interested parties as soon as possible after the conclusion of the event. In this way it was felt that much of this useful information would get to the researchers and end users before it was effectively out of date. Final copies of papers and biosketches were requested by July 31, 1989.

It must be noted that due to this attempt to quickly compile the document, there are some potential problems. The transcriptions have been checked by the workshop organizers for gross errors or misrepresentation and these corrected. No attempt has been made to edit the manuscript in detail, and drafts have not been distributed to participants for editing. For this reason, there may be errors and omissions in the reporting of, in particular, the breakout sessions. We apologize, in advance, if this has occurred. If any of the participants find that they have been grossly misrepresented, please notify us immediately and we will distribute an errata to the document. We hope that this will not have occurred, but took that chance in an effort to distribute these proceedings quickly.

Final Comments

The organizers wish to thank, once again, the sponsors of the workshop for enabling the event to be held. We are also indebted to Mr. Sayeed Choudhury, graduate student, Department of Civil Engineering, The Johns Hopkins University for his assistance in organizing the workshop. The assistance of Ms. Gretchen S. Liedtke and Mr. Hal Bowman of JHU during the workshop is also gratefully acknowledged.

We must also thank at this time all the participants for attending and for their contributions. We are very happy with the outcome, and hope that all the attendees found the workshop as informative and enlightening as we did. We encourage the distribution of these proceedings to interested individuals. Limited additional copies are available from the organizers. We sincerely hope that this event will make a significant contribution in the definition and establishment of the infant field of earthquake injury epidemiology and that the dissemination of the material presented in the various forms at the workshop will indeed assist in the enhancement of life safety in future earthquake events.

INTERNATIONAL WORKSHOP ON EARTHQUAKE INJURY EPIDEMIOLOGY FOR MITIGATION AND RESPONSE

will be held at

The Johns Hopkins University
Baltimore, Maryland, U.S.A.

July 10 – 12, 1989.

In a major earthquake, such as the 1985 Mexican or 1988 Armenian events, intensive ground shaking near populated areas can result in the severe damage and even collapse of inadequately-constructed buildings. The potential for loss of life in such a collapse is high, in addition to the economic loss associated with the structure and its contents.

Now is the opportune time for an international workshop on the epidemiology of injuries in natural disasters. The purpose of the workshop is twofold: evaluation and discussion of existing information from past events, and the formulation of a practical set of guidelines for future research and data collection.

The basic objectives of the workshop are the following:

- To review the state of the art in the rather diverse field of disaster epidemiology. This will include reviews of data collected in past events of causes of death and injury patterns.
- To define the field of earthquake injury epidemiology. This includes defining the scope of the problem area and establishment of a research agenda.
- To identify relevant expertise. Who are the individuals/organizations who have made, or have the potential for making, significant contributions in the area.
- To identify and unify relevant sources of data.
- To introduce the problem area to related research communities and begin communication between relevant groups, including architecture, structural engineering, earthquake engineering, emergency medicine, injury epidemiology, search and rescue, occupant safety, and occupant behavior.
- To enhance communication between the research community and the user or practitioner community concerned with life safety in buildings.

Participation is by invitation only; size is restricted to 35 partcipants to ensure significant interaction.

International Workshop on
Earthquake Injury Epidemiology for
Mitigation and Response

The Johns Hopkins University
Baltimore, Maryland, U.S.A.

July 10-12, 1989

I. Welcome and Introductions–Dr. Nick Jones

Dr. Jones welcomed participants to Baltimore and The Johns Hopkins University (JHU) on behalf of the JHU Department of Civil Engineering. He introduced other members of the workshop organizing committee: Dr. Fred Krimgold, architect from the Virginia Polytechnic Institute and State University; Dr. Eric Noji, JHU School of Medicine; and Dr. Gordon Smith, JHU Injury Prevention Center. He acknowledged the support of the National Science Foundation (NSF) as the principal sponsor and Dr. William A. Anderson, Critical Engineering Systems, NSF, as the program director. He also thanked the following organizations, which provided additional funding, and personnel within those organizations, who provided administrative, logistic, and program support: Office of Foreign Disaster Assistance (OFDA) and Dr. Ellery Gray and Oliver Davidson; National Center for Earthquake Engineering Research at the State University of New York at Buffalo and Jelena Pantelic and Ian Buckle; Hoechst Company and Dr. Evangelyn W. Kanabus; and JHU Department of Civil Engineering and Dr. Ross Corotis.

Dr. Jones stated that the goal of the workshop was to define the new and challenging field of earthquake injury epidemiology with the basic objective of enhancing life safety in buildings during earthquakes. He noted that keynote speakers and subsequent presenters would elaborate on research needs and questions relative to understanding the mechanism of the cause of death and injury in earthquake-induced building collapse and damage and applying those findings to improve building design, preparedness, disaster management, search and rescue techniques, medical response, and the recovery process.

Dr. Jones introduced Dr. Steven Muller, President of JHU, and Dr. W. David VandeLinde, Dean of the G.W.C. Whiting School of Engineering, JHU, who welcomed workshop participants on behalf of the University and the Schools of Engineering, Public Health, and Medicine. Dr. Muller briefly reviewed the history of JHU and described its current organizational configuration. He commended the interdisciplinary, international, and service-oriented nature of the workshop and expressed the hope that the experience would be

personally and professionally rewarding to all. Dr. VandeLinde affirmed the President's welcoming remarks and emphasized the valuable contributions to be made by the workshop. He expressed appreciation for the funding provided by the NSF, OFDA, NCEER, and Hoechst Company, as well as the international representation in attendance, and he concluded with a wish for a successful conference.

In presenting logistical and organizational details, Dr. Jones noted that copies of biographical sketches and papers would be distributed along with summaries of the breakout discussions and workshop conclusions. Following that, Dr. Noji welcomed workshop participants and introduced the keynote speaker, Dr. Michel Lechat, Dean of the School of Public Health and

Professor and Chairman of the Department of Epidemiology at the University of Louvain in Brussels, Belgium.

II. Keynote: International Survey on Corporal Damage as Related to Building Structure and Design–Dr. Michel Lechat

Dr. Lechat described the magnitude of the problem from both the historical perspective and potential for future disasters and commended this workshop as a first attempt to address the problem of earthquake injury by bringing together diverse expertise. He discussed the five phases of disaster and the opportunities for mitigation and response activities in each phase, noting that the emphasis has shifted from postdisaster rehabilitation to predisaster planning. Dr. Lechat explored the efficacy of antiseismic building design for reducing injuries and suggested research questions as follows:

- What percentage of the population in earthquake-prone areas is protected by antiseismic construction?

  –What is the cost for complete protection based on an assessment of risk?
  –Are antiseismic buildings affordable everywhere?
  –Where are they needed?
  –What is the cost?

- Can antiseismic design be implemented for housing, apart from the larger buildings, in rural and urban areas?

  –Is it compatible with cultural and social patterns of habitat?
  –What is the cost?
  –How do housing factors relate to trauma?
  –How can education be promoted at the community level?

- What can be done about existing houses? Should they be renovated? destroyed? replaced?

Dr. Lechat concluded that whatever the success of antiseismic engineering, in many areas response will be the prime component of disaster management. He identified research questions related to response as follows:

- What housing structure risk factors are associated with earthquakes, especially in old houses or technologically modified habitats?
- What is the correlation of deaths, casualties, and survival rates with specific types of structures?

In conclusion, Dr. Lechat described the developing interest worldwide in multidisciplinary research on the problem of earthquake mitigation and response and suggested that one outcome of the workshop could be to prepare a preliminary protocol and set forth tasks to guide the research of the future.

In response to a question about the reliability of the figures he had cited on the Armenian, Mexican, and Romanian earthquakes, Dr. Lechat stated that some figures were based on estimates made by medical and rescue personnel onsite and others–notably those from the Armenian earthquake–were extracted from a published paper that was written by an American rescue team on the basis of personal contacts and a survey.

III. Presentations

Earthquake-induced Building Collapse–Fred Krimgold, Virginia Polytechnic Institute and State University, Falls Church, Virginia

Engineering for Earthquakes: Overview and Redefinition of Roles–Nick Jones, Johns Hopkins University, Baltimore, Maryland

Impact of Structures on the Human Population: Injuries in Earthquakes–Eric Noji, Johns Hopkins University, Baltimore, Maryland

Research Issues Involved in Studying the Epidemiology of Injuries Following Earthquakes–Gordon Smith, Johns Hopkins University, Baltimore, Maryland

Earthquake Epidemiology: Spatial and Statistical Aspects–David Alexander, University of Massachusetts, Amherst, Massachusetts

Methodologic Issues in the Epidemiologic Studies of Disasters–Harutoun Armenian, Johns Hopkins, University, Baltimore, Maryland

Assessment of Strategies to Reduce Fatalities in Earthquakes–Andrew Coburn, Cambridge Architectural Research Limited, Cambridge, England

Built Environment and Host Characteristics–Anne Coulson, University of California, Los Angeles, Los Angeles, California

Built Environment and Host Characteristics–Michael Durkin, Durkin and Associates, Woodland Hills, California

Search and Rescue Operations after Earthquakes: Past Experience and a Future Practical Approach–Julio Lescarboura, Oficina de Investigacion Y Proteccion Civil, Caracas, Venezuela

USAR Strategies: Attempting to Minimize Risk–David Hammond, Palo Alto, California

A Computer Model for the Recovery of Trapped People in a Collapsed Building–Keishi Shiono Tokyo Metropolitan University, Tokyo, Japan

Federal Urban Search and Rescue Capabilities in the United States–Laurence Zensinger, Federal Emergency Management Agency, Washington, D.C.

Decade for Natural Disaster Reduction–Riley Chung, National Research Council, Washington, D.C

The Medical Severity Index of Disasters–Bo Brismar, Huddinge University Hospital, Stockholm, Sweden

Effective Utilization of Victim Volunteers in the Emergency Response–Constance Holland, VSP Associates, Sacramento, California

Medical Care of Entrapped Victims in Confined Spaces–Richard Kunkle, Special Medical Response Team, New Florence, Pennsylvania

Measurement of Medical Care Needs Following Earthquakes–Louis E. Mahoney, Health Research and Services Administration, Rockville, Maryland

The Study of Volunteer and Emergent Organizational Response–Dennis Wenger, Texas A&M University, College Station, Texas

Modes of Failure of Buildings Under Seismic Actions–Roberto Meli, Inst de Ingenieria, UNAM, Mexico

Interpretation of Damage to Houses and Casualties–Toshio Mochizuki, Tokyo Metropolitan University, Tokyo, Japan

Estimate of Post-earthquake Search and Rescue Manpower and Equipment Needs– Charles Scawthorn, EQE Engineering, San Francisco, California

Reducing Earthquake Casualties: An Overview–Karl V. Steinbrugge, El Cerrito, California

Types of Earthquake Injuries and Reasons for Death After the Armenian Earthquake–Robert Charchoglyan, Hospital Erebuni, Erevan, Armenia

Retrospective Disaster Reanimatology Study of the Earthquake in Armenia in December 1988– Edmund Ricci, University of Pittsburgh, Pittsburgh, Pennsylvania

Detection-Extrication in the Armenian Earthquake of December 1988–Joel Abrams, University of Pittsburgh, Pittsburgh, Pennsylvania

Suggested Problems for Field Research in Earthquake Disaster Operations–Louise Comfort, Graduate School of Public and International Affairs, Pittsburgh

IV. Plenary Discussion I

In several brief periods during the plenary sessions that were devoted to presentations, participants were able to question presenters. Those questions and responses follow.

Mr. Durkin was asked if he had any insights as to why the injury and fatality rates were higher in the dormitory than the office building in San Salvador. He noted that the office building, which was of the waffle-slab construction type, did not fragment as much as the column-beam-type dormitory structure. He added that through a series of interviews with survivors, information had been collected on their locations, what actions they were able to engage in prior to rescue, and time until rescue, but he said an analysis of the data had not been completed.

To questions about the status of the foreign disaster response team that is being organized and coordination between that team and the national team, Mr. Zensinger replied that OFDA personnel have been working to ready the American team for future international deployment and that several national teams are being formed.

Dr. Comfort asked Dr. Alexander if, in his spatial model, he had factored the differential conditions of ground soils into the calculation of distance from the epicenter in relation to the numbers of deaths and injuries. Dr. Alexander said that this variable was considered at the start but that he was unable to simplify the geologic complexities of the chosen site to a level necessary for the model. He pointed out that no difference was found between the efficacy of models based on the point epicenter, which is a stylized concept, versus the line epicenter, which is more realistic. Similar distances in either model produced similar damage results.

In a final question for general consideration, one participant observed that problems of trapped casualties are more significant than those of victims who are rescued quickly by themselves, family, or friends. He asked for data on response for victims entrapped in collapsed buildings versus other segments of the casualty population. Dr. Comfort, speaking on the basis of her observations as a member of the Pittsburgh team in Armenia, pointed out that trapped victims represent the most difficult problems to solve but the other of casualties have the greatest impact on hospital and medical facilities because of the numbers involved.

V. Plenary Discussion II

Dr. Krimgold invited questions and comments related to the workshop presentations and the first two breakout sessions. Mr. Andrews asked if any group had succeeded in covering the entire list of questions. Dr. Krimgold said the questions were formulated

primarily to focus thinking on the topics. He added that although no group had succeeded in producing a protocol for field research, much useful information and many suggestions had been generated, which the workshop committee would respond to and recirculate.

Dr. Comfort asked how the product of this workshop was envisioned as fitting into the research field. Dr. Krimgold explained that it would be an iterative process evolving from this first broadly multidisciplinary meeting, with structure and content developing in parallel. Discussions in the remaining breakout sessions would focus on implications for an interdisciplinary research agenda. He pointed out that previous discussions had surfaced a number of existing protocols, which must be considered in relation to the survey methodology of the workshop, as well as other material that will be incorporated in the development of a more comprehensive programmative approach. Dr. Krimgold noted the beginnings, in the IDNDR presentation, of bureaucratic and organizational support for the broader approach that is evolving.

Dr. Comfort asked if teams of international researchers would be formed to study disasters. Dr. Krimgold said he did not know, but there would be an opportunity in the set of discussions to explore the realities of the data collection situation.

Referring to the previous day's discussions, Dr. Krimgold stated that the choice of the broad title "Earthquake Injury Epidemiology" for the workshop had been challenged in light of its narrow focus on the field of search and rescue. Dr. Lechat commended the specificity of focus and cited the worldwide demand for multidisciplinary research on how structural design relates to the problem of injuries. He suggested that much could be learned from studying other types of natural disasters as well.

Dr. Krimgold acknowledged that the ambiguity of the title may have helped to ensure the broadest possible discussion of the problem. He noted that "Mitigation and Response" in the second line of the title is equally important, focusing as it does on the detailed understanding of the mechanism of injury and fatality in building collapse and structural failure, which can contribute to the specific modification of design or evaluation of existing structures or vulnerabilities. Dr. Smith added that much valuable information can be gathered during the search and rescue period to create a feedback loop that might suggest simple and relatively inexpensive modifications to existing structures to reduce their injury-producing potential. Dr. Aroni contended that although search and rescue is an important focus in itself, injuries due to the physical environment go much beyond search and rescue. One issue is that different environments, such as those influenced by building contents and nonstructural damage, create different problems for search and rescue.

Dr. Lechat identified a need for an inventory of traumas and injuries as a resource for (1) search and rescue efforts, (2) prevention, (3) health education for the public, and (4) training for the professionals and the correlation of these factors with engineering and design elements. Dr. Krimgold pointed out that these applications echoed Dr. Armenian's suggestion that research approach be tied to practical application. Dr. Sanderson identified another research need in this context as how to estimate the volume and characteristics of

the demand for emergency medical systems within the first 12 to 72 hours.

Dr. Armenian suggested that an outcome of this meeting could be a definition of the different instruments and technologies that could be brought to bear on research questions by the many disciplines represented. To illustrate, Dr. Krimgold noted that discussions in his group had already produced a request by the medical response people that engineers, in their postevent survey, focus on the characteristics of total collapse as well as initiation of collapse.

Dr. Safar asked for clarification of what the next steps would be. He suggested that one outcome might be the establishment of communication among disciplines required to address overlapping topics and the maintenance of that communication link; however, he expressed doubt that a broader collaboration could result at this point.

Dr. Lechat's suggestion for a product and outcome of the workshop was an international study of building damage as related to injuries, including topics such as biases in measurement and ornamental and other agents in building design and engineering that cause the injuries.

Citing a worldwide need for information on new rescue equipment, procedures, and research, Dr. Lescarboura suggested that another outcome could be an international data center and clearinghouse that could be accessed by computer.

As a point of clarification, Dr. Krimgold explained that the NSF sponsors workshops to help form research communities and develop a consensus on what constitutes a research agenda in new subject areas. The primary product of this workshop, therefore, would be a concept of a relevant agenda and the contributions to be made by the various disciplines. The agenda will suggest relationships between individual efforts that may be initiated by the participants or any others who have access to the documentation of the meeting. He noted that there had been a broad presentation of ongoing work in the area of earthquake injury epidemiology that essentially represented the state of the art. The documentation is intended to provide guidance for researchers as well as research-funding organizations.

Dr. Comfort proposed that some mechanism, such as periodic meetings or organized presentations of research, be explored to provide a systematic means of communication among the disciplines. She said the workshop had been helpful in that it brought people together with a common problem and served as a focus for bringing information together from their disciplinary perspectives. Dr. Krimgold said another meeting could probably be justified as soon as there were some answers but that the contribution of this meeting would be framing the questions and providing the targets for future research in the field. He noted that participants would receive full documentation of the presentations and proceedings as soon as possible.

To Dr. Aroni's question about when a response from the NSF could be expected, Dr. Krimgold said there would be no response, but the documentation will be used by the

NSF in evaluating unsolicited proposals from the research community and in guiding the direction of the general program.

Dr. Alexander commented on the fact that there had been no suggestion to form a research group or professional organization for the dissemination of ideas and information about this new field. He said he sensed a question among the participants as to how they would keep in touch. Dr. Krimgold said that a free market of ideas was encouraged with the hope that the power of the problem would drive its own progress and organization.

VI. Wrap Up, Summary, and Conclusions

Dr. Krimgold stated that the workshop discussions had indicated excellent prospects for the field of earthquake injury epidemiology. There is much work to do and a wide range of developing hypotheses to test.

Dr. Safar asserted that disaster response research must be multiprofessional, and he expressed gratitude to the workshop organizers for bringing the relevant professions together in this meeting, citing Johns Hopkins University as the "matchmaker." Although sporadic efforts were undertaken in the 1970s and 1980s to encourage communication among engineers, public health professionals, and physicians, no research plans were developed and no ongoing communication was established.

In considering how to use the data and recommendations generated by the workshop, Dr. Safar suggested a framework used in resuscitation research. This framework includes evaluation of the following factors for each research need or question:

- Scientific importance
- Clinical importance
- Socioeconomic importance
- Feasibility to be studied.

On the basis of these evaluations, research questions can be ranked, and the rankings can be used in making funding decisions.

Dr. Safar stated his view that a multidisciplinary approach is essential, but prevention should be separate from response. Engineers are primarily concerned with prevention, but they can also contribute to response and resuscitation aspects by helping to develop improved extrication techniques and better communication technologies.

Ms. Holland contended that prevention and response should not be separated in emergency management. The prevention measures instituted must necessarily guide the response.

In response to requests for feedback on the discussions, the workshop organizers provided the following highlights of their sessions.

Epidemiology

Dr. Smith identified the case study approach as useful for generating hypotheses, collecting indepth information, and developing ideas for followup research. Such an approach could be used to study questions such as why some people are injured and some are not, and why some people develop crush injury syndrome and others do not. Differences in management of injuries and subsequent outcome could also be studied. Dr. Smith suggested the development of a basic one-page form for collecting engineering, medical, and epidemiologic data to be used in the field.

Dr. Smith stated that the epidemiologic study of injury versus building design also might be enhanced by:

- Better use of existing technologies, such as mapping and photography.
- Determination of variables that affect data collection (i.e., how soon after the earthquake to conduct interviews of victims, what information should be collected immediately, what can be collected later).
- Consideration of indepth studies of smaller situations, e.g., a village, rather than large disasters.

With respect to the last item, Dr. Comfort pointed out that most casualties occur in urban areas, which would be much different from the small village scenario.

Engineering

Dr. Jones identified several multidisciplinary questions with engineering components:

- What is the time and space distribution of death and injuries?
- How is that distribution related to building type?
- Is search and rescue worthwhile?

He also noted that improvements in search and rescue will depend on advances in technology.

Dr. Jones questioned whether quantitative studies of building collapse mechanisms are needed. Quantitative information, in terms of percentage of building volume lost and degree of disintegration, may not be relevant to injury patterns. Information on behavior patterns may be more important. Dr. Jones also raised the question of whether scales are needed to reflect injury.

Dr. Smith added that input from engineers was needed to determine the role of non-structural components in injury.

Dr. Jones cited a need for broader consideration of the relationship between building damage and injury. Engineers need to think more about injury-related outcomes of building damage. He remarked that attempts (ATC-21) to assess the collapse potential of buildings and identify those buildings with the highest lethality have not yet been successful. Thus far, predictions only relate to damage.

Dr. Krimgold suggested the development of a format for two sets of questions on:

- Engineering performance of buildings
- Health variables and consequences of building occupancy.

A network could be created to collect parallel sets of data to answer relevant research questions and identify any correlations. Dr. Jones recommended the inclusion of behavioral factors.

Dr. Aroni agreed that behavioral factors are important. He also pointed out that building codes are meant to prevent static failures of buildings; however, buildings should be designed in consideration of the dynamics of earthquake behavior. A building should be designed so that if it fails, injuries are minimized. Building collapse is usually associated with the unexpected; therefore, it is difficult to include all variables.

Social Sciences and Organizational Research

Dr. Krimgold identified a need to focus on the assessment of the organization of response and where input of information is feasible and needed. Strategic information relates to the allocation of resources, and tactical information relates to the building and rescue procedures.

Dr. Krimgold suggested a need to study the feasibility of field research. This would include research on organizational responses and specific problems of rescue. Informal versus formal responses also need to be considered, and, in particular, how to study informal responses. Dr. Krimgold pointed out that formal planning should include some effort to improve the efficiency of informal responses.

In the area of information and management, Dr. Krimgold noted the issues of information transmission, the hierarchical structure of information, and the application of management concepts to incident command. Command and information structures should be examined in relation to engineering concepts.

Dr. Krimgold also identified a need to evaluate simulations that could be used to advance the understanding of management and information flow in actual situations.

Medical/Health

Dr. Noji cited the investigation of airplane crashes according to a well-defined protocol as a useful analogy for the study of earthquakes. He suggested a need to learn from this methodology and extrapolate to earthquakes.

Dr. Noji reiterated the need for a multidisciplinary approach to refine models that predict which buildings will fail and resultant deaths and injuries. The need for such models is particularly acute in California.

Dr. Brismar added that the medical severity model is useful for estimating resources needed for casualty loads. Improvements in one model can be used to enhance other models.

General Discussion

Dr. Armenian put forth for consideration the following levels of observation with respect to data collection:

1. Earthquake level–mortality and characteristics of the earthquake
2. Building level–buildings versus morbidity and mortality
3. Individual level.

Information at the earthquake and building level may not be relevant to the individual, but all information at the individual level pertains.

Dr. Comfort commented that time of response should be added into the levels of observation. She stated that there are multiple variables within every level of analysis, and it is necessary to identify those variables, the order in which they occur, and their relative strength.

Professor Lechat urged that the effort represented by the workshop be extended to the international level. He noted that the European Scientific Union is supporting a cooperative international study on casualties versus structural damage. Professor Lechat asked workshop participants to use their private networks to increase awareness of the subject and assemble international groups to pursue needed research. The ICSU has received several proposals to study earthquakes, and Professor Lechat suggested that information from this workshop would be useful in developing study protocols. Dr. Krimgold offered to send the proceedings of this workshop to the ICSU. Professor Lechat also suggested that a followup workshop be organized in conjunction with the meeting of the International Epidemiological Association in Los Angeles in the summer of 1990.

Dr. Jones commented that there had been considerable interest in this workshop and that a followup meeting was tentatively being planned. Dr. Krimgold pointed out that

the International Conference on Emergency Medical Services, to be held in Crystal City, Virginia, this summer, includes a session on search and rescue. He also reiterated the need to work with other professional groups and continue to elaborate data collection priorities.

Workshop participants joined in expressing their appreciation to Drs. Jones, Krimgold, Noji, and Smith for organizing the workshop.

BREAKOUT SESSION 1

Breakout Session 1: Comprehensive Reference to Existing Data

Moderator: Gordon Smith

Participants: Joel Abrams, Harutoun Armenian, Bo Brismar, Louise Comfort, Juan Diaz de la Garza, Michael Durkin, David Hammond, Julio Lescarboura

Dr. Smith asked participants to review what has been done with the existing studies and with the few data people from the different disciplines have collected. He asked whether one could go back to previous incidents (e.g., Armenia) and collect more data to fill in data gaps and to answer questions. He also asked whether data on patient injuries and building damage could be correlated and whether press syndrome is better studied in mine collapses than in earthquakes.

- Because each discipline has its own perspective, it would be beneficial to have a conceptual mapping of the state of the art so as to put together data from these different disciplines. (Durkin)
- What should the government do, and how can scarce resources be allocated in a timely manner? Accurate feedback from each discipline is needed to be able to put data together, not only across disciplines but internationally too. Information from many earthquakes is needed so as to have enough data. (Comfort)
- Where do the different disciplines interact? What information or parts are missing from the different data models? (Smith)
- There are two types of earthquakes–rural and urban. The Guatemala earthquake is an example of a rural earthquake, whereas the Armenian and Mexico City earthquakes were a mix of both, because initially no one knew what happened in the rural areas surrounding the main impact area. A different approach is needed when dealing with rural or urban earthquakes. With rural, there are not many dead, and the injuries are mostly spinal, head, and pelvic fractures seen in the first 24 hours. This workshop has concentrated on heavy concrete buildings and more needs to be said about rural structures–peasant houses. (Lescarboura)
- Medical rescue capacity, medical transportation capacity, and hospital treatment capacity are all important to:
  - Remove injured from disaster area
  - Provide immediate medical treatment

- Transport injured to hospital
- Provide treatment in hospital.

These three capacities are linked and when one of them is faulty, the number of injured or dead is affected. Therefore, when a faulty link is discovered, volunteers should be sent to help alleviate the problem. (Brismar)

- Areas that are developed versus areas that are underdeveloped should be examined; housing type as well as available resources may vary. (Abrams)

- What data are available, and how can they be used in some logical, reasonable way? Why are these data needed? What decisions are made at every level in terms of rescue and prevention? More data can be collected from Mexico City but for what purpose? (Armenian)

- If occupant survival is good but the medical treatment capacity in not, long-term survival will be affected. For example, in Russia helicopters were needed. Transportation close to the site of impact within the first few minutes and hours is essential. (Lescarboura)

- It is important to define the questions that should be asked when a disaster happens. These questions need to be written in some organized manner; it is not enough for rescue workers to have them in the back of their minds. (Armenian)

- What is the need for emergency transportation? Is there evidence that more people would have survived the Russian disaster if more helicopters had been available? To collect data from old impact sites or to collect data in a future disaster, a defined set of questions should be available. (Smith)

- To deal with different levels of analyses (e.g., rural versus urban), different kinds of information are needed. Quito (Ecuador) earthquake was assumed mild because Quito was not severely hit; however, three surrounding rural areas were badly hit. This was an economic and ecological problem that worsened with time because no defined questions were asked, problems were not solved, and the disaster was not evaluated correctly. Because no data were available, the wrong policy decisions were made. A framework of questions needs to be identified that can be put into context to get the specific information from the impact area. (Comfort)

- Important data include: (1) time of day when impact happened, (2) intensity of quake, (3) type of construction in area, and (4) density of population. The data will change depending on the type of situation. (de la Garza)

- At different government levels, different questions need to be asked and answered. The thinking process should be organized by the kinds of decisions that have to be made pre- impact, impact, and post-impact. (Armenian)

- Identifying the information requirements creates a capacity to recognize problems. Data from past earthquakes become beneficial in recognizing patterns of action that

have been successful in previous incidents and in fashioning particular responses to current and future quakes. (Comfort)

- A hierarchical model in which to fit questions should be built. (Smith)
- The dimensions of such a model would be: (1) time dimension (pre-earthquake, earthquake, and post-earthquake), (2) level of decisionmaking organization (hierarchically or functionally), and (3) nature of services. (Armenian)
- Within a public policy framework, it is important to define function. Local, republic, state, national, and international jurisdictional levels have different organizations within them, such as public health, engineering, communication, and transportation. In the United States it is not easy to move from one jurisdictional level to another. If information is organized by function, knowledge bases can be set up that are modular for each organization so that for a particular disaster, information can be selected out of the wider framework. Thus, only information that is really needed is accessed. (Comfort)
- Function refers to organizational level of decisionmakers. (Smith, Armenian, Comfort)
- A matrix (conceptual model or organized framework) could be developed to see where questions fit. (Smith)
- The first axis would be organizational levels, which would range from local to national and international; the second axis would be time, ranging from pre-impact and impact to post- impact and long-term; and the third axis would be discipline. (Armenian)
- Organizational level (e.g., Ministry of Health, administrative hospitals, physicians) determines the sequence of information. What kinds of questions does each organizational level deal with? This is the process of disaster management: the event, the assessment of need, the mobilization of resources and personnel, assignment of tasks, and evaluation of performance. (Comfort)
- Organizational levels will vary with country. (Armenian)
- Time is wasted moving from one jurisdictional level to another, especially from local to republic, and republic to national. In addition there are all kinds of constraints when moving from the national to the international level (for example, Armenia). To collapse time and distance, information should be organized in a way that everyone at each level can recognize immediately–organize information by function at each jurisdictional level, and ask the same questions at each level. With the right questions, the time needed to mobilize rescue operations at each level can be shortened and the efficiency of response operation increased. (Comfort)
- Postimpact research should ask the questions: What kinds of decisions would these data help eventuate? How will this information help in future impacts? Would evaluating current rescue operations help in the future? Function is the interaction between organization and discipline. (Armenian)

- Function is within the larger framework of jurisdictional organization. An assessment of needs is necessary at each jurisdictional level. Engineers, physicians, and people in charge of transportation will ask different questions to assess need. People at the local level need to ask the same set of questions to different organizations. (Comfort)

- Each discipline organizes its own framework according to its needs to define commonalities and differences in different situations. (Armenian)

- What is the magnitude of the impact? A key decision at the national level is how to make better estimates of the dead, injured, etc. (Smith)

- It is important to communicate with people who monitor these disasters with modern technology (e.g., computers) to have an accurate idea of magnitude of impact. There should be no delay in getting preliminary data, such as epicenter (to know which towns or areas are worst hit) and what time of day (to know the probable location of people–inside or outside building). Sometimes the country of impact may be in a worse position than other countries to know the magnitude of impact because data collection equipment has been destroyed. In addition, remote sensing is becoming declassified. For example, Americans knew a disaster had happened in China (Tangshan) but could not reveal it because that would have revealed the intelligence gathering equipment they had available. (Lescarboura)

- There is a need to go back to old disasters and collect previously classified information to help predict the need for rescue efforts in the future. (Smith)

- A four-dimensional matrix is needed. Time is the fundamental index, then organization, discipline, and function. (Abrams)

- The sequence in which questions are asked and the order in which data are delivered will probably be determined by the actual event. It is important to decipher where obstacles have occurred in previous decisionmaking processes. (Comfort)

- What are the avenues of intervention that are available currently? (Armenian)

- Intervention should be to save lives, not to minimize economic loss or anything else. (Abrams)

- All potential action points that could be implemented in a disaster situation should be identified. What information is needed for each action point? (Armenian)

- What will result is a decision tree where each action has an outcome that brings about another action, which may be at a different functional/organizational level. (Abrams, Comfort)

- The first thing is to let people know of the impact through manuals in various emergency and public services. (Comfort)

- The decision tree starts at the bottom with the impact. (Abrams)

- Conceptually, it is easier to start with a local person, such as a physician or fire department member. (Smith, Abrams)
- Experience shows that it is important to train local people (e.g., in CPR) because they are on the spot. It takes time for medical people to arrive. (Lescarboura)
- Information should be collected from past disasters on how the local people coped with the impact, how they could have done better, and what situations they did not handle well. (Smith)
- The buildings destroyed need to be identified to ascertain how may people may have been injured, how many people were in them. Having a basic structural map of an area to know where people may be found at different times of the day would be helpful. This information should be made available for all metropolitans within earthquake areas to assist in defining the needs for response. (Comfort)
- It would be helpful to map the restricted areas to identify buildings that may collapse and the probable density of occupancy and reaction of occupants in case of an impact. (Lescarboura)
- The interventions available to save lives–knowing building locations and where to begin rescue efforts–should be identified. (Smith)
- Different jurisdictional levels will all need the same information but for different purposes. (Comfort)
- Temporal bias is driven by the response–pre-impact activities are thought of in terms of response. Engineering primary prevention includes: (1) producing buildings that will not collapse, (2) retrofitting buildings to mitigate collapse, and (3) training occupants to evacuate more efficiently. Making policy changes that affect the physical setting involves a timeframe of decades. (Durkin, Comfort)
- Medical prevention would include (1) deciding if tetanus vaccination is necessary and (2) knowing how many people are trained in rescue operation pre-impact. (Armenian)
- From a rescue perspective, buildings are examined for possible retrofitting. If that is not economically feasible, resources are invested in rescue operations. (Smith)
- Can a monetary value be attributed to a life saved? If so, would the community be ready to spend that money (and time)? With correct information, that same amount of money and time could save many more lives. (Comfort)
- How can epidemiological techniques be used as generators of information for all the phases of earthquake response? Medical management questions could be answered by an epidemiological research protocol–possibly case-control methods to look at some outcomes. (Armenian)
- Fifteen to twenty years ago studies were descriptive, whereas the focus of studies in the past 5 years has shifted. What kinds of information are needed to take more timely action to save more lives? (Comfort)

- Can it be determined which buildings will have injured people? Different characteristics of buildings need to be identified and categorized according to their injury and death potential. (Smith)
- The most appropriate activity of various international rescue teams is to transfer the latest technology to local people (who know the buildings, floor plans, etc.) and instruct them in the use of equipment. (Lescorboura)
- International help is always a backup to local help because of the time factor. It is necessary to determine what needs to be done, by whom (on national level), when, and where before bringing in more sophisticated and advanced help. (Comfort)
- Variables and the interaction of these variables should be identified to determine high-risk people and high-risk situations. Does interaction of these variables increase individual risk? (Armenian)
- There is a need for a multivariate model of risk. (Comfort)
- Housing type as a factor of risk should also be taken into account–wood versus other materials. (Smith)

Breakout Session 1: Comprehensive Reference to Existing Data

Moderator: Eric Noji

Participants: William Anderson, Donald Cheu, Andrew Coburn, Miroslav Klain, Richard Kunkle, Henry Lagorio, Michel Lechat, Toshio Mochizuki, Robert Olson, Jelena Pantelic, Edmund Ricci, Craig Wallace

Dr. Noji requested that participants consider the value of data taken from past earthquakes in answering questions about earthquake injury. He distributed a listing of 14 questions to act as a guide for the discussion. Listings of specific past building studies and sources of possible building data related to injury were also distributed.

- There is a need to define the type and scope of data required (e.g., structural, medical, time of extrication, types of buildings). (Lechat)
- A compilation of data bases on past earthquakes should be considered. (Ricci)
- A considerable portion of biomedical data related to earthquake injury is in the non-health literature. (Noji)
- Retrospective and prospective (e.g., questionnaires, observational collection) approaches for both should be used for data collection. (Kunkle)
- Autopsy data should also be incorporated into data analysis. Michael Durkin is beginning to compile this type of data. (Noji, Kunkle)
- In general, there is a low level of confidence in the quality of data from past earthquakes. (Olson)
- Primary sources of information should be established onsite. (Olson)
- Data on other types of disasters (e.g., Kansas City Hyatt collapse, tornadoes, hurricanes) may be useful. (Anderson)
- The value of evaluating data from past earthquakes depends on the questions being asked. (Noji)
- The Office of Foreign Disaster Assistance data base is another source of information on past earthquakes. (Wallace)

- Techniques that can be used to determine how previous data were collected should be identified. (Noji)
- Studying maps of structural damage from past earthquakes can be useful for evaluating general points about an earthquake. (Coburn)
- It appears easier to collect data on building and other structural damage than data on injury and mortality due to earthquakes. (Noji)
- The Japanese have done considerable tracking of past earthquakes. (Noji)
- The pace of cultural change also influences the ease with which data on structural damage can be collected. (Olson)
- Agencies such as the Bureau of Vital Statistics are not generally considered to be a useful source of collecting data on past earthquakes. (Noji)
- Sending research teams to old earthquake sites to collect more data could be considered. (Noji)
- Literature in the field can be reviewed, and the researchers could be contacted as potential sources of additional background data. (Olson)

Breakout Session 1: Comprehensive Reference to Existing Data

Moderator: Fred Krimgold

Participants: David Alexander, Samuel Aroni, Ian Buckle, Robert Charchoglyan, Anne Coulson, Constance Holland, Frank McClure, E.L. Quarantelli, Lee Sanderson

Dr. Krimgold established the focus for discussions as putting the narrow concerns of rescue and postdisaster support into a public health context.

- The workshop title suggests a broader perspective than that presented in the workshop so far. An attempt should be made to evaluate the whole field of references for earthquake injury epidemiology to put into perspective the relative importance of search and rescue in relation to the whole spectrum of potential hazards. (Sanderson)
- Comprehensive reference to existing data can provide a preliminary inventory of previously untapped data sources, establishing what they are and identifying information gaps. (Quarantelli)
- In the attempt to develop models and examine relationships that might estimate the extent of injuries after an earthquake, very few relevant and verified data have been found that would make such estimates possible. It is hoped that new information, such as that from the Armenian Civil Defense, can be located.

Dr. Krimgold distributed a chart that contained partial information on major earthquakes since 1970 to illustrate existing data gaps. He said already collected and organized analyses of data as well as retrospective studies would be helpful in eliminating these gaps.

- There is a need to draw together threads of the wide variety of material presented in the plenary session, which demonstrated that a corpus of ideas and approaches is evolving. (Alexander)
- Earthquake injury epidemiology is likely to cover recovery of the dead, care of the injured, rescue of the entrapped, avoidance of disease transmission and injury, behavior and its effect on risk and injury, and patterns of mortality and morbidity. If search and rescue is to be the area of concentration, the search focus must be fairly specific because there may be different sets of data for different focuses. (Alexander)

- Search and rescue may be too limited a focus for these discussions. (Quarantelli)
- It is difficult to put the question of comprehensiveness of data in perspective without knowing the relative importance of one type of injury risk versus others. (Sanderson)
- Because the idea is to look at data that has been collected and to fill the data gaps on the chart, perhaps the problem should be approached by attempting to locate the simplest types– morbidity and mortality and building stock–and proceed toward the more complex– behavioral, logistical, and treatment. (Alexander)
- Attempts to locate new data should not be limited to any timeframe; elaborate records of ancient earthquakes may exist. (Quarantelli)
- Carlo Pelanda's group at ISIC did massive studies on search and rescue and the handling of casualties in the Peru earthquake aftermath; however, most of the data have not been translated. (Quarantelli)
- Dr. Alexander has treatment data on the Peru earthquake.
- It is important to know the quality–homogeneity and reliability–of the data gathered to fill in such a chart. (Alexander)
- There is a lack of data by any standard; therefore, the search is for any type of report, even descriptive studies, that gives reliable information on the nature of the activity. (Krimgold)
- The question is not whether enough numbers can be found, but whether numbers can be found that are sufficiently comparable such that models, regularities, and generalities can be derived that go beyond the case study and permit creation of a subdiscipline or field of study from which more universal generalities can be made. (Alexander)
- Are there any studies comparable to the Glass study, for example, on Chile? (Krimgold)
- Chilean studies are known to exist, but the quality of data is questionable. (Aroni)
- It is difficult to ensure the rigor of data. For example, in an ongoing pilot study of deaths and injuries in four earthquakes, 1,600 questionnaires have been collected and are being analyzed. Variables such as behavior, cultural differences, and earthquake magnitude, time, and location have made the process very labor-intensive. (Aroni)
- The right questions are being asked, but the answers are hard to come by; if the right beginnings are made now, transferrable data that could answer the questions would be available many years from now. (Aroni)
- Dr. Aroni's study illustrates the best-case scenario for research; studying different earthquakes with similar survey instruments will provide more comparable data than metanalyzing different statistics generated by different people for different purposes. (Sanderson)

- Two questions are involved: How reliable are the data? How robust are the data? No distinction is made in earthquake death totals between those caused by earthquake injury and those from other causes. (Alexander)
- There is a need for a more precise definition of earthquake injury. (Alexander)
- The key issue is not how good the definitions are but that they be explicit so that others can agree or disagree. (Aroni)
- Injured rescue workers and those injured in aftershocks have been included in the definition of earthquake injuries. (Aroni)
- What questions, arranged by priority, should guide the evaluation of existing data? (Krimgold)
- There is a need to sort out the geography of the disaster area, which may include only a few buildings or cover many square kilometers of villages and mountainous areas, to locate potential victims. (Alexander)
- A new data base has been developed on the San Francisco earthquake as reconstructed from newspaper accounts, letters, coroners' records, and information from the national archives on the U.S. Army's performance in the disaster. Sort capabilities include street and building addresses, and building types are available from the Sanborn maps; therefore, it may be possible to correlate injuries and deaths with types of construction. (McClure)
- The new data base and book illustrate that it is possible to reconstruct past earthquakes from existing data if that is the objective, but the task requires great effort. (Aroni)
- Another example of retrospective research is the series of surveys on the Armenian earthquake, which are in progress; it may be possible to correlate injuries sustained, as reported from hospital data, with building damage. (Krimgold)
- Another key question is the extent to which access to new information is restricted for political reasons. (Aroni)
- The character of the Armenian earthquake–the number of deaths and extent of the catastrophe, coupled with the loss of records–has made reconstruction of the event very difficult. (Charchoglyan)
- It would be helpful to know if reports, analyses, or studies exist on significant earlier earthquakes in the U.S.S.R., which might provide amplification or understanding of injury and building relationships. (Krimgold)
- A practical outcome of the workshop would be a list of recommended antiseismic building types to guide reconstruction. (Charchoglyan)

- A workshop focusing on the Armenian earthquake should be convened after the ongoing investigations are completed (Charchoglyan), but this might lead to a case-by-case approach rather than one that leads to developing models that are more broadly applicable to most events. (Alexander)
- Is it possible to develop general models? In doing so, is research constrained to particular types of analyses and sets of data? (Alexander)
- Is it better to look at individual events and study the questions that are most important in the context of the event? (Alexander)
- The research process is iterative, from particular to general and back, especially in areas where there are few data. (Aroni)
- In disaster studies, there is a strong tendency to concentrate on particular events and fail to make generalizations that would lead to finding efficient solutions to problems. (Alexander) There are archives in Iran and Italy that could provide figures on casualties, descriptions of building damage, and, to a lesser extent, behavioral and social information on ancient earthquakes. (Alexander)
- How does one deal with information from sources that do not accept or are not aware of the protocol of the study? (Krimgold)
- A new type of study called secondary analysis (as distinct from metanalysis) can be applied to any available data; guarded conclusions are made based on an accumulation of sources, and the conclusions can be refuted or validated as further information becomes available and decisions made relative to further study. Developing computer technology and growing library data bases should facilitate this type of study. (Coulson)
- Data on the Cincinnati earthquake was located in the appendix of a promotional book published in 1815. (Coulson)
- A paper with previously unpublished conceptual framework and preliminary data has been published as a product of the Romanian conference. One volume contains behavioral information on victims of the Romanian earthquake of 1977. (Aroni)
- Behavioral information is also available from the Whittier earthquake. (Aroni)
- Publications of historical and geographical societies of the past are a potential source of data from which correlations could be made. (McClure)

Dr. Krimgold distributed a list of 12 building disasters on which it is assumed that more detailed information exists. He asked if the structures of these or similar buildings could be studied in detail to gain a sense of contemporary building performance in relation to death and injury.

- Data are often tied to a single building; individual building and whole block studies are needed. (Alexander)
- As indicated in the Coburn and Scawthorn presentations, there is a significant sensitivity in overall injury estimates to the collapse of a single high-occupancy building, and as yet, only a limited capability exists for making assessments about the collapse potential of buildings. (Krimgold)
- There is information in recent literature on building structure and cultural or behavioral patterns as they relate to damage and injuries, for example, the 20 buildings that collapsed as a result of the 1977 Romanian earthquake. (Aroni)
- Postevent data collection procedures should be standardized. The Italian and Guatemalan studies demonstrate how arbitrary the process can be. (Krimgold)
- Prior vulnerability studies, coupled with behavioral postulates, are needed for comparison with postdisaster damage if the objective is to obtain data that can predict the likelihood of events with particular injury patterns or totals. (Alexander)
- The importance of deploying multinational teams to capture certain types of information was illustrated by the experience of the Pittsburgh team at the Armenian earthquake. (Krimgold)
- A protocol for performing building autopsies should be developed; much can be learned from the damage. (Coulson)
- Information gained from building autopsies could be used to develop protocols for building triage in terms of deploying search and rescue teams. (Holland)
- Hospitals' and doctors' records should be mined for the information they contain. (McClure)
- Generalizations relating building structure to damage cannot be made in the case of the Armenian earthquake because of the deficiencies that were present in the building material. (Charchoglyan)
- In a practical sense, there will probably never be enough major earthquakes to provide data for making generalizations that are applicable to all areas of study; therefore, case studies will continue to be a valuable approach to earthquake injury epidemiology, especially if assessments are sought for specific areas.

Breakout Session 1: Comprehensive Reference to Existing Data

Moderator: Nick Jones

Participants: Richard Andrews, Calvin Freeman, Maria Luisa Garcia, Ben Ho, Roberto Meli, Charles Scawthorn, Keishi Shiono, Dennis Wenger, Karl Western, Luis Zeballos

Dr. Jones began by telling the group that the purpose of the session was to identify what and where the existing sources of data on past earthquakes are and whether those data sets are of value to earthquake injury epidemiology. The data discussed should be comprehensive, not just injury-specific data. A list of prepared questions and two other handouts (lists of possible building data related to injury and specific building studies) were to be used as starting points for the discussion.

- There is a need to develop a matrix of the different types of data needed (e.g., on building collapse, search and rescue, hospital treatment) and to indicate whether they are available. (Scawthorn)
- Information on buildings and injuries besides that from earthquakes (e.g., in literature on search and rescue, fires, mining accidents) can be useful. (Wenger)
- Different disciplines are interested in different data sets. For example, engineers would be interested in building collapse patterns; medical professionals would be interested in data on injuries. (Scawthorn)
- There are different variables in occupant survival, such as structural elements, non-structural elements, and social/behavioral elements. (Zeballos)
- There is a need to identify all the data sets. For example, Presbyterian Hospital has medical records of the 250 to 300 people who were injured in the Whittier earthquake. This is only one among many data sets. To start, an inventory of data is needed. (Freeman)
- Data can be tracked down (e.g., data on all significant fires after U.S. earthquakes in the 20th century), and the data will have value. The question, however, is the relationship between the different variables. (Scawthorn)
- How are the data valuable? From a public health perspective, it would be valuable to have data to support public education on how to behave during an earthquake. From an engineering perspective, data on why structures collapse and how to minimize that would be valuable. (Andrews)

- Whether the relationship between data on injury and survival is valid must be determined. It has been found that once someone is injured, they enter into a whole separate chain of events regarding how they are rescued, depending on the event. For example, excellent earthquake paramedic systems were available in both Mexico and Armenia, yet a person injured in one of these events very well could have survived, while a person with the identical injury in the other place did not survive. (Ho)

- In point of fact, multidisciplinary teams do not work because people are always following their own interests. Maybe it should be asked what are the quality data across the disciplines–emergency medicine, civil engineering, social behavior, etc. (Wenger)

- There is a need to identify whether there are data sets on specific events. For example, Mexico's Juarez Hospital had reasonably complete structural data and injury data. (Jones)

- The DRC has an excellent data base on the organizational aspects of the Mexico earthquake. This was a random survey of the population of Mexico City about two weeks after the earthquake. Interestingly, the survey showed that a much higher number of people reported being injured (135,000 persons) than the hospital data showed (25,000 persons). An analysis of organizational response, including search and rescue, was also conducted. (Wenger)

- There is much information on the Mexico City earthquake, but the validity of the information must be determined. (Zeballos)

- In general, there are many data on Mexico, but specific data sets on specific buildings need to be identified. (Jones)

- Concerning the value of the data, the most important questions are will they be used and how will they be used? (Garcia)

- It might be useful to make the distinction between raw data (e.g., a survey) and interpretive data. Also, the data do not have to be immediately usable but may become valuable later when combined with other data. (Freeman)

- Earthquake injury epidemiology is an infant field. One objective of this workshop is to work toward developing some research methods and protocols, agendas, and applications. The areas in which the most data are potentially available should be identified. (Jones)

- It would be more beneficial to gather data by field/discipline rather than event/building because there is a great difference in the quantity of available data in the different fields (e.g., civil engineers have more information than others). (Wenger)

- Whether information overlaps should be identified, such as that on Juarez Hospital. (Jones)

- Medical injury data can be obtained from Juarez Hospital itself, and the Minister of Health has well-established information. Also, another hospital that partially collapsed, the General Hospital of Mexico City, established a Committee of Security in 1985, and medical data can be obtained there. (Garcia)

- Not much structural data exists on the collapsed buildings in Mexico City because the buildings were cleared away as soon as possible. (Meli)

- The Building Safety Board of California looked at about 270 hospital building cases in Southern California for seismic resistance. These baseline data would be helpful. (Freeman)

- A study of the Imperial County General Services Building was conducted in 1979, specifically, on occupant behavior. (Andrews)

- Structural and medical studies were done after the Kansas City Hyatt fire. Were any organizational or psychological studies conducted? (Jones, Wenger)

- There is a great deal of data on earthquakes in Japan. (Meli) However, much of the data are poor. (Shiono)

- It should be noted that the emphasis here has been on modern urban settings. In many parts of the world (e.g., Mexico, the Middle East), earthquakes are likely to happen in a rural setting, and this should be considered. (Zeballos)

- Japanese data on earthquakes can be found in the proceedings and material from the world conference held in July of last year in Japan. There are also problems with other (non- Japanese) data. What do epidemiologists believe the state of the art is in this field? (Wenger)

- Data are almost never collected properly. (Scawthorn)

- The data may not be complete or necessarily detailed, but until a methodology is developed, the data that exist need to be identified. What about information on the VA Hospital in San Fernando? (Jones)

- The Los Angeles Fire Department might have information. The VA's. records contain very little data. (Scawthorn)

- The VA Hospital itself probably has data. (Andrews)

- What about Ruben Dario, San Salvador? (Jones)

- Only one building collapsed, and three or four hospitals were damaged. There were some good studies on injuries associated with structure. The Minister of Public Health has some data, but they are not detailed. (Zeballos)

- Are data available on correlations between structural and nonstructural damage? (Wenger)

- There are not because it is qualitative and anecdotal information. Non-earthquake data would be useful to this effort and may be more accessible because those events are smaller and isolated. Also, there is a book on structural building collapses by Jacob Feld and useful information in the Engineering News Record. (Scawthorn)
- What about the Marine Barracks event? (Jones)
- The study was more of a criminal proceedings. The emphasis was not on building collapse but rather on injury (by explosives) in a warlike situation. (Ho)
- Those who do not die by crushing in an earthquake often die by fire. Fire should be studied. John Brian has compiled good data on this subject–on search and rescue and much other good data. (Wenger)
- A University of Maryland group compiled a fair amount of data in this area, which would be worthwhile to investigate. It seems that there are good organizational data on non-earthquake events. (Jones)
- Draybeck's studies are the best. In general, there are much data on search and rescue. (Wenger)
- Although it is agreed that there are problems with existing data, are they nevertheless valuable? (Jones)
- Two things should be done: (1) re-examine the existing information and circulate it among the various disciplines and (2) develop methodology for improving future data collection. (Ho)
- There is a need develop a simulated model for existing data. (Zeballos)
- Current data should be used to modify fire and evacuation drills. (Ho)
- However, there is the danger of making recommendations that are based on inaccurate data. In particular, casualty data need to be refined, and tactical and search and rescue data also need to be examined. (Andrews)
- Are there any detailed casualty/injury data in California? (Scawthorn)
- No, this is an example of what needs to be examined and re-analyzed. (Andrews)
- In summary, there clearly is a need to go over existing data, discard the questionable information, and use the remainder as a base to move on to future data-gathering efforts. (Jones)

BREAKOUT SESSION 2

Breakout Session 2: Consensus on Field Research Protocol and Implementation

Moderator: Gordon Smith

Participants: David Alexander, William Anderson, Juan Diaz de la Garza, Michael Durkin, Richard Kunkle, Michel Lechat, Edmund Ricci, Badaoui Rouhban, and Craig Wallace

Dr. Smith asked the participants to help develop a protocol that would improve data collection at the next disaster, a consensus as to the type of information one would want to ask in a given situation, and a way of prioritizing questions according to everyone's field of expertise.

- There is a hierarchy of questions, from simple to sophisticated. Questions that appear simple on the surface are "What is death?" and What is injury in an earthquake?" A more sophisticated question would concern behavior and logistics. Can a research strategy be developed that goes from simple to sophisticated questions? (Alexander)
- There may be causes of death by an earthquake that are not recorded. In some cases, earthquakes do not actually cause death but speed up the dying process. For communicable diseases there are good reports; maybe a better way of recording injuries and what they consist of should be developed. (Alexander)
- It is essential to define what constitutes injury and if it can be counted. Initially, the international disease classification of injury as the underlying cause of death can be adhered to, but maybe the underlying cause of death should be recorded, as in the case of someone on an artificial respirator dying because of a power out caused by the earthquake. (Smith)
- Prevention is the answer to the fundamental question, "What can be done?"–prevention through (1) construction of antiseismic buildings, (2) education of potential victims, (3) better detection of rescue people/organizations, and (4) training of rescue personnel. In addtion to accurate information, "quick and dirty" indicators are needed. (Lechat)
- One of the main problems is that many studies are case specific and cannot be compared between events. Generalities need to be found. (Alexander)
- Maybe the concentration should be on signs, not diagnoses, for example, injuries that require medical care. Operationally, this may be a very reliable comparison across national boundaries, in spite of not specifying how much medical care is required. (Lechat)

- To correlate building types with injuries, knowing the types of injuries is more important than knowing the number of injuries. (Kunkle)
- Injuries should be counted to discover what new interventions are needed. (Lechat)
- Can injury epidemiology be predicted? On what basis? Building damage and collapse can be predicted and correlated to injury. Perhaps past events should be examined to make the connection between epidemiology and archeology in a predictive capacity for future events. (Alexander)
- How easy is it to obtain detailed data on types of injuries and to come up with a broad classification of injuries? (Smith)
- Records compiled during an overwhelming disaster are not as accurate or detailed as those collected on a regular routine basis. (Kunkle)
- Numbers may be unavailable or falsified for political reasons. (Anderson)
- Assessing out-of-hospital deaths is difficult. (Ricci)
- It is difficult to work backwards, from hospital cases to the buildings from which victims were taken. It is particularly difficult if the local system arranges hospitals geographically so that people can go only to the hospital closest to where they live; for example in Santiago, Chile, 30 percent of the victims had nonexistent addresses just so they could go to the best hospital. In addition, information needs to be collected on people who were not injured. (Durkin)
- Relating the type of injury to the type of building collapse is necessary for better prevention. Triage is a first step; the physician will give information on the type of injury, which can then be used for future prevention. (Lechat)
- This conference has concentrated on time at the expense of space, which is acceptable if it is known exactly where the earthquake impacted and what spatial dimension was hit. In reality, the affected area is often not clearly known. Plans of the houses, even crude ones, are needed so that potential victims can be helped within the first 24 hours after impact. (Alexander)
- Data on better prevention and better construction to mitigate the effect of impact and better search and rescue techniques are needed. (Lechat)
- A form that will collect raw data necessary to various disciplines, primarily to assist in organizing victims and building better buildings, should be developed. (Kunkle)
- Can it be known exactly where people were at the time of the impact–what floor, in stairwell, under doorframe? It would also be helpful to know where there are people living alone and where there are old people. Is it possible to collect more data in advance? (Lechat)

- In Rome, there is an online computer 24 hours a day recording earthquakes of any significance. Within 10 minutes it can give the epicenter, the settlements affected, and the injury, panic, and damage impact. What is needed is a reanalysis of the information already collected in the kind of capacity that will enable prediction of injury distribution, behavior, and special distribution. (Alexander)
- Injury in previous disasters was not defined well. A suggested definition should be tiered as (1) requiring hospital care and (2) other medical care. (Smith)
- There may be variations in defining "needing medical care, needing intensive medical care" across cultures. (Ricci)
- Doctors from many countries respond to major disasters, and that makes record keeping even harder. (Anderson) In some cases, the hospital itself is damaged by the impact so that the information is very incomplete. (Durkin)
- For medical supplies, the number of injuries is needed as well as a rough idea of type of injury. For the purposes of this session type of injury is not necessary. (Lechat)
- Injury control/reduction is an objective, it maybe that through education people will sit in hallways and come away with a broken clavicle instead of being crushed if they remain in other parts of the building. However, we need data to make these decisions. (Smith, Durkin)
- It has been shown in this workshop that diagnosis is important for prevention. (Lechat)
- Untrained people are doing the preliminary rescuing and initial diagnosis; therefore, the diagnosis must be quick and dirty for the local rescuers to know what they can do. (Durkin)
- There will be never total control over any impact situation. Documentation for future research may be partially faulty because of misconception–someone was thought to be able to walk but could not. On the other hand, there may be a clinically sophisticated person diagnosing the victims giving accurate details. A document should be so designed as to be usable in either case. (Kunkle)
- There are different levels of data: (1) a generic set of data that may be needed for the entire city to refer to later, such as number dead, and (2) specialized or detailed information on one building or one hospital. With different levels of data, some form of data collection is needed. (Smith)
- Other people, not doctors, are needed to collect good, useful data, and they need to go out with the first rescue teams. (Kunkle)
- An assessment team should be sent to the site. It is necessary to relate injury to building collapse or other agent (beam falling, roof collapsing) with occupant behavior and knowledge, and time delay. These correlation studies will enhance prevention education and determine procedures of rescue team. (Lechat)
- Sample surveys of building occupants should be conducted. (Smith)

- A sample survey produces selective information, and it may not be known if the injury sample or building sample is valid. Data are collected but are they valid? Sophisticated sampling techniques are needed unless the data are for hypotheses development only. (Anderson)

- That is the danger with medical hospital data–some information is collected twice while other data escapes data collection completely. (Lechat)

- Is it possible to use people who come back to damaged buildings to salvage valuables as informants? (Smith)

- Is it important to study high-rises, when it is already known that the outcome is death, compression, or crush syndrome? Wouldn't it be better to research standard buildings where death is not the only result? Different apartment buildings may collapse differently. (Lechat)

- Build in safer ways so that things collapse in such a way as to leave voids and where supporting columns would not collapse completely. (Kunkle)

- Similar buildings can have different collapse patterns: (1) identify hazardous buildings pre- impact, and (2) allocate resources postimpact because it will be known which buildings need what (an engineer's approach–clinical approach). Also needed are community surveys of repetitive building types and indigenous architecture as well as soil type and behavior actions. (Durkin)

- Is there any data on injuries from decorative architecture; Is a square room safer than a rectangular room? (Lechat)

- Nonstructural components, such as a porch right above an evacuation route, would make it safer for the people to stay inside. (Durkin)

- Why not study this experimentally, just as was done with automobile safety and dummies? As buildings are demolished all the time, lessons could be learned from this. (LeChat)

- The closest that engineering has come to this is shaking tests for buildings. (Alexander)

- Engineering advice is needed to know whether collapse patterns differ from building to building. (Smith)

- Japanese studies use dummies. These studies partially explain injury mechanism but do not go into the preventive actions the building occupant could engage in. (Durkin)

- Japanese large shake tables could be used to do full-scale simulation of the building under earthquake stress. (Lechat)

- This is being done by structural engineers, but medical personnel could learn a lot by using dummies in the situation. (Ricci)

- In an urban environment the isotropic landscape varies, which influences the outcome of an earthquake; maybe generalities concerning that can be identified. (Alexander)
- The Red Cross trains people on a homogenized basis, for example, telling people to stand in doorways. (Doorways are not always safest.) A more localized approach is needed based on the type of buildings people work and live in. (Durkin)
- Maybe organizations that do postdisaster audits, should be consulted, for example, FAA. Everytime there is an accident FAA sends out investigators; therefore, they have a protocol on structural, environmental, and behavioral aspects and impacts and their consequences. (Anderson)
- Would it be useful to include data on social, economic, and cultural characteristics of the affected area? (Rouhban)
- What type of buildings do the injured or dead come from? Can a risk equation be formulated? (Smith)
- Who does triage? What were the people doing at the time of impact, and what was their initial response? The two questions are interrelated. (Lechat)
- Why were certain courses of action taken as opposed to others? Where did rescuers learn their behaviors? (Anderson)
- Many classifications of structural damage miss the dimension of damage to people, except in the cases where it is implicit, as in the building codes. (Durkin)
- In the Mexico City earthquake, many schools were affected. It is important to do evacuation drills, especially for schools and government buildings. It is also important to know occupancy of hospitals (i.e., how many beds are available). (de la Garza)
- Before a form can be developed, variables need to be examined for major unanswered questions that are identified. There should be differentiation between what we need to know and what we have sufficient knowledge on. (Ricci)
- How are the injuries correlated to type of building collapse? (Smith)
- There is a need to know how injury, behavior, and architectural engineering interact to save lives pre-impact and improve preparedness. (Alexander)
- Search and rescue need to be included in interaction. (Anderson)
- Individual behavior includes behavior before, during, and after impact. (Alexander)
- Individual response versus organizational response should be identified. (Ricci)
- Time sequence is earthquake, building and occupants' performance, injury versus noninjury, evaluation, and search and rescue. (Durkin)

- Who is providing information needs to be documented–chief physician or mother-in-law? Data are needed on (1) building characteristic, (2) behavior (before, during, and after), (3) reaction to warning (delay a time factor), (4) intervention (rescued by whom and when), and (5) outcome (injury, noninjury, or death). (Lechat)

Breakout Session 2: Consensus on Field Research Protocol and Implementation

Moderator: Eric Noji

Participants: Joel Abrams, Bo Brismar, Anne Coulson, Julio Lescarboura, Toshio Mochizuki, Charles Scawthorn, Keishi Shiono, Dennis Wenger, Luis Zeballos

Dr. Noji distributed a listing of 25 questions drafted to serve as a framework for the discussion, along with two sample data collection forms for consideration. The discussion centered on question 1: What are the fundamental questions that need to be answered?

- Basic questions that need to be answered include:
  - Nature of injury
  - Location of victim
  - Method of extrication. (Scawthorn)
- It is important to determine the type of structure (e.g., house, hut, high-rise), setting (e.g., urban or rural), and spatial location. (Brismar)
- There is a need to standardize diagnosis of injury. (Zeballos)
- It is important to be onsite at the time of the earthquake to avoid loss of "perishable" data. (Noji)
- There should be an emphasis on the importance of observational data for initial data collection, then possibly use of a simple questionnaire, and later detailed data collection. (Noji)
- Video (raw footage not edited for newscast) is a useful tool for initial data collection. (Scawthorn)
- Local onsite collaborators are important for data collection. Foreign research teams should put themselves under the local authority for supervision. (Zeballos)
- There is a need to outline a protocol for data collection to define data needed and time points of data collection. (Brismar)
- Any questionnaires designed for immediate data collection should be very short and simple. (Abrams)

- There is definitely a role for expert computer systems in this research field, for example, for:
  - Prospective planning for disasters
  - Training local rescue workers (e.g., computer simulation)
  - Onsite data collection
  - Computer simulation of building collapse.
- The only possible use for surveys (and respondents) is with those who were not severely injured or killed. Informant sources should be used for collecting onsite observational data. (Wenger)
- It is important to reach advance agreement with local authorities that they will follow a specific protocol designed for data collection. (Coulson)
- Data from other events that cause building collapse could be applied to earthquake research. Emergency response systems to other disasters (e.g., fire) should also be studied. (Noji)

Breakout Session 2: Consensus on Field Research Protocol and Implementation

Moderator: Fred Krimgold

Participants: Harutoun Armenian, Ian Buckle, Robert Charchoglyan, Donald Cheu, Calvin Freeman, Ben Ho, Constance Holland, Frank McClure, Roberto Meli, Jelena Pantelic

Dr. Krimgold distributed a master data form, data collection form, and draft of variables to be considered for studying the epidemiology of injuries following earthquakes. He noted that both forms were intended to collect data from the sites where major rescue activities were in progress. The shorter data collection form is intended for use by nonresearchers and rescue operators. He said the purpose of the session was to consider the following:

-What decisions will be influenced by the data collection?
-What questions need to be asked to inform these decisions?
-What is the appropriate way to collect that information?

- It would be useful to address the issue of field research protocol from a methodologic perspective by identifying input from the other disciplines that could be added to the statistical and population-based sociometric data usually collected by epidemiologists to create a more informed basis for action to save lives. For instance, odds ratios for survival assigned to specific building types could be used in a formula with other independent risk factors, such as handicaps, to calculate overall risk as a basis for taking preventive action. (Armenian)
- Global classification for buildings have not yet been established, nor have enough data been collected on injuries in specific building types to develop reliable lethality or life-safety ratios. (Krimgold)
- A multidisciplinary approach to the ongoing epidemiological case-control study of injured and uninjured survivors of the Armenian earthquake would be to add questions to generate quantifiable and measurable information on buildings occupied by study subjects that would complement health and behavior information already being collected. (Armenian)
- The draft data collection form includes questions to elicit information on the pre-event character of the building and damage as a result of the earthquake, but it

may be necessary to include specific choices for types of construction, as well as a checklist of building types, to guide epidemiologists and nonspecialists in gathering data. (Krimgold)

- It may be difficult for nonspecialists to estimate loss of volume. (Krimgold)
- It might not be possible to correlate lethality ratio with loss of interior space as was postulated. More data might be required to understand the circumstances. (Krimgold)
- Surveys are presently conducted by engineers to explain the damage and make vulnerability studies. While this level of complexity is not necessary for epidemiologic use, measurement of building strength is needed in addition to the data called for in the draft form to make useful building and injury correlations. (Meli)
- There is a need to modify the priorities of the engineering surveys to include the study of buildings that are vital to epidemiological study because of occurrence of fatalities even though they may be of little interest to engineers. (Krimgold)
- For epidemiological study, each outcome must be related to building information for that case. (Armenian)
- Medical responders require information on the potential for particular types of injuries in buildings to be able to estimate supply and medical staff needs. (Cheu)
- Damage surveys, which give the total percentage of buildings in various damage categories, cannot be compared with aggregate injury information to produce useful data for epidemiological study or emergency response. (Krimgold)
- All deaths in a building may not be attributable to building collapse; some may be related to failure of the emergency response system. (Ho)
- Ideally, the data collection form should be used to collect information from all building occupants, injured or not, to provide information useful for the particular epidemiological application chosen. (Freeman)
- It might be easier to accumulate information for epidemiologic study by selecting buildings based on type of use or occupancy, such as the medical residence and hospital in Mexico City. (Freeman)
- Each person interviewed for the Armenian case-control study is asked to provide addresses of three or four friends or relatives to increase the possibility of contacting the same populations for future studies. (Armenian)
- A question on earthquake education received should be included on the draft form to help public policymakers evaluate existing programs or initiate new ones. (Holland)
- Epidemiological methods can be used to evaluate the effectiveness of procedures and processes that are involved in rescue operations. (Armenian)

- The data collection form can be used to try to ascertain, on the basis of specific sites, what the potential might be for saving lives after a collapse; an autopsy component may be necessary to determine the number of late deaths. (Krimgold)
- Ideally, victims should be tracked throughout the complex response system so that data can be gathered that would link the steps of the postextrication process. (Krimgold)
- A critical role for emergency response teams is to gather medical intelligence to guide search and rescue teams. (Ho)
- California is in the process of standardizing a triage tag. (Cheu)
- The emotional response to earthquakes and other disasters influences prioritization of rescue activities. (Pantelic)
- Provision should be made on the form to record time of observation because of the possibility of possible aftershock. (McClure)
- The estimates currently in use for relating damage to numbers of fatalities need to be validated. (McClure)
- There is a need to focus search and rescue planning on the large percentage of self-rescues and victims rescued by family and friends because of the burden on hospitals and casualty collection points. (Cheu)
- Another objective of field research is to gather information that is available only in the context of the search and rescue activity to establish an empirical basis for engineering practice. (Krimgold, McClure)
- A structural engineering code does not promise that a building will not be damaged by a major earthquake. Seismic design is successful if building occupants can be evacuated even though the building may require subsequent demolition. (Buckle)
- Can a formula be developed to relate deaths and injuries to structure types and thereby eliminate the problem of unknown numbers? (Charchoglyan)
- Different survey instruments may be required to capture the general information needed to plan for emergency resources and the specific information required to plan actual search and rescue efforts. (Meli)
- Both applications require the same types of information but on a different level of detail. (Krimgold)
- If the intent is to use the data collection forms at the next disaster, special data collection teams should be deployed along with the emergency response personnel. (Ho)
- It may be expedient to use a form already familiar to the response teams, such as the standard paramedic form. (Ho)

- In implementing field research protocols, guidelines are needed to dictate appropriate times for collecting different types of information (i.e., acute versus delayed collection). (Armenian)
- An alternative or complement to field research into the causes of death, injury, homelessness, etc., might be the study of human survivors and undamaged buildings to identify factors that contributed to their survival. (Armenian)
- Standards for family knowledge of basic first aid should be raised to reduce the potential for administering the wrong first aid. (Holland and Buckle)
- How can field research protocols be implemented in the 85 to 95 percent of search and rescue activities that take place before the formal emergency teams arrive? (Krimgold)
- Data collection teams perform a valuable service and are as important at the rescue site as journalists. (Armenian)
- A valuable function for the first data collection teams to arrive onsite is to set the scene for later information gathering. (Freeman)

Specific suggestions for implementing field research protocols included:

- Station data assessment teams at hospitals that receive injured victims. (Holland)
- Limit the size and number of forms. (McClure)
- Use multicopy forms. (Ho)
- Use a question sheet and cards to record answers. (Armenian)
- Make use of the most advanced technology for interviews, including laptop computers and advance types of battery operated equipment. (Freeman and Armenian)
- Develop an "automatic casualty estimation model" with a well-structured problem that can be constantly updated with new information and used for reconnaissance. (Krimgold)
- Consider the possibility of using residents of the earthquake site for acute data gathering and develop a protocol that they can use to relay information to rescue teams in the process of mobilization. (Krimgold)
- Identify and utilize the experience and training of persons who have lived through previous disasters. (Meli and Armenian)
- Develop and put in place national and international protocols to facilitate movement of rescue teams across jurisdictions. (Holland and Cheu)
- Use an incident commander to coordinate data gathering activities. (Ho)
- Standardize terminology among disciplines. (Holland)

- Concentrate planning for research on domestic application and then adapt to the international scene. (Krimgold)
- Utilize local public safety professionals of all types. (Armenian)

Breakout Session 2: Consensus on Field Research Protocol and Implementation

Moderator: Nick Jones

Participants: Richard Andrews, Samuel Aroni, Sayeed Choudhury, Andrew Coburn, Louise Comfort, Maria Luisa Garcia, David Hammond, Miroslav Klain, Austin Moede, E.L. Quarantelli, Lee Sanderson

Dr. Jones began the session by saying that the purpose of the discussion would be to define the variables of earthquake injury epidemiology. As a starting point for discussion, he distributed a list of prepared questions and a list of potential variables to be considered in studying the epidemiology of earthquake injuries. Two draft data collection forms (a long master data form and a short form) were also distributed to be considered when the issue of data collection was discussed.

- It is very important that each discipline identify its own needed questions. Perhaps a set of hypotheses needs to be tested, for example, the time of the earthquake or occupancy of a building. (Coburn)
- Perhaps the most fundamental question is, "What is the distribution of death/injuries as a function of variables?" In addition, determining the different variables is critical. (Jones)
- To help decide priorities, a data set is needed of the scale and types of problems that will be encountered (e.g., tactical information on what kinds of search and rescue works best, what kinds of medical treatment works best). Also needed is gross aggregate information on loss that relates to injuries, not just to economic loss, which is what most loss studies examine. (Andrews)
- Much of the research on earthquakes has been conducted by the insurance industry, but many strategies still can be suggested by these data (e.g., treatment/supplies data). (Andrews)
- It is good that a likely distribution of injuries (a model) is being sought. For example, to what degree has the Mexico earthquake been used as a model for California? (Aroni)
- The information can only be used in a general way. Operational lessons were learned (e.g., on using search dogs in Mexico City). One very important area that was not covered at all in the information from Mexico and Armenia was fire and toxic problems. (Andrews)

- It should be pointed out that the supplies received in Mexico were not necessarily the ones needed, and this distracted airplanes and energy from what was needed. (Garcia)
- Lessons from one earthquake should be applied to other earthquakes; after the parameters that affected death/injury in Mexico are understood, they should be applied to California, Peru, etc. (Coburn)
- The data need to fit into a general model. Search and rescue is only one part of all that needs to be studied. (Aroni)
- Earthquake injury epidemiology focuses on the events after the fact. Questions that will prevent injury in the future are not being asked. (Comfort)
- The protocol is serving many purposes. What is the protocol meant to do? (Quarantelli)
- This form is not a protocol; it is more like a list of definitions. To proceed, a decision needs to be made on what to study. For instance, in Armenia, the question was asked if more people could have been saved. (Klain)
- The worst thing is to develop a protocol that is too general. (Aroni)
- However, there are different levels of analysis and action. A state government uses information differently from a county fire chief. Organizational information is needed, not general theoretical information. (Comfort)
- Although there are tactical and operational considerations, it would be a mistake to say the research objective should be finding purely operational solutions. Much of the purpose of the academic research is to find new and different ways to cut up the pie because, as it is, the pie is cut in only a few ways. It would be better to gather as rich and general data sets as possible, and then look at them for operational aspects. (Andrews)
- The model is a moving circle that can be entered at many points and used appropriately in many ways. (Aroni)
- Perhaps the focus should be on search and rescue. (Coburn)
- How does search and rescue fit into the overall issue of response to the earthquake? Other things need to be looked at as well. (Comfort)
- Search and rescue is important to different degrees, depending on the country. For example, if someone had gone to Armenia prior to the earthquake, he or she would have been able to predict that the buildings would collapse. It would have been clear that search and rescue was going to a problem. In California, where it is of course a problem, it is not as big of a problem. (Aroni)
- In an earthquake, almost everyone dies of building collapse or fire. (Andrews)

- Not necessarily. Sometimes parts of buildings fall and kill people, and search and rescue is not needed. For example, after the 1985 Chile earthquake, where 200 people died, none would have been helped by search and rescue. (Aroni)
- The list of questions is directed at different people–it does not tell whom the protocol addresses. (Klain)
- Concerning search and rescue, the questionnaires need to be modular (one for engineers, one for doctors, etc.). Then researchers can interpret the results. (Comfort)
- This questionnaire was an attempt at a multidisciplinary form that would involve several people. Relatively simple scales of both structural and medical damage (injury severity scores) would be convenient to use. (Jones)
- Scales are valuable, but in an earthquake, people are working against time. Look at the arrival time of equipment and people instead. (Comfort)
- The questionnaire does not deal with the rescue hypothesis but with the event. (Aroni)
- The point of the form is to determine the key time for rescue.
- Had some of these factors on the form been known, there might have been a different response in Armenia. (Comfort)
- A point about search and rescue: The issue of behavior after an earthquake should never be neglected. Interview the survivors and try to relate the injury to the person's behavior. (Aroni)
- This may differ with the discipline; the individual may not necessarily be the only one to study. (Comfort)
- Knowing what questions to ask is extremely important. (Klain)
- One of the questions on the form–on casualty/building estimates–is very valuable for search and rescue. The search is a prioritizing tool (the triage concept). It is not always true that the highly organized search and rescue effort saves the most lives or is cost effective. (Andrews)
- A much more specific set of questions aimed at the victim/neighborhood level is needed. (Comfort)
- It will be difficult to develop only one effective search and rescue protocol. It may be more effective to develop and use more than one and then to compare the compatibility of one with the others. (Jones)

BREAKOUT SESSION 3

Breakout Session 3: Research Applications, Implementation, and Dissemination

Moderator: Gordon Smith

Participants: David Alexander, Richard Andrews, Bo Brismar, Robert Charchoglyan, Andrew Coburn, Julio Lescarboura, Frank McClure, Charles Scawthorn, Luis Zeballos

Dr. Smith began by asking the following questions: Is training necessary? What kind of training? Is it logistically feasible? How do we train the public and rescue people? Has training caused problems in past events?

- Because geographical situations vary, rescue teams should be trained regionally, especially in those regions lying along earthquake lines. Also, local people should be trained so that people will have some idea of what to do once the impact starts. (Charchoglyan)
- It has been shown that skills acquired through training in California (physicians, private industry) have not been retained well. In an urban area, the numbers of people who need training are very large. Because of this it becomes necessary to retrain large numbers of people. Is there perhaps a better way to do this? (Andrews)
- From the experience in Nicaragua (1972) and Mexico (1985), it is clear that more than local assistance must be relied on. On the other hand, hundreds of highly qualified people are not necessary either. It is sufficient to have just a few highly qualified people to direct local people. Earthquakes are an international problem, and therefore outside/international help should be provided. The advantage of outside help is that these people will be less involved emotionally and therefore be able to make more rational decisions than local people. It is suggested that an emergency type approach is used where, as soon as a disaster happens, a rescue team is sent to a neighboring country (neighbor to disaster country) to wait for political approval of assistance. This reduces delay in terms of getting ready, travel time, and the time it takes for the various ministries to authorize the appeal for help. (Lescarboura)
- In California, it is not intended that international assistance will be used. In the State Department or other organizations, there is no structure for outside help. What has happened elsewhere–outsiders coming in and doing what they think is best–is not wanted in California. (Andrews)
- For Latin America, Africa, some European countries, and other third world countries, it is a different approach–outside help is needed. (Lescarboura)

- Time can be divided into predisaster, emergency, restoration of services, and reconstruction. Each discipline should research the activities it can perform during these different time periods. During the preparation phase, a profile is needed, i.e., population maps, facilities location, and type of structure. During the emergency phase, it is necessary to know the magnitude of the impact and to estimate the consequences–population-wise, building-wise and facility-wise–a sort of chronology of the disaster events. During the first 48 to 72 hours, everyone is concerned about search and rescue operations to provide medical assistance. A methodology needs to be defined for this specific time; a methodology for hospital treatment should also be outlined. After 72 hours, there is concern about the life- line services: water quality (contamination) and supply, communication, and outbreaks of diseases, such as cholera or typhoid. On the fourth day, a decision needs to be made about what to do with the bodies, whether to bury them or cremate them, and a protocol for identifying them needs to be developed. After one week, the concern is for temporary settlements, food and medical supplies, and evacuation route. After two weeks, the psychological impact should be dealt with. If there is such a chronology, rational methods to prioritize tasks during a disaster can be identified. (Zeballos)
- How can the situation be assessed in the beginning? How can accurate casualty estimates be made? Initial casualty estimates should be compared with postevent estimates to define how accurate they were. (Smith)
- In California, there are rapid postevent estimates. (Andrews)
- Is it possible to take Mexico City pre-event pictures and compare estimates at certain time periods, and, based on that, refine the estimation procedure? (Smith)
- One approach would be to divide the town between teams and assess damage by visual observation and by asking people. (Zeballos)
- With every earthquake, one tends to underestimate the extent of the damage. (Andrews)
- In Armenia, the rescue operations were concentrated in the towns. Only on the third and fifth day did the rescue people turn to the villages, which had almost completely disappeared. A lot of data were lost this way. The bottom line is people should start rescue work immediately, whether they have data or not. (Charchoglyan)
- With Mexico City, much of the damage was not visible, so no outside help was requested for the first 48 hours. Only the local people knew exactly where the disaster areas were, and disaster areas were often right next to intact areas. When outside help was requested, there was concern that the helicopter's vortex could cause buildings in the badly hit areas to collapse. In actuality, this was not true if the helicopter stayed 100 feet away from such buildings. (Scawthorn)
- Underestimating damage is a common and serious problem. (McClure)
- Compared with the size of the city, the amount of damage in Mexico City was not much. (Coburn)

- That is a difference of perception. The magnitude of impact was high; however, the damage initially seemed low. (McClure)
- A spacial model could provide a vulnerability analysis of a particularly susceptible geographic area and give some indication of possible mortality. (Alexander)
- The Japanese have trained people in emergency response. (Scawthorn)
- Although rescue is the primary concern, it is also important to assess how much has been damaged, how many hospitals need to be mobilized, and how many airlifts may be needed. (Lescarboura)
- Money and time are needed to get sufficient help and supplies. (Andrews)
- Assessment is best carried out by a person physically going into the area and recording the level of damage and the amount of help needed, because some damaged areas could be missed from the helicopter. (Andrews)
- Pre-impact prediction of numbers is necessary, and better postimpact estimation is needed. The data are needed quickly. It may be necessary to analyze how data were collected in previous earthquakes to learn from previous misconceptions. (Smith)
- A hypothetical scenario is needed so that there can be an idea of possible damage and local and international rescue workers can plan resources needed in event of impact. (Zeballos)
- Knowing where the epicenter of the earthquake is can identify which area is most heavily affected by the impact and provide a rough estimate of what and how many resources may be necessary. (Lescarboura)
- A building inventory is necessary. Damage scenarios should be used, as well as a possible impact situation (e.g., 7.5). The life-lines available and a hospital that can be mobilized should identified. (Andrews)
- Scenarios are a powerful tool. (Coburn, McClure)
- Both deductive modeling and inductive modeling are needed. Inductive consists of going out into the field, observing damage, collecting data, and coming up with a predictive map. Deductive consists of knowing where the epicenter is and estimating the damage around it. The deductive modeling substantiates the inductive modeling. (Alexander)
- A model is needed to sample buildings and populations to assist with the estimate. The degree of building damage should be correlated with the consequent human injury. (Smith)

Breakout Session 3: Research Applications/Implementation/Dissemination

Moderator: Eric Noji

Participants: Donald Cheu, Louise Comfort, Michael Durkin, Maria Luisa Garcia, Ben Ho, Miroslav Klain, Toshio Mochizuki, Jelena Pantelic, Edmund Ricci

Dr. Noji requested that participants consider users of research needs, including Federal agencies, search and rescue workers, and researchers in the field (engineers, health care providers, sociologists). He identified a need for the health care community to be able to predict injury and death, based on building structure and collapse characteristics and related to geography.

- Deaths and injuries vary among earthquakes. (Mochizuki)
- Emergency planning for earthquakes requires the identification of areas where casualties are likely to be. (Cheu)
- Increased efficiency of response requires coordination, which often must be achieved at the local level because most first responders will be local fire stations. (Comfort)
- The capacity of first responders should be evaluated in relation to vulnerable buildings and number of people. (Comfort)
- An increased response capability is likely to reduce the severity of the disaster. (Comfort)
- The validity of assumptions used to correlate injuries with building characteristics must be examined, especially when extrapolating correlations to other areas.
  - Critical factors may be different even where there are apparent similarities.
  - Decisions about modifying buildings, changing future buildings, and relocating EMS resources should consider the validity of assumptions used in the model. (Ho)
- Validity of extrapolations from one earthquake to another, with respect to structures and casualties, must be established. (Noji)
- Information that architects need from medical practitioners includes:
  - Severity and type of injury

- Factors (behavioral, sociological) that may render occupants more or less susceptible to injury
- Treatment of people in collapsed buildings and operational constraints for different types of treatment
- Institutional, e.g., medical records.

- The problem is how to link medical information with the attribute of the physical setting. (Durkin)
- Physicians need to recognize that factors such as building performance and people's behavior may affect the traditionally assumed linear relationship between number of injuries and the intensity of the earthquake. (Ho)
- Public agencies and current administrators need information on EMS resources for policy planning and emergency response. (Comfort)
- All predictions about earthquakes and casualties need to be qualified, which makes it difficult to predict needed resource allocations. (Klain)
- The time when an earthquake occurs can change the outcome. (Klain)
- In some situations, i.e., Armenia, it would not be possible to prepare for an earthquake of the magnitude of the one that occurred; however, it is necessary to study what happened and try to improve procedures. (Klain)
- A good emergency response system is needed on an everyday basis, which can be supplemented on an emergency basis. (Klain)
- In California, it is known that an earthquake will occur, but not when. When should caches of equipment and supplies be prepared for mass casualties? (Cheu)
- It is impossible to have sufficient supplies for a massive disaster; therefore, all areas need to have basic supplies. (Klain)
- There needs to be a capability to mobilize resources. Alternatives, as well as predictions, are needed to plan for emergency situations. (Comfort)
- Resources must be protected and volunteers organized. (Ho)
- The premise that roads will be operational cannot be assumed. (Pantelic)
- Information should be readily available, e.g., in the beginning of phone books, so that rescue operations can be self-contained. (Ho)
- Public education is needed to set priorities for protection of the public. (Klain)
- Because earthquakes occur infrequently, it is necessary to establish linkages with other disaster situations so that responders are better able to respond in various situations. (Pantelic)

- EMS people should assume the role of incident commanders, who make global assessments of the situation and direct the efforts of other people. (Ho)
- Consideration needs to be given to how to involve private EMS operations in a response. (Ho)
- An earthquake could trigger other events such as releases of hazardous wastes or underground petroleum. (Ho)
- In Armenia, martial law had to be instituted to maintain civil order. There must be a structure to coordinate the response. (Klain)
- Casualty modeling can be useful in determining the best tools and best methods for reaching people in a disaster situation. For example, different tools could have been brought to Armenia if it had been known that much of the building material was soft concrete. (Ho)
- Information is needed from the engineering community on proper tools and equipment for urban areas and the comparative efficacy of equipment and search and rescue techniques. (Noji)
- Most search and rescue equipment is used for other purposes (Noji), and research on its use in a disaster is based on the last incident involving human victims. (Ho)
- Manufacturers are not likely to invest money to develop disaster-specific equipment that is used relatively infrequently (note the analogy to funding research on rare diseases). (Noji)
- A researcher should be sent to an earthquake scene as a reconnaissance person to identify needs for research and response purposes. (Pantelic)
- A researcher should have a portable computer for recording information at an earthquake scene, such as numbers of schools, buildings, etc. (Ho)
- The University of Pittsburgh is developing packet radios to link to computers. (Comfort)
- An international capability should be developed to send dispassionate researchers to emergency situations. (Ho)
  - Requires advance signing of international protocols
  - Political and diplomatic considerations can interfere. (Pantelic)
- In any major disaster, there is a high probability of conflict among responders. (Pantelic)
- Researchers at an earthquake site must not become involved in the search and rescue operations or they risk losing their objectivity. (Comfort)

- Researchers at an earthquake site should collect professional, accurate information to be reported back to the research community and ultimately to the policy community. (Comfort)
- Valid information is based on valid data collection. (Comfort)
- Officials may object to the collection of research information, and efforts to ensure such collection may have to be initiated for each incident. (Cheu)
- The dissemination of research information requires that researchers be involved in planning; interactions between planning groups and researchers are essential. (Ricci)
- Although perhaps not feasible, the best approach would be for researchers to freely offer their information to the scientific community for whatever use. (Ho, Comfort)
- Government representatives have a different agenda, but they may be able to collect information as disinterested parties. (Pantelic)
- Enough research has been conducted in the United States and abroad over the past 10 years to allow comparative studies. (Durkin)
- Multidisciplinary research groups should be established in areas where there is high seismic activity. (Durkin)
- There is growing sophistication about the kinds of information needed. (Durkin)
- Responsible Government agencies need current research information (the book on search and rescue used by FEMA is based on World War II). (Noji)
- Information should be disseminated to the (1) research community, (2) NRC-EERI, and (3) the policy community. (Comfort)
- Policy organizations should be created that include those responsible for taking action in emergency events.
  - Concise summary information is needed along with backup documentation
  - Information needs to be tailored to the audience. (Comfort)
- Researchers may not be interested in policy, but policy requires leadership and motivation of individuals who possess technical credibility. (Pantelic)
- EMS requires interplay between the professional community and the public and the voluntary and private sectors. (Ricci)
- NAS has published a report deploring the poor status of EMS. (Noji)
  - NAS is a recognized, neutral authority
  - Professional organizations can help to remedy the status of EMS. (Comfort)
- The University of Pittsburgh has developed a data base of research findings in emergency management that is funded by FEMA but not widely used.

  - The data base has been set up for sociologists and is not easily accessed by others. (Comfort)

- A useful data base cannot be created by those who are not involved in EMS. (Ricci)
- Sometimes a fear that information will get into the media precludes the free release of information. (Cheu)
- Data must be packaged differently for different audiences. (Ho)
- Information should be disseminated without consideration of who gets the credit (copyright). (Ho)
- Timing is also important to the dissemination of information, e.g., a national SAR meeting was in progress at the time of the Mexico City earthquake and facilitated a unified response with rescue dogs. (Ho)
- A library project might include the compilation of national reference lists by discipline. (Comfort)
- Information services and data bases need to be linked and shared. (Pantelic)
  - SUNY Buffalo has an information service that abstracts journals on architecture, urban planning, etc.
  - Montefiore Hospital has an EMS data base. (Noji)

Breakout Session 3: Research Applications/Implementations/Dissemination

Moderator: Fred Krimgold

Participants: Harutoun Armenian, Juan Diaz de la Garza, David Hammond, Richard Kunkle, Henry Lagorio, Michel Lechat, and Roberto Meli

Dr. Krimgold suggested that data gathering activities should be structured to have practical applications and asked for ideas on how best to formulate research questions and disseminate information to that end.

- More emphasis is needed on the prevention aspect of earthquake injury epidemiology. (Lechat)
- A simple questionnaire should be developed to gather health hazard and building and engineering data; the questionnaire could be tested by an international team at future incidents. (Lechat)
- The first step would be to develop the questionnaire and circulate it for review. (Dr. Lechat offered to send a sample questionnaire.) (Krimgold)
- Review would be conducted by the professional level of each discipline. (Lechat)
- One questionnaire may not satisfy the needs of all disciplines. (Meli)
- What should be the strategy to deliver the questionnaire where it is needed? (Krimgold)
- Data collection must be conducted onsite by a team that is not involved in rescue activities. (Kunkle)
- Only one form, which includes questions from all disciplines, is needed. (Kunkle)
- How can continuity be ensured? (Krimgold)
- Epidemiologists and experts in the other disciplines could be identified worldwide for rapid mobilization to the disaster site. (Armenian)
- Specific studies should be developed to guide use of the questionnaire. (Armenian)
- What are the "ethics of being there" as they relate to the need for gathering data in the acute period after a disaster? (Krimgold)

- The critical and immediate need for data related to patient care in itself justifies acute data gathering activities. (Kunkle)
- Volunteer engineers are a resource for onsite collection teams. (Hammond)
- Is it possible to get comprehensive data on a site as widespread as Armenia, or can individual indepth studies be used to begin to provide a solid basis for the estimates that presently guide earthquake response? (Krimgold)
- The approach should be one of gathering information for emergency and disaster management rather than research. (Armenian)
- Mitigation resources are limited so there is a need to relate the focus of data gathering to response. (Krimgold)
- Any disaster management plan must have an information component. The survey instrument and delivery system could be drilled and tested by local resources as part of a disaster preparedness plan. (Armenian)
- Primary clients for the product of disaster research are OFDA, FEMA, OES, and other organizations that have disaster management responsibilities. Secondary consumers include the engineering and epidemiological communities. (Krimgold)
- Compilers or interpreters of data from the questionnaire must be aware of the variety of earthquake types and ground movements as well as the constantly changing nature of urban environments when drawing conclusions from historical earthquakes. (Lagorio)
- The critical earthquakes in most areas are usually of the same type. (Meli)
- The characteristics of the earthquake may be a "washout" if the focus is on specific collapses. (Krimgold)
- The difference between pre-event projection of loss and postevent reporting is that there is limited capacity on the part of engineers to predict collapses. (Krimgold)
- Loss estimates cannot be relied on to guide rescue activities; rational and efficient rapid reconnaissance techniques are needed. (Krimgold)
- Is there a role for high resolution satellite photography in the acute period after a disaster? (Armenian)
- Security constraints against revealing the resolution of satellite photograph imagery is a deterrent at this. (Krimgold)
- Data collection should occur close to the site to be useful in the short, critical period after an event. (Krimgold)
- One drawback to aerial reconnaissance, including helicopter surveillance, is the inability to see and evaluate internal building damage; an advantage would be the speed with which a large area can be surveyed. (Kunkle)

- Rapid computer analysis would be a necessary adjunct to aerial photography and could ensure that the full extent of earthquake damage would be known immediately. (Armenian)

- The strategy of evaluation is important, relating what is seen to the injury and fatality distribution in order to facilitate the search and rescue effort. Reconnaissance is an element of the information concept. (Krimgold)

- A questionnaire like the one suggested by Dr. Lechat (to test variables and establish relationships) could be distributed to provide operational personnel with guidelines as types of information needed from a disaster site. (Kunkle)

- An organized and coherent strategy for disseminating important information to the local level of emergency response services should be developed. (Krimgold)

- Could the proposed international network of local professionals be a resource for data dissemination as well as collection? (Krimgold)

- The most effective response is going to be from local organizations. (Krimgold)

- Other relief organizations could be identified to provide support. (Kunkle)

- A confounding factor in the development of a dissemination strategy is that 85 to 95 percent of the rescue is accomplished by people with whom the organized rescue effort has little or no contact. (Krimgold)

- Could the worldwide network of Red Cross-trained cadres be mobilized for information dissemination by including in their training program a standardized earthquake module and scheduling regular updates? (Armenian)

- The Red Cross has played a significant role in immediate response activities. Ten percent of the population exposed through a training program to the 10 primary principles could probably be the basis for informing a spontaneous local earthquake rescue activity. (Krimgold)

- If "grassroots" populations for information dissemination are used, the American Heart Association data on the rapidity of skills deterioration must be recognized. Individuals chosen and trained for data collection or dissemination must be highly motivated or the tasks should be of low complexity. (Kunkle)

- Fire and emergency medical services (Kunkle) and community response teams, such as those organized in Los Angeles (Hammond), have a high level of commitment and previous training and could be a resource for local data collection teams.

Breakout Session 3: Research Applications/Implementation/Dissemination

Moderator: Nick Jones

Participants: Joel Abrams, Samuel Aroni, Anne Coulson, Calvin Freeman, Constance Holland, Jun Kanda, E.L. Quarantelli, Peter Safar, Lee Sanderson, Keishi Shiono, Dennis Wenger

Dr. Jones began by saying the discussion would be about applications of earthquake research, problems with implementation, and identification of who needs the research information. He distributed a list of questions and asked the members of the group what kinds of earthquake casualty estimates they would use.

- Complete information on what happens during an earthquake could be collected, but would it actually help containment and control? (Coulson)
- A rapid assessment of the impact of an event is very important. (Freeman)
- Engineers would like to believe they can predict whether and how a building will collapse, but only in a general sense. Engineers design against damages but do not really know the relationship between damage and injury. (Jones)
- Engineers can provide against damage and injuries. (Abrams)
- Engineers design with a paradigm of economy, and they do not consider the possibility of failure. There is a great amount of uncertainty, but there is a developing field of probability statistics that can be used. (Aroni)
- Engineers deal with mathematical equations and certainties; however, there is a trend toward probability concepts. (Jones)
- From a response perspective, there are two concerns:
  - Response management (macro)
  - Operational decisions (micro).
- Engineering can help in both areas. (Freeman)
- If good data are available, it can be predicted how many people will be killed. (Shiono)
- Information is needed on the necessary emergency medicine available in the shortest time because minor injuries can become life threatening (e.g., a slight head injury can become crippling within 1 hour). There are numerous unknowns in an earthquake, such as dust inhalation. Immediate onsite data are imperative. (Safar)

- The data sets can be separated into three types:
  - Prediction/estimate data (which are the data that engineers and others need); these lead to prevention
  - Scouting data, from someone sent into the area
  - Retrospective data (can be used to learn lessons from past events). (Safar)
- From an engineer's perspective, a huge model from which parts could be taken would be the most desirable. It would require time zero data. (Jones)
- Response managers are between the predictive and census parts of the operation; what is needed is a rough estimate of casualties. (Freeman)
- There are two ways to get that data:
  - Make a prediction based on past data
  - Make a quick onsite assessment. (Abrams)
- A third way to get data is to take a little bit of information, such as conducting a reconnaissance by counting buildings. (Freeman)
- An initial reconnaissance is not counting, but a more general assessment of severity. (Abrams)
- The idea that one model or protocol can be developed for all the data is unrealistic. Some disciplines here are trying to combine while others are trying to separate. (Quarantelli)
- Ideally, there would be one large model, and certain sections could be pulled out. Within the conceptual framework, there is much overlap. (Jones)
- Information that could be used is the information based on building stock–information on those buildings that may go down later in an aftershock and cause injury. (Holland)
- The idea that it is possible to get an aerial, high-tech, onsite assessment telling us where people are is unrealistic. A casualty estimate is the most asked for piece of information. Most trapped people are pulled out immediately by volunteers, and for the first 3 days, EMS personnel are basically on their own. (Wenger)
- Casualty estimates involve more than only trapped people. There are other mass medical problems for a long time afterwards that are underestimated. In addition, it seems as if emergency responders have been taken by surprise about mental health and mass care issues. (Sanderson)
- The reason for this workshop is to improve the response–to learn retrospectively from each event. In Armenia, doctors came in 3 hours after the earthquake, but they brought no needed supplies. However, the fact that they got in there with their expertise at all showed that there had been some improvement in response. Compare that with the earlier Peru disaster, for example, where it took 4 days for them to get in. (Safar)

- In the VA Hospital incident, there were all kinds of onsite misunderstandings that could have been improved. More research in operational search and rescue is needed. (Aroni)
- There has been very little research in search and rescue. (Jones)
- The methods that do not work are known, but what will work needs to be identified. (Abrams)
- The problem in most areas is coordination, not supplies or equipment, as was heard in Constance Holland's paper. (Wenger)
- Sociologists need help from engineers to change people's behavior through education. For example, when sociologists teach people to move under a desk or door jamb, are they teaching the right thing? (Holland)
- What should be emphasized during response? Who receives immediate support from the resources? These priorities have to be set largely before the event occurs. (Freeman)
- There is a tremendous need for victim survival education. During an event, 95 percent or more of people simply rely on their own instincts, not on education. "Scenario training" should be advocated for the home or workplace, where most people are located during an earthquake. It encourages people to plan ahead and it reduces their panic, which often leads to injury. (Aroni)
- An interesting example of the behavioral factor is the earthquake in Tangshan that happened during the night. There were many severe spinal injuries there. It appeared that those who sat up in bed had many spinal injuries, while those who stayed lying down on their backs did not incur as many. (Jones)
- This is interesting because a coma kills fastest, and the best position for the comatose is to be prone with the head back. (Safar)
- It would be helpful to differentiate between casualty estimates, which are large bodies of data that are predictive, and other information that is needed by emergency responders, etc., right after the event. (Abrams)
- In Dr. Shiono's model, how was it decided that two-thirds of those who died in the Mexico earthquake died slowly? (Safar)
- It was the ratio of the survival rate of those extricated alive to the total number of people extricated. (Shiono)
- Dr. Shiono's model is more of a conceptual framework than a representation of real data. (Jones)
- Are there data on extricated people who are injured but still alive? Are there data on how they died, if they died? It is very important to know this. For people found dead, it is too complex to tell only from the body's appearance how long they have been

dead and what they died of. A gross autopsy is needed to check for lethal injuries. (Safar)

- This concerns the tagging idea–to tag an extricated dead body as soon as possible with observations. (Jones)
- Tagging may help to gather certain statistics. But search and rescue should include a third component, resuscitation. (Safar)
- This meeting is leaving out a critical group of people, both to planning and recovery–those involved with legislation and planning budgets. (Holland)

BREAKOUT SESSION 4

Breakout Session 4: Research Needs and Agenda: Multidisciplinary

Moderator: Gordon Smith

Participants: Bo Brismar, Michel Lechat, Julio Lescarboura, Toshio Mochizuki, Peter Safar, Keishi Shiono

- In the medical discipline, there is a disaster index:

$$\frac{N.\ S}{MRC; MTC; HTC}$$

N = number of victims
S = severity of injuries
MRC = medical rescue capacity
MTC = medical transport capacity
HTC = hospital treatment capacity

N and S determine the casualty load. They depend on good construction. MRC, MTC, and HTC–any one of these can be the critical factor. For example, in Armenia, MTC was a major problem. It is important to know what MRC a community has. MTC depends on roads and population density. Extricating a lot of people when MTC and HTC are not available does not save more lives. Some questions that need to be asked are:

- Were hospitals destroyed in the impact?
- How far is the closest available hospital?
- Is there transportation available?

Each discipline has a different equation. (Brismar)

- Time should be a factor of any disaster index. Resuscitation without evacuation makes no sense; it is like search without rescue. (Safar)
- Severity of injuries may be deemed less serious if HTC is very good, as in California. The level of MRC, MTC, and HTC will determine if and how much outside help is needed. (Smith)
- Certain types of construction can affect injuries in terms of type of injury and severity of injury. (Lescarboura)

- From an engineering point of view, is it possible to estimate construction type and possible intensity of damage in case of an impact? Is magnitude of impact a factor? (Smith)
- The levels of building collapse should be defined in terms of inner space that remains after impact: slight damage, heavy damage, and collapse levels. The volume change in a building can be used as a determinant of degree of damage. (Shiono)
- There is a difference if buildings stand alone with open space around them or if they are right next to one another. If the building stands alone, one should evacuate; if the building is surrounded by other buildings, one should not evacuate, it is better to stay inside. (Brismar)
- Volume change can be a determinant of exterior damage as well as interior damage; for example, if no beams collapse, the volume change will be slight and damage will probably be slight, and therefore injury too will be slight. (Smith)
- It has been observed that small rooms were not as damaged as big rooms in an earthquake. (Lescarboura)
- Why is it important to estimate the number of casualties and injuries? (Safar)
- This deals with rumors versus preliminary data. Preliminary data are necessary for prevention; rumors are for search and rescue. (Lechat)
- Rumors are important. In Mexico City, Juarez Hospital had seven floors. The decision to start in one spot as opposed to another was based on local information as to where the children were located and the knowledge that children's quarters are more confined. (Lescarboura)
- Engineers can test on a shake table and predict what will happen to a particular type of building. (Smith)
- Knowledge of building construction is important, not only for prevention, but also for estimating necessary resources. (Brismar)
- Where are plans of the building kept? For example, it is important to know where the staircase is. (Lechat)
- It would be beneficial to develop a data base in which to store digitalized plans of buildings. (Lescarboura)
- MRC refers to qualified first-aid medical personnel who have access to equipment and supplies. The equation refers to how many patients one MRC team can see in one hour. MTC/hour refers to how many patients one MTC team can transport per hour. HTC/hour means how many patients the hospital can admit and take care of per hour. (Brismar)
- Concerning hospital treatment capacity, the limiting factor is not the number of beds, but the number of trauma units or number of operating tables available. (Lescarboura)

- The limiting factor is medical personnel. (Safar)
- In a hospital, there is a ratio between the number of beds/operating tables and the medical personnel available. (Brismar)
- Depending on the type of hospital (general versus specialized for transplant, for example) the ratio varies, so that number of beds is not an accurate way of determining hospital treatment capacity. (Safar)
- What data can treatment people give to engineers to improve prevention services? (Smith)
- Because of falling debris, in particular glass, people should be trained to stand in a "safe place" for 3 minutes and then evacuate in a controlled fashion. However, should evacuation routes (e.g., exit ways) be better constructed since they often seem to be the first constructions to collapse? Also, since people are told to keep away from windows and stand in doorways, are these doorways strong? (Lescarboura)
- As tests are performed on cars for safety, so should tests be performed on houses. Is it possible to identify, for example, two types of ceiling: one that caves in and that could kill in the event of an impact, and one that bends and is more flexible so less people will die? (Lechat)
- How easy is it to collect data on what parts of a building cause and/or intensify injury? (Smith)
- The bathroom is the room where most survivors are found because of the availability of water. (Lescarboura)
- Can data be collected on specific injuries being caused by specific constructions? For example, an adobe wall was reinforced with pebbles which when the wall collapsed, shot out like bullets and caused specific injuries. Such information is important. (Lechat)
- Clinical studies showed that the neck rest in the car seat prevented cervical injuries. This is not prevention of disaster, just prevention of the extent of the impact. Can the same be done with earthquakes? (Smith)
- Triage at what level? (Lechat)
- Early retrospective followup is necessary. Data should be collected from people who worked with victims as soon as panic situation is over. (Safar)
- Should people wear identification tags? (Lescarboura)
- What is the best way to obtain important information from rescuers, such as in what rooms were survivors found–information such as the bathroom is a good place because it is a small room with many supporting structures (e.g., steel bathtub). (Smith)

- It is best to gather data not as a structured interview but as a casual conversation with rescuers, who may welcome the opportunity to get "it" off their chests. The best place to learn is in the field. (Lescarboura)

- It is important to know what injuries were caused by, for example, a falling beam or adobe pebble. (Smith)

- When good equipment is available, the concentration is on the badly injured, whereas when only rudimentary equipment is available, the concentration is on the lightly injured. Perhaps it is better to concentrate on the lightly injured, as they have more opportunities to survive. (Lechat)

- By the time specialized equipment and specialized personnel arrive, the lightly wounded are already in a medical facility of some kind, leaving the badly injured to be rescued from the disaster area. Therefore, there is no question of triage. (Lescarboura)

- The type of equipment needed depends on the type of building. (Shiono)

- It would be very interesting to research the type of equipment needed for a particular type of building. Perhaps by using the right kind of equipment with different types of buildings, the survival rate can be increased. (Lechat)

- The use of heavy equipment, such as cranes, is for demolition purposes. To rescue people, one needs to use drills for tunneling, jacks, cutting saws, flame cutters, and laser equipment. It is comparable to doing brain surgery with a hammer and chisel instead of with the laser beam. (Lescarboura)

- Is heavy equipment necessary when there are reinforced concrete slabs or structures with no steel rods to reinforce them? (Safar)

- Special equipment needs specialized personnel. (Shiono)

- The people who do not die in the first five minutes stabilize themselves and can live at least 11 to 15 days without water as long as there is ventilation. If they have water, they can live even longer. Therefore, there is no need to hurry. The important thing is to keep the ventilation route open. All too often heavy equipment chokes the air routes with dust, thus endangering survivors' lives. A number of victims die of dust inhailation. (Lescarboura)

- Why should people wait 3 minutes after an impact before evacuating? (Brismar)

- In one-story buildings, people need to get out immediately. In buildings with two stories or more, they should wait because an earthquakes's primary wave is followed, at the most 1 minute later, by a secondary wave which is the wave that can make buildings collapse. It is believed that within 3 minutes, most of the collapse will have occurred so people will know which routes of evacuation are still open to them, whereas if they run immediately they could fall with the floor caving in. Most people are killed during the evacuation. (Lescarboura)

- Data show that there are fewer casualties when ground-floor occupants rushed out and high- rise occupants stayed put. High-rises with large window areas that collapse cause a gush of glass, which is another reason evacuation should not be immediate. (Lechat)

- In 1976 in Peru, an impact exercise was conducted that gave rise to two problems: (1) the exercise casualties had nothing with which to pin or stick on their identification tags, so they had to tell the medical personnel what was broken or whatever and, more important, (2) actual sick people arriving at the hospital were assumed to be part of the exercise and therefore were not treated. (Lechat)

- There is a need for detailed data on survivors who eventually die in the hospital. How did they die and when? Being able to reconstruct how victims died is crucial. (Safar)

- Every victim upon extrication needs to be tagged as to time of extrication, etc. (Smith)

- By comparing number of injured with number of injured who eventually died, can it be calculated whether it was worthwhile to extricate them? (Lechat)

- There are data on extricated people and dead people, but no data on what they died of. (Safar)

- Can a victim survive without medical attention after extrication? (Shiono)

- Every injured person needs medical attention. As with a car accident, a person can walk away and die a few hours later from a ruptured spleen. (Safar)

- With car accidents, the damage measured as G-force can be an indication of passenger injury. (Smith)

- The same could apply to construction impacts–the amount of damage to the building can be an indicator of extent of injury to the victim. (Lechat)

- Rescue people who frequently go to disaster areas may need psychological help. (Lescarboura)

Breakout Session 4: Research Needs and Agenda: Multidisciplinary

Moderator: Eric Noji

Participants: Samuel Aroni, Louise Comfort, Calvin Freeman, Ben Ho, Henry Lagorio, Roberto Meli, E.L. Quarantelli, Dennis Wenger

Dr. Noji asked that participants identify priorities for new and ongoing research, focusing particularly on interdisciplinary approaches. Dr. Quarantelli proposed a distinction between interdisciplinary and multidisciplinary approaches. He described interdisciplinary approaches as best in principle but difficult to achieve because of the necessity of having a common research design. Multidisciplinary approaches may be more practical and possible. If agreement can be reached on the questions to be addressed, a common methodology is not necessary.

- Research questions need to be reconsidered with input from many disciplines. Interdisciplinary approaches evolve from multidisciplinary approaches when there are researchers who can cross disciplinary lines. (Comfort)
- The focus should be on problems rather than disciplines. (Comfort)
- Johns Hopkins is interested in the rapid assessment of health care needs in disaster situations–information must be collected acutely to predict needs. (Noji)
- An interdisciplinary approach should be sought but with the realization that a multidisciplinary approach may work best. The best approach depends on the people involved, but it is necessary to reach joint definitions and understanding of terms. (Aroni)
- The norms of the group will determine who is willing to act on action-oriented problems. (Comfort)
- Casualty estimations require information on variables such as geography, engineering, medical, and operations research factors. (Noji)
- Regular peer review will support the evolution from multidisciplinary to interdisciplinary approaches and lead to a more informed interdisciplinary product. (Comfort)
- The problem of measurement could be approached by the use of ordinal scales that could be developed into a logic set and related to decision processes. (Comfort)
- From the user perspective, data are not cross-linked, the right questions are not asked, or data are lacking. (Ho)

- Predictions relevant to responses to emergencies must be based on models, previous experience, or anecdotal information, but every acute incident is approached as new.
  - Important medical information includes the number (or percentage) of orthopedic injuries, crush injuries, and cases of dehydration. (Ho)
- It is important to identify factors likely to affect the disaster outcome or factors needed to predict the range of probability if an event occurs. (Aroni)
- Responders need information on logistics, practical medical care, and whom to rescue first. (Noji)
- Reports on the numbers of dead and homeless are important, but more information is needed. (Lagorio)
- Research should be focused on mitigation after earthquakes and on prevention.
  - Building design to minimize injury
  - Structural design
  - Injuries caused by nonstructural factors, e.g., windows, facades. (Meli)
- Structural systems should be designed to avoid damages from moderate earthquakes and avoid collapse from exceptional earthquakes. (Meli)
- The relationship of nonstructural components of buildings to casualties is not known. (Lagorio)
- The ratio of injuries resulting from structural and nonstructural components is not known. (Freeman)
- It may be that structural components play a lesser role than anticipated and behavioral components a greater role. (Aroni)
- The interrelationship between physical and behavioral factors may be most important. (Aroni)
- The role of behavioral factors has important implications for public education. (Comfort)
- Some topics and problems are purely disciplinary and should be identified as such. However, they need to be viewed in process terms. (Wenger)
- A multidisciplinary approach is needed to establish key linkage points.
  - Organizational and behavioral problems have such linkages. (Wenger)
- Levels of analysis can be interdisciplinary, multidisciplinary, or single disciplinary; the interrelatedness between problems spans the levels of analysis. (Comfort)
- Solutions lie at the intersections of problems. (Aroni)

- Pre-impact mitigation requires a multidisciplinary approach, e.g., for an engineer to build an escape route in a building, he or she needs to know where the people are. (Ho)
- Such an approach has been used for fires. (Aroni)
- In Armenia, those near windows survived the earthquake. (Comfort) It is possible to design a building with a concrete core that can serve as the supporting skeleton and route of escape. In many buildings, the staircase is the weakest part. (Meli)
- Buildings in Texas are designed to have a core that can withstand tornadoes, but in earthquakes the mass acceleration comes from the ground and the most survivable part of the structure may not be the heaviest. (Aroni)
- Behavioral and structural considerations need to be combined in designing an escape route. (Aroni)
- Escape routes must have access and egress so that building occupants are not entombed. (Ho)
- Escape training needs to be specific for the type of disaster. (Aroni)
- Rescuers need to know what training the occupants have had so that they can be located. (Aroni)
- Peoples' reaction in a disaster depends on their mindsets. (Comfort)
- Information derived from the interface of engineering and injury studies can be used to design better buildings (a goal of this workshop). (Noji)
- U.S. buildings would have failed in Armenia and Mexico City but not in the same way as the buildings at those locations. (Aroni)
- In the United States, an annual average of 2 percent of new buildings are added that are designed according to the provisions of the seismic code. (Lagorio)
- More attention should be focused on older buildings in the United States. (Freeman)
- Information should be used to achieve greater efficiency in using resources available in a variety of disciplines. (Comfort)
- The 72-hour organized response factor is based on recommendations from VA hospitals and experience in Mexico City. (Aroni, Wenger)
- In Mexico City, only a small fraction of the city was affected, so the rest of the city was able to respond; in Armenia, the disaster was widespread. (Aroni)
- Different buildings are affected in different types of earthquakes. (Aroni)
- The Scawthorn model can be used to predict which buildings will fail. (Noji) The model can include information on building types and numbers of people in the building. (Ho)

- A building census can give clues about the potential magnitude of the disaster. (Freeman)
- A potential major problem is a breakdown in communication and resultant uncoordinated response. (Comfort, Ho)
- Lethality indexes should be prepared for certain buildings. (Ho) International people can offer some advantages in emergency situations, because the local people are naturally concerned about their families. (Aroni)
- One way to integrate information from disciplines may be to create ordinal scales for each discipline–severity of injury, collapse index, resources, etc.– and formulate alternatives for action agencies. (Comfort)
- Decisions that California must make would be helped by modeling.
  - Whether to use public transportation for search and rescue
  - Whether to emphasize getting casualties out or resources in. (Freeman)
- If research is designed to solve action problems, then it must include measurement of changes.
  - Ordinal scales may be best
  - Sensitivity of scales should be examined in relation to disaster outcome. (Comfort)
- R&D and applications need to be integrated to solve problems. (Aroni)
- The development of proper equipment for search and rescue may be subject to free marker forces, but pioneering work should be pursued in a focused way. (Aroni)
- The design of instruments is a research task, but the application of the instruments needs to be evaluated. (Comfort)
- Aircraft safety and accident investigation procedures offer a useful analogy to earthquakes: the incident should be reconstructed in great detail as the basis for future design changes. (Ho)
- Action research is a new evolving area designed to change outcomes. (Comfort)
- Retrospective studies of earthquakes should be used to design and test models that will predict outcomes. (Aroni)
- Information from experience and research must be integrated into a systems approach that will be undertaken by a communal team. (Aroni)

Breakout Session 4: Research Needs and Agenda: Multidisciplinary

Moderator: Fred Krimgold

Participants: Richard Andrews, Ian Buckle, Donald Cheu, Andrew Coburn, Anne Coulson, Miroslav Klain, Frank McClure, Jelena Pantelic, Lee Sanderson, Charles Scawthorn

Dr. Krimgold asked each participant to suggest specific research needs and questions for an agenda that could implement the five strategies to reduce earthquake fatalities and be communicated to the research funding community as having the potential to advance the field.

Research Needs and Questions

- Research is needed on special tactical issues related to rescue and medical treatment, such as:
  - Verification of any loss of volume hypothesis that would provide methodology for conducting the search process more effectively
  - Improved methodology for administering treatment to trapped victims
  - Relationship of time periods and expectation for survival correlated with personnel requirements during those time periods to maximize rescue efforts. (Andrews)
- Research is needed on general strategic issues related to scaling the level of the problem with the level of resources that would be required in major urban emergencies, as well as techniques for proceeding as quickly as possible from pre-event estimates of requirements to postevent summations. (Andrews)
- How can the international research community help legitimize and publicize mitigation and preparedness measures in high-risk areas? These measures could include:
  - World risk mapping
  - Addressing the questions that are critical to reducing fatalities on a global level
  - Studying past hyperfatality events for clues to reducing future mass casualties
  - Exploring ways to extrapolate data from the casualty models that predict numbers of deaths per building to mass casualty models. (Coburn)

- What is the minimum data collection effort required to develop response models? (Coburn)
- How can technology be expedited to produce better tools for rescue of victims from collapsed buildings? (Pantelic)
- There is a need to continue the development of a coordinated framework for research that identifies the phases of mitigation and response, roles of the various disciplines, and resources and technologies needed to reduce earthquake casualties. (Buckle)
- Uniform and consistent definitions and methodology should be developed for use by all disciplines in conducting the epidemiology surveillance necessary to inform future activities and permit large-scale evaluation of progress made in prevention. (Sanderson)
- There is a need for a series of epidemiologic case-control studies of building occupants in past earthquakes to establish risk factors for variables, such as engineering, behavior, and protective equipment, so that education can begin on how victims can take ameliorative action. (Sanderson)
- Information on which to base planning for earthquake response is needed on vulnerability of various building types, how to effect earlier response by medical teams, how to effectively coordinate the medical response, how hospitals function after earthquakes, and injury types. (Cheu)
- Definitions and terminology should be standardized. (Cheu)
- The maximum amount of data should be collected on as many earthquakes as possible to validate existing life-safety ratios. (McClure)
- As a preliminary step to developing a questionnaire, as much data as possible should be collected, with careful attention to historical reconstructions. (Coulson)
- Early response surveillance is needed to determine what happens in the immediate aftermath of an earthquake. (Coulson)
- Research activities should be planned and research questions framed well before arriving on the site. (Coulson)
- Funding organizations should expand their approach to include multidisciplinary representation on the postdisaster teams that they dispatch in order to make the data collection effort more comprehensive. (Andrews)
- A paradigmatic flow chart or systems model approach should be developed that outlines the whole multidisciplinary process so that problems can be attacked systematically. (Scawthorn)
- What can be done to promote stronger ties between government policymakers and the research community, possibly modeled after the Japanese fire service's ad hoc think tanks? (Scawthorn)

- There is a need to test the efficacy of search procedures and apply the latest technology to the detection effort. (Zeballos)
- How can medical care administered to victims onsite be standardized on an international level? (Zeballos)
- A vulnerability analysis of hospital and health facilities is needed to find correlations between structural, nonstructural, and behavioral factors. (Zeballos)
- What are the long-term psychological effects in the affected populations and subsequent social and economic implications. (Zeballos)
- Can better portable water purifiers be developed that are capable of supporting large populations? (Zeballos)
- What physiological factors and common sense techniques can inform survival strategies? (Zeballos)
- The research agenda should be action-oriented and respond to the immediate need for management information for both planning and response. (Krimgold)
- Research that has the greatest life-saving potential would answer the questions: What can be done to improve rescue and treatment within the first 24 hours of the group of patients who are most seriously injured? Could they be saved by proper treatment? Should they get first aid before extrication? How much first aid should be taught? How can the local and regional emergency response be made more effective? What equipment can be designed to aid the rescue effort? (Krimgold)
- How can the theory of "late deaths" be verified? (Klain)
- To improve search and rescue planning, a concentrated effort is needed to verify the current assumptions on the numbers of lives lost for each hour's delay in rescue. (Krimgold)
- Extrication difficulties, not the lack of medical personnel, is the limiting factor in the delivery of medical care to the seriously injured. (Krimgold)
- Research is needed to improve resuscitation methodology. (Cheu)
- Verifying hypotheses such as those related to loss of interior space would have important application to the problem of building triage as it relates to deciding where to begin the search for victims. (Andrews)

Discussion Points

- While it is important that the research community continue its dialogue with the user community, resources and support for basic research are also vital to this emerging area of study. (Andrews)
- Insufficient tools for extrication and rescue was a major obstacle in Armenia. (Klain)

- What level of effort to save a life can be justified? (McClure)
- Society makes de facto decisions on issues of health and safety (for instance, when it accepts less than optimal building design and construction standards).
- It is the responsibility of the epidemiological research community to provide a rational framework for developing a balanced program for allocation of resources between the mitigation and response components. (Krimgold, Scawthorn)
- Moral, political, and psychological considerations are often more powerful determinants of action and resource allocation than rationality. (Andrews)
- The emphasis in planning for emergency preparedness should be on mitigation to effect the greatest reduction in casualties for the money. (Coburn)
- Mitigation and response research are equally important because of uncertainties as to when or where the next disaster will occur. (Andrews)
- Societal values are reflected in heroic search and rescue efforts; therefore, they have a great influence on response decisionmaking. (Scawthorn) Decisionmaking relative to disasters also has political consequences (Zeballos) and is influenced by the government's need to maintain credibility. (Scawthorn)
- The judgment of the State of California about the value of search and rescue has provided the basis for development of strategy in that state. (Andrews)
- Logic based on time of day and type of building should guide search efforts. (Buckle)
- A rational reconnaissance approach is necessary for those situations where the scope of the disaster is not known in the period of time available for maximum recovery of victims. (Krimgold)
- There is much to be learned about the characteristics of building collapse and the validity of the present system of building classification. (Krimgold)

Breakout Session 4: Research Needs and Agenda: Multidisciplinary

Moderator: Nick Jones

Participants: Joel Abrams, David Alexander, Robert Charcoglyan, Sayeed Choudhury, Michael Durkin, David Hammond, Constance Holland, Jun Kanda, Richard Kunkle, Edmund Ricci

Dr. Jones began the session by saying its purpose was to bring out the cross-disciplinary research needs of the participants. The indices to measure each discipline need to be identified. For example, the injury severity score could be a valuable medical measurement. A simple scale to measure building collapse (perhaps measuring percent volume) also would be helpful. Dr. Jones distributed a list of prepared questions to aid the discussion.

- Generally, a scale is needed to describe seismic performance in buildings that could be linked to severity of injuries. For example, building X suffers nonstructural damage; does this cause minor or major injuries? (Durkin)
- Another type of measurement could be the degree of a building's disintegration. For example, is the floor system intact with cavities or completely collapsed so that people trapped cannot be rescued? (Abrams)
- Such a scale or index needs to use an interdisciplinary terminology so all disciplines can understand what it means. (Holland)
- There are numerical scales and linguistic scales, and there are techniques for relating the two. (Abrams)
- This is the classic modeling problem: it must be neither too complex nor too simple. The model should help in identifying if injury is directly related to building damage, as opposed to, say, a person's physical condition or behavior. (Alexander)
- Engineers have a terminology for an index; however, with injury-related damage, there needs to be more differentiation. There are categories of degrees of building collapse. (Kanda)
- Unfortunately, few building studies exist of totally collapsed buildings; thus, engineers do not have a clear idea of the differences of collapse. (Jones)
- This discussion centers on an assumption of optimal conditions (e.g., how people and buildings ought to respond), but earthquakes often happen in suboptimal conditions. (Alexander)

- The lack of a building study in the case of Juarez Hospital in Mexico is an aberration. Also, people are often injured by falling objects. (Hammond)
- A common language on this subject is important (Holland, Kanda) and needs to be developed. (Durkin)
- Scores should be developed inductively. Also, divisions should be made using operational considerations, for example, can the building be repaired? (Alexander)
- Forms have been developed for this. It would be a good research idea to examine all of them and look for compatibility. (Jones)
- So far, structures have been emphasized. What about other areas (e.g., medical)? (Abrams)
- A disaster severity index would be at least an initial way of making estimates to bring the needed help. (Jones)
- An index of building collapse does not necessarily relate to medical injuries. Also, using an injury severity index does not solve the medical problems in an earthquake; two injuries that have the same medical severity score may require vastly different treatments. (Kunkle)
- Physicians have not yet even developed a systematic body of medical data that merely describe the range of earthquake injuries, let alone relate injuries to structures. Even before severity scores, good descriptive data on injuries are needed. (Ricci)
- The same holds true with behavioral indices on an international level–survival behaviors across cultures can vary to a great degree. (Holland)
- Although there may not be a common language, multidisciplinary teams should always be used during earthquakes. At least then different concepts of the situation can be merged together. (Ricci)
- More needs to be learned about the modern medical techniques for earthquake victims, and specially trained personnel are needed for these events. (Charcoglyan)
- During these events, a disaster management coordinator is crucial, one who understands both medical and engineering needs. (Jones)
- In many localities it has been found that there may be a disaster management plan, but it does not really work in the chaos of the first few days following an earthquake. Eventually, however, the plan does start to work. (Abrams)
- Many of these plans have been developed, but they are not actually used in the field after a disaster. Operational people must be involved in these plans. The most effective thing to use and distribute are checklists, something that can be put in your pocket. A study of these management systems is needed. OFDA is looking at these plans. (Holland)

- Engineers and architects need to be involved in these operations. In Armenia, Joel Abrams became involved because Peter Safar knew people could not be reached without him. (Ricci)
- Coordination among groups is essential. For example, doctors can assess whether an injured person needs to be fully extricated immediately or can be left temporarily so someone else can be saved. (Abrams)
- Consideration needs to be given to what to teach the public about survival and how to teach it. (Ricci)
- Two groups of people who need to be involved and informed during an earthquake are public information people and lawyers. There have been instances of firemen who will not extricate a person for fear of a lawsuit. (Holland)
- In engineering, the general rule is that if state-of-the-art design is used and no negligence is found, the engineer is not liable for damages. (Jones)
- In California, there have been cases where, if the state of the art changes after design, an engineer can be held liable for damages. (Durkin)
- Presumably, these people have insurance or else they would not be able to do their jobs. (Kunkle)
- On a more general level, there need to be more good deductive studies on earthquake injury in addition to all the good inductive ones. (Alexander)
- Researchers outside the United States seem more willing to conduct deductive studies. (Holland)
- California leads the way in research studies, but these seldom make use of international information. (Alexander)
- The research community needs to look at these various models more openly. (Holland)
- There is resistance to the global approach. (Jones)
- There is a difference between a global model and a global map. (Durkin)
- It is valuable to have a map first, then a model. (Ricci)
- When devising a building scale/score, perhaps the injury component should be factored in, rather than having a separate scale and score. (Jones)

BREAKOUT SESSION 5

Breakout Session 5: Research Needs and Agenda: Intradisciplinary

Moderator: Gordon Smith

Participants: David Alexander, Haritoun Armenian, Samuel Aroni, Louise Comfort, Anne Coulson, Calvin Freeman, Michel Lechat, Frank McClure, Edmund Ricci, Luis Zeballos

Dr. Smith began the session by asking each participant to address the issue of which parts of the building may be safest and whether injuries may be due to nonstructural components such as a ceiling tile.

- Better statistical data is needed so rescue people know what to expect. (Freeman)
- A measure for factors that affect earthquake injury and survival, for example, socio-cultural aspects, should be developed. What could save people assuming no one could get to them? It is not so much construction reinforcement as behavior, especially as related to age. For example, younger people are more susceptible because they have more energy to dissipate. Prior training does not seem to change behavior. (Aroni)
- What does the damageability of buildings to death ratio mean? Looking at pictures of previous earthquakes can give a lot of insight, for example, vertical elements that uphold the roof. (McClure)
- A different type of construction is necessary for earthquake impact than for earthquake plus fire impact. (Aroni)
- Occupants in buildings with glass walls, as in San Francisco, should be trained to stay put in case of an impact. (McClure)
- It is safer to stay inside the building even in unreinforced masonry buildings. (Aroni)
- Should uninjured people be studied? Perhaps those who come back to salvage cherished valuables should be questioned. (Smith)
- Many problems are associated with interviewing people who are in mourning or in shock. (Comfort)
- Guilt is also a very strong feeling present in impact victims, for example, "I ran faster than my wife." (Aroni)
- Can regular survey techniques be used since even banal data can trigger great emotional responses? (Alexander)

- The optimal time to conduct an interview is unkwown, but some suggest that people should wait 3 weeks' postimpact for the relatives to overcome the grief. (Smith)
- Interviewees may have different responses over time, for example, physicians may exaggerate their involvement over time. (Arn enian)
- After some time, some people may relate other people's experiences as their own. (Comfort) Injuries and deaths should be studied as a consequence of structure, behavior of individuals, time of impact, and prevention/rescue efforts implemented to come up with a list of research needs for prevention, education, search and rescue efforts, and training in general. Methodological problems should be outlined such as defining injuries, and a simple list of indicators that can be tested in the field in future impacts should be made. (Lechat)
- It is necessary to develop observations, methodologies, approaches, models, and conclusions that transcend cultural boundaries. General models of a deductive kind are needed. Meanwhile, poor data should not be discarded but analyzed so as to improve the quality of the other data. (Alexander)
- The relationship between heart attack victims and earthquakes needs to be investigated. (Alexander)
- It is difficult to differentiate between heart attacks that are induced by earthquakes and heart conditions aggravated by impact to the point of a heart attack. (Aroni)
- Could the survivability from heart conditions be aggravated by a possible lack of medical attention due to the impact? (Smith)
- It is important to extract maximum data from the information collected. (Aroni)
- Heart attacks are oversubscribed because (1) physicians often misdiagnose and (2) if a patient has a history of heart disease, his cause of death is often assumed to be heart attack. Therefore, one must be careful about data received. Pre-event designing and definition of population, etc., are necessary. There should not be so much interest in where fracture occurred (head or leg) but how it occurred (brick falling or floor caving in). People should be identified (blood sample or DNA identification) so that one can go back and interview them and find out whether they are in a hospital, evacuated to a neighboring village, or something else. (Coulson)
- There is a need for (1) more descriptive studies on injured people and resuscitation potential for the greatest life-saving expectancy and (2) research education of public to change behavior of both professionals and lay people. Behavioral change can be tested in a simulated stress situation. (Ricci)
- In California, it was observed that it is very difficult to change behavior. (Freeman)
- A computer game could be developed to train people about what to do in an earthquake situation. (Coulson)

- It should not be too hard to teach people to check exits and gas and water outlets. What is the transition of responsibility in the decisionmakers' chain when trying to get rescue help out expediently. The decisionmaking process should be reconstructed to substantiate and justify decisions taken and to learn for future events. (Comfort)

- Death should not be the only outcome in which there is interest since nothing can really be done for those people. Injuries should be further investigated in terms of how to better prevent them. Survivors are the most important of all as they can teach us most about positive behavior, appropriate structure, etc. (Armenian)

- With each new incidence, in each discipline, at each level, new methods are developed. These methods should be evaluated and those that are unproductive should be eliminated.

- Case studies on survivors may reveal a variable that should be investigated in a control case study. (Armenian)

- It is necessary to differentiate between successful methods of field intervention and unsuccessful ones so that the mistakes are not repeated. (Freeman)

- The timing process accounts for the survival and severity of the injuries–the time it takes for first-aid medical help to arrive at the scene of disaster, the time it takes to transport injured people to hospital, and so on. (Zeballos)

- Of all those injured, 10 percent are complicated injuries, 10 percent are minor-to-severe injuries, and 80 percent are minor injuries that do not need followup treatment. This 80 percent could perhaps answer simple questions such as:

  - Where were you at the time of impact?
  - What kind of injury did you sustain?
  - Who gave you the first medical care?
  - How many family members did you lose?
  - How many people lived in your house/building?

  This would be an easy and feasible way to collect data. (Zeballos)

- Would a change in construction alter the severity of a survivors' injuries? It might be beneficial to study earthquakes where few people were hurt. (Lechat)

- Studying success stories, such as the earthquake in Chile, would be very informative. (McClure)

Breakout Session 5: Research Needs and Agenda; Intradisciplinary–MEDICAL/HEALTH

Moderator: Eric Noji

Participants: Bo Brismar, Robert Charchoglyan, Donald Cheu, Juan Diaz de la Garza, Victor Esch, Ben Ho, Miroslav Klain, Richard Kunkle, Peter Safar

Dr. Noji stated that the key research issues for medical personnel relate to the medical care of the victims of building collapse. He asked each participant to suggest research needs and questions.

Research Needs and Questions

- How are the victims of collapsed structures different from standard trauma victims? (Ho)
- Are crush ATLS protocols needed? (Ho)
- How should first responders be trained? (Ho)
- What supplies do first responders need and in what quantities? (Ho)
- What quantity of fluids should be given to victims? (Ho)
- How should victims be monitored? (Ho)
- What are the best preventive measures? (de La Garza)
  - Strengthening of certain buildings to resist earthquakes
  - Coordination of emergency medical services
  - Standardization of equipment and training.
- How do types of injury relate to the patient's clinical condition? (Noji)
- What useful information can be obtained from recent earthquakes? (Noji)
- What can be done to change the outcome (i.e., death) for victims who are seriously injured? (Klain)
  - Identify/define these victims

- Identify best rescue methods
- Determine what can be done for them
- Coordinate rescue with medical management.

- What is the appropriate role of physicians (vs. EMT) in emergency situations? (Esch)
- How should terrorism be handled (use of explosives to bring down buildings)? (Esch)
- How can the United States improve its capacity for heavy rescue? (Esch)
  - Identification of resources (e.g., crane operators, structural engineers, medical care providers).
- What injury patterns are associated with specific events? (Kunkle)
- Why are there differences in types of injuries in different earthquakes? (Kunkle)
- What is the cause of renal failure associated with crush injuries? (Kunkle)
- What is the best treatment to avoid renal failure? (Kunkle)
  - Laboratory research and field test of treatment.
- Can a controlled treatment study be designed for the next earthquake? (Kunkle)
- How can a patients be identified for followup, especially when there are language barriers? (Kunkle)
  - Surgical marks.
- How can a system be set up for collecting data on who got what treatment and what was the outcome? (Kunkle)
- Should rescue teams be trained and precertified? (Kunkle)
- How can the speed of response be increased? (Kunkle)
- How can access to patients be improved? (Kunkle)
  - Technologies
  - Equipment, tools.
- How can patients be treated (given drugs) if they cannot be reached? (Kunkle)
- How can rescuers determine if victims are alive? (Kunkle)
- What is the role of surgery in resuscitation medicine? (Safar)
- What is the appropriate resuscitation response for slowly dying victims? (Safar)
- What happens–during different time periods–to those who ultimately die? (Safar)

- Case sequential study.

- Who should be rescued first? (Safar)
  - Those not injured can survive a long time.
- What is the pathophysiology of the dying process? (Safar)
  - Laboratory and clinical studies needed.
- How can the estimated 44,000 victims of an earthquake in the San Francisco area be saved? (Cheu)
  - Organization of hospitals
  - Emergency water supplies, etc.
- What is peculiar about an earthquake disaster from a medical point of view? (Brismar)
- How can data be collected to form a research base? (Brismar)
- What minimal equipment is needed for rescue teams? (Charchoglyan)
- How can information about patients be obtained so that the physician can determine where to send the patient for the best treatment? (Charchoglyan)
- What is the role of the field hospital? (Charchoglyan)
- How can the gravity of crush syndrome be determined? (Charchoglyan)
- How can crush syndrome be best managed and treated? (Charchoglyan)
- What is the role of trental in preventing the development of infection and ARDS? (Noji)
- What is the role of tranquilizers in preventing "rescue death"? (Noji)
- Should tourniquets be used on the extremities of trapped victims to prevent crush syndrome? (Noji)
- Should there be controlled release of tourniquets? (Kunkle)
- How can it be determined whether amputation is necessary? (Charchoglyan)
- What is a standard protocol for treating crush syndrome? (Charchoglyan)
- How does an earthquake affect the mental health of a population? (de la Garza)
- What information is available on the rate and mechanism of dying of the accessible injured who ultimately die? (Safar)
  - C.-Y. Sheng, 314th PLA Hospital, Beijing, article on outcome of those rescued over 5 to 6 days following 1976 earthquake. Trauma 1987.

- What is the potential of instant life support for victim? (Safar)
- When should life support be recommended? (Safar)
- What is the cost-effectiveness of life support? (Safar)
- What is the difference between crush injury and crush syndrome? (Cheu)

Discussion Points

- There was a large volunteer effort from the public during the Mexico City earthquake. (de la Garza)
- The percentage of crush victims in the Mexico City earthquake was small, although complete information is not available. (de la Garza)
- The official mortality estimate from the Mexico City earthquake, based on death certificates and unclaimed bodies, is 4,000 to 5,000 deaths. (de la Garza)
- A recently translated PAHO report provides statistics on the types of injuries, numbers of persons trapped and rescued, etc., in the Mexico City earthquake. (de la Garza)
- The number of cases of renal failure associated with crush injuries was very small in Mexico City. (de la Garza)
- Damage to communication systems hampered early response in Mexico City. (de la Garza)
- After the first 12 to 24 hours, the Army took over in Mexico City. (de la Garza)
- The first stage of rescue in Mexico City was performed by local people; therefore, efforts are being directed to training volunteer teams. (Garcia)
- The Pittsburgh group has identified three types of victims: (1) those who are immediately killed; (2) those who are lightly injured and freed and can get to first aid on their own; and (3) those who are seriously injured and subsequently die. Only for the third type of victim can the outcome be changed. (Klain)
- The role of physicians onsite during an emergency is controversial. (Esch, Noji)
- Rescue teams must be able to take care of themselves so that they do not become an additional burden in an emergency situation. (Kunkle)
- A system is needed that would bypass diplomatic channels to allow precertified rescue teams to get to the disaster. (Kunkle)
- A quick-response medical team should accompany the assessment team to the disaster. (Kunkle)

- New EMS equipment should be developed in the laboratory. (Kunkle)
- Most equipment used in rescue is designed for other purposes. R&D is expensive and not likely to be undertaken to develop equipment that is rarely used; therefore, equipment must have multiple uses. (Noji)
- During a demonstration of concrete breaching devices, the products could not perform as the manufacturers claimed. The simplest devices, i.e., sledge hammers, were the most effective, but also the most labor-intensive. (Ho)
- Dogs can be used effectively to identify live versus dead victims, e.g., the San Bernardino train crash. (Ho)
- Many pieces of equipment work very well in a standard EMS setting but are difficult to use in mass casualty situations. (Ho)
- Physicians should direct the efforts of other rescue personnel. (Ho)
- The majority of victims (80 to 90 percent) extricate themselves, and paramedics can manage their care. (Kunkle)
- Difficult extrications require one-on-one response. (Kunkle)
- Two sets of equipment are needed; for intensive care of single patient and for standard care of many patients. (Kunkle)
- Questions for research might be evaluated in terms of the following (Critical Care, Oct. 1988):
    1. Scientific importance
    2. Clinical importance
    3. Socioeconomic importance
    4. Feasibility.
- Such an evaluation can be used to devise a ranking for funding. (Safar)
- Physicians need to communicate and collaborate in a collegial fashion to prevent critical injuries. (Safar)
- Animal models are being used to study crush and asphyxiation injuries and their treatment. (Safar)
- Clinical research is difficult to do under the pressure of resuscitation. (Safar)
- Resuscitation and life support should be part of search and rescue (S&RR). (Safar)
- Progress in disaster medicine will improve everyday EMS. (Safar)
- Everyday EMS is the first line of response. (Safar)

- In the Soviet Union, fourth-generation antibiotics are used to stop secondary infections. Flagyl is used for sepsis prophylaxis. (Charchoglyan)
- In Armenia, trapped victims were given tranquilizers to avoid "rescue death." (Charchoglyan)
- Field hospitals may provide clean facilities for rescue operations that would reduce the incidence of iatrogenic infections. (Esch)
- Twelve hours are required to establish a 50-bed field hospital. (Cheu)
- Time is the first important factor for survivors of earthquakes. (de la Garza)
- The French promote the use of tourniquets on every crush victim. The tourniquets are not released until the patient reaches a fixed medical facility. (Kunkle)
- In Armenia, dust from helicopters was a problem only during the first 12 to 48 hours. Helicopters were essential because there were only two roads. (Charchoglyan)

Breakout Session 5: Research Needs and Agenda: Intradisciplinary

Moderator: Fred Krimgold

Participants: Richard Andrews, Constance Holland, Julio Lescarboura, Dennis Wenger, Hal Bowman

Dr. Krimgold asked participants to discuss the capacity of various disciplines (other than medical and engineering) to respond to an impact situation. He explained that if the formal sector, such as the military, fire department, and civil defense, participated 100 percent, only 10 to 15 percent of the problem would be addressed, and this number is even less on the international level.

- Each group, whether fire brigade, medics, police, or engineers, should have a data collection team, like a G2 in the army. Then all these data should be assembled into a document. (Lescarboura)
- Perhaps the best way to gather data is to conduct structured interviews after the impact. (Krimgold)
- Two approaches to data collection are (1) initial observations at time of impact and immediately thereafter (no defined sample; some formal sector observations; but mostly contacts and family groups provide information on activities and possible future sampling) and (2) survey research after the impact. (Wenger)
- Survey research involves comprehensive formal sampling. (Krimgold)
- It is important to document the (1) magnitude of the rescue activity as opposed to nature of task and what people are doing; (2) characteristics of the people engaged in rescue work, such as age, sex, and social class; and (3) what rescue operations were carried out. It is important to keep all of the data, because they may become important later on. (Wenger)
- It may be necessary to return to the site postimpact and complete data in terms of where, when, and what the mass assault was doing. (Bowman)
- Is it possible to increase the efficiency of recovering victims? Can a policy be developed to support greater efficiency, without creating conflict between the formal and the informal sector? If the demand for manpower is bigger than can be responded to with formally trained personnel, can those who are formally trained provide professional leadership to an informal group? (Krimgold)

- Whether educational programs have increased number of survivors needs to be evaluated. If education efforts have no long-term benefits, then those resources are best invested elsewhere. (Holland)

- The question of how to deal with volunteers needs to be addressed. In practice, fire departments, police, and law enforcement services do not like to deal with volunteers. (Andrews)

- There should not be a distinction between the formal and informal sectors because an impact situation is new for everyone, and both sectors should approach it in an integrated fashion. (Wenger)

- It is important to train local people to gather data so that this can be done immediately after impact. All that really needs to be reported is time of impact and what happened. (Lescarboura)

- Local people may opt to search and rescue family and belongings instead of gathering data. (Holland)

- What might some of the dos and don'ts of light search and rescue training be? Is there any similar training program? (Andrews)

- Even with proper training, some very basic mistakes can be made–for example, moving someone with a back injury because what constitutes a back injury is not known. (Kringold)

- Organizations such as the fire department may not want to use volunteers at the time of impact; however, if told beforehand how many people to expect they may be ready to informally organize large groups at the time of impact. (Bowman)

- Search and rescue is not a methodological problem. To improve the response effort, data, theories of behavior, and questions that search and rescue people have from previous disasters should be compiled and analyzed. A behavior theorist might ask how new groups are formed or how tasks are to be allocated–questions that are probably very different from the questions search and rescue people would ask. (Wenger)

- There is a need to merge formal and informal tasks. Trained people will have to do informal tasks as well, for example, doctors removing debris. (Lescarboura)

- Much of the data studies the phenomena and not how the phenomena can be affected. Long term (5 to 10 years) followup of training programs is needed in terms of (1) do people remain up to date on training information, (2) do they still live in the same neighborhoods, and (3) do sectors such as the fire department retain their emergency readiness even when an impact does not occur for years. The elements that affect these behaviors need to be identified. (Holland)

- Search and rescue training needs to be linked to an ongoing organization like a school or work environment. (Andrews)

- There is a need to bring together the formal side, such as fire departments, and the less formal side, such as the engineering community. (Krimgold)
- People who may not be professionals but have leadership qualities should be used. (Lescarboura)
- At the time of the impact, uninjured people want to help and will respond if the person directing them has the appearance and behavior of one in authority (e.g., wears a white coat). (Bowman)
- What constitutes a formal group? How do we access various resources (e.g., the medical component and the crane operator) and initiate communication between them? (Krimgold)
- DRC has been studied for 27 years. There are serious problems with ICS when it is used for something other than which it was originally designed. (Wenger)
- An autonomous decentralized response should be developed. This would allow for immediate, autonomous, local action without centralization of information. (Krimgold)
- In a normal emergency, one can wait for precise definition of need from local people; however, in a catastrophic emergency, the need must be anticipated. A decentralized operation would provide for this. (Andrews)
- The ICS system has basic concepts that are useful, but it is not applicable to every disaster. A better approach than incident command or a decentralized approach would be to concentrate on creating an information center to which data can be reported. (Holland)
- Is it possible to review ICS to adapt it to the earthquake context? (Krimgold)
- OFDA should arrive with a command system when assisting foreign countries. (Andrews)
- The ICS system, which was implemented in eight disasters, seemed to have organizational problems such as, no liaison between different departments. (Wenger) Similar problems were discovered during practice drills (2 staging areas). (Holland)
- The ICS system seems to work best for people who are involved in developing and exercising the plan. Do the problems observed in these settings apply to earthquakes? Is the ICS an appropriate model? (Wenger)
- Centralization is a dynamic concept. Initially, postimpact search and rescue efforts are decentralized but gradually become centralized. (Lescarboura)
- What centralized data are necessary and what organizational level should deal with which problems? Is there a hierarchy of information in response organization? The control of operations will follow the information. (Krimgold)
- The people who have the resources and the know-how become the leaders–the ones in control. (Lescarboura)

- How are OES input needs to be captured? Drills? Structured interviews? (Krimgold)
- Elaboration on the issues crucial to the first week postimpact is needed. (Andrews)
- The response operation and the research should be accomplished by separate teams; otherwise, the data will be contaminated. (Wenger)
- Researchers must not get involved in response operation, but they must report injured people that perhaps only they observed. (Lescarboura)
- The rescue operator may get overburdened, taxed, and tired and consequently may not make the best decisions. The general principle should be for the researcher not to get involved, but saving a life is an exception. (Wenger)
- Pre-impact modeling has a narrow focus. The theoretical strength of ICS is the planning. Documentation begins immediately after impact and is for the purpose of history and liability assessment. (Andrews)
- Documentation is extremely important. Workshops and field exercises should be conducted on how to deal with a potential earthquake. (Lescarboura)
- Can training and exercise be evaluated? (Krimgold)
- In California, there are two kinds of evaluation: (1) ongoing evaluation for the purpose of adjustments in the course of the exercise and (2) permanent evaluation for the purpose of long-term corrective action. (Andrews)
- The potential research base can be widened by studying exercises in addition to actual disaster events; this will increase the amount of data available and therefore make it more feasible to generalize from the data. (Wenger)
- How amenable would drill managers be to an outside researcher? (Holland)
- DRC has been successful because (1) it preserves data confidentially and(2) it treats events and exercises anonymously; only problems, patterns, and processes of a disaster event are mentioned. (Wenger)
- What has been described as needed is a multinational, multidisciplinary, and multiorganizational approach for collecting data where local organizations contact other local organizations worldwide. Is this feasible? (Krimgold)
- The feasibility of the multinational, multidisciplinary, and multiorganizational approach to research needs to be examined. (Wenger)
- There are many obstacles to data collection and interpretation. Is it better to study low impact events in California or large impact events such as Mexico City? Accessibility versus transferability of data is a real issue. (Krimgold)

Breakout Session 5: Research Needs and Agenda: Intradisciplinary (Building)

Moderator: Nick Jones

Participants: Joel Abrams, Ian Buckle, Sayeed Choudhury, Andrew Coburn, Michael Durkin, David Hammond, Jun Kanda, Henry Lagorio, Toshio Mochizuki, Charles Scawthorn, Keishi Shiono

Dr. Jones began by saying that the group was brought together to address the specific research needs of the building professions. As a starting point, he noted that in the previous sessions, problems had been identified with using specific indices or scales to assess aspects of an earthquake, such as injury severity scores or percent volume loss to characterize collapse. This lead to the idea that perhaps injury severity and building collapse should not be separated. In addition, behavior also has to be considered. Dr. Jones asked the participants to try to identify what specific areas the building professions should address. He also distributed a list of prepared questions to stimulate discussion.

- Is there a design component? Perhaps the question should be raised if buildings should be designed for collapse rather than no collapse? How much information is there on collapse typology? (Coburn)
- Mexico would have been the best site to study this; however, as Professor Meli pointed out in an earlier session, there are no studies of collapsed buildings. But there may be a research need here to systematically categorize types of building collapse. (Jones)
- There was a limited reanalysis of buildings in Caracas and Los Angeles. (Hammond)
- A collapse study depends on how a building was designed and constructed–would it then be applicable to other buildings, say in Japan or in Australia? The easiest way to improve safety is to increase design volume (e.g., multiply by 2 in Mexico, by 3 in Armenia). (Kanda)
- Two factors were identified in the previous session: damage per se and the type of building failure. An injury severity scale would need to take both of these into account. (Abrams)
- Engineers look at the mechanism of why things fail, but maybe the failure should be related to the death/injury outcome. (Jones)
- It has to be related to the likely kinds of injury (data that are hard to get) and the likely extrication methods. (Abrams)

- Engineers can contribute to search and rescue by reconstructing onsite what a collapsed building was. (Coburn)
- The building code can be referred to for certain information, for example, occupancy rate. (Lagorio)
- Most fire departments have fire fighting plans that show where exits, corridors, and elevators are. These are not very detailed and do not contain structural information, but at least they are a start. However, it is difficult to get access to these and other building plans under normal circumstances; it is unrealistic to expect to have instant access to them in an emergency. (Hammond)
- There will never be absolute numbers or absolute certainty during these emergencies about the best response. The best system is based on the judgment of experts on the scene. (Abrams)
- The ATC-20 is a compilation of what has been done to study collapsed buildings. It is intended for engineers to assess buildings after an earthquake. It will be available in 30 days. (Hammond)
- The ATC-21 is a study of buildings before the earthquake. The scope of ATC-20 is limited. It contains a structural collapse scoring system that is very simple and therefore may be inaccurate. (Scawthorn)
- Japan has such a system also. (Kanda)
- Is there much value in doing this sort of design research on collapse potential and mechanics on existing buildings? (Jones)
- In California, thousands of buildings have been assessed by firms, but these are usually very limited studies consisting of the following:
  - A structural engineer conducts a preliminary walk-through.
  - If the engineer feels it is warranted, the assessment is continued (and it often is not) and engineers make a calculation of hazard versus some load level.
  - After the engineer determines that the building is going to sustain damages, the study ends.
  - The study rarely includes a full structural analysis. (Scawthorn)
- In these kinds of studies, the engineers will determine if there is structural damage, and they may or may not predict that the walls will separate. (Hammond)
- But there can be a higher safety factor level (e.g., as in the case of the Mexican Metro constructed over a subway station). (Coburn)
- In a real collapse, there are so many complex factors. (Kanda)
- Collapse is very much a function of ground motion. (Scawthorn)

- But no one would design a building to collapse. A client will not hear of us talking about collapse. (Scawthorn)
- This is true, but it is also true that any building will collapse with enough of a shock. (Abrams)
- With regard to preserving voids, let's be realistic. For a high-rise construction design, if it were suggested that it go from a flat slab construction to a beam and slab construction, everyone would laugh at it. (Scawthorn)
- The bottom line question is whether there should be research in this area of collapse mechanics. (Jones)
- Yes, there should be studies. But it is impossible to look at it from the design aspect. To study existing buildings for collapse mechanisms, it is necessary to begin with broad categories of buildings (e.g., flat slab construction). (Abrams)
- For reinforced concrete, the collapse mechanism has been investigated. (Jones)
- Collapse has been studied but not in a quantitative way. (Scawthorn)
- What has been done with masonry buildings is to study the progression of weaknesses in a building. (Coburn)
- Attempts have been made to study this in existing buildings in Chile. (Buckle)
- To help search and rescue, void ratios need to be known as well as where the beams are. (Scawthorn)
- Quantitative data from the field are needed. Perhaps collapse could be defined numerically. (Shiono)
- This would be equating terminology to describe a collapse with a numerical score. (Scawthorn)
- Percent volume loss is a valuable element to assess, as is whether walls have separated from the building. (Hammond)
- After an earthquake, any diagnostic and clinical evaluation needs to be precise. However, the operational evaluation does not need to be so precise. (Durkin)
- It is possible for a building to trap people without there being a large percent volume loss. (Coburn)
- Percent volume loss is a one-parameter estimate with all its inherent limitations. But take it a step further and look at a mean or a standard deviation or void space. (Jones)
- It may be possible to estimate the rescue factor as a product of percent volume loss. It is not simple, but it is a first step. The goal is to maximize number of lives saved. (Abrams)

- Estimation can be done by looking at categories of buildings that have collapsed. What has Japan done in this area? (Scawthorn)

- Collapsed buildings have not been correlated with numbers of injuries; this is a weak point of our system. (Shiono)

- Regarding the 1972 NOA studies, what was their reception by policymakers? (Scawthorn)

- They were confused as to how to relate those data to general preparedness. However, they responded well to the damage assessment components by rebuilding three dams and

  reinforcing other structures. The studies focused primarily on demand on medical facilities, and it was very successful in motivating hospitals to start thinking about and planning for an emergency. (Lagorio)

- What can be done in the short term? (Jones)

- The issue of engineering for detection and extrication has not been addressed. What about new equipment? For instance, is a water cutting device useful? Is helicopter-transportable equipment necessary? Some of these ideas are infeasible, others are more realistic. This is a resource-limited area, so priorities need to be set. (Abrams)

- There is a potential testing opportunity coming up–a five-story building will be crushed at the University of California at San Diego. They have promised us we can test afterward for aftershocks and cut into it and test other things. They want our input and our help. (Hammond)

- A similar study is being done using a steel-frame building that will be demolished in Baltimore at the end of August. Everything will be removed from the building (no nonstructural elements). Also, in Seattle, OFDA through Pacific Rim Disaster will be bringing a building down in August as a training exercise. We as engineers need to be involved in participating in and studying these kinds of exercises to see what the real needs are for equipment and other things. (Jones)

- A problem with such exercises is that everything is removed right away. (Lagorio)

- Of the estimated 25,000 dead in Armenia, how many of those were killed instantly and how many could have been saved with better equipment–5,000 or 20,000? This should be the reason for improving equipment. (Buckle)

- That is not known and it is the primary question. The only data available are the number of live extrications and the number of dead extrications. (Abrams)

- In Mexico City, 10 people were located on the Tuesday after the Thursday earthquake. After many mistakes, help finally got to the building on Thursday morning. The people were extricated. There were more mistakes. On Friday, there were two people alive. (Hammond)

- There are other important questions:
  - What is the initial distribution of death and injury, and how does it change over time? (Jones)
  - In an ideal situation, how many people could be extricated and survive? (Buckle)
  - What are the best medical responses to these extricated people? (Durkin)
  - What percentage of people are injured to what degree, and how many are dead at time zero? (Coburn)
- Followup interviews about injuries in Mexico and San Salvador are being conducted. (Durkin)

PRESENTATIONS

Speaker Presentation Schedule:

Monday, July 10 – Keynote

Lechat

Monday, July 10 – 10:15 a.m. – 12:00 p.m. – Presentations 1:

Krimgold, Jones, Noji, Smith

Monday, July 10 – 1:15 a.m. – 2:45 p.m. – Presentations 2:

Moderator: Smith
Alexander, Armenian, Coburn, Coulson, Durkin

Monday, July 10 – 3:00 p.m. – 4:30 p.m. – Presentations 3:

Moderator: Krimgold
Hammond, Lescarboura, Shiono, Zensinger

Monday, July 10 – 4:30 p.m. – 6:00 p.m. – Presentations 4:

Moderator: Noji
Brismar, Holland, Kunkle, Mahoney, Wenger

Tuesday, July 11 – 8:30 a.m. – 10:00 a.m. – Presentations 5:

Moderator: Jones
Meli, Mochizuki, Scawthorn, Steinbrugge, Tiedemann

Tuesday, July 11 – 10:15 a.m. – 12:00 p.m. – Presentations 6:

Moderator: Krimgold
Abrams, Charchoglyan, Comfort, Kvetan, Ricci

Tuesday, July 11 – Dinner

Hays

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AUTHOR	TITLE OF PAPER
Abrams	Detection - Extrication in the Armenian Earthquake of December, 1988
Alexander	Earthquake Epidemiology: Spatial and Statistical Aspects
Armenian	Methodologic Issues in the Epidemiologic Studies of Disasters
Brismar	The Medical Severity Index of Disasters
Charchoglyan	Types of Injuries and Reasons of Deaths after the Armenian Earthquake
Chung	Decade for Natural Disaster Reduction
Coburn	Assessment of Strategies to Reduce Fatalities in Earthquakes
Comfort	Suggested Problems for Field Research in Earthquake Disaster Operations
Coulson	Built Environment and Host Characteristics
Durkin	Built Environment and Host Characteristics
Hays	Data Acquisition for Earthquake Hazard Mitigation
Hammond	USAR Strategies - Attempting to Minimize Risk
Holland	Effective Utilization of Victim Volunteers in the Emergency Response
Kunkle	Medical Care of Entrapped Patients in Confined Spaces
Kvetan	American Critical Care Team at a Foreign Disaster Site The Armenian Experience
Lechat	International Survey on Corporal Damage as Related to Building Structure and Design
Lescarboura	Search and Rescue Operations After Earthquakes: Past Experiences and a Future Practical Approach
Mahoney	Measurement of Medical Care Needs Following Earthquakes
Meli	Modes of Failure of Buildings Under Seismic Actions
Mochizuki	Interpretation of Damage to Houses and Casualties
Ricci	Retrospective Disaster Reanimatology Study of the Earthquake in Armenia in December, 1988
Scawthorn	Estimate of Post-Earthquake Search Rescue Manpower and Equipment Needs
Steinbrugge	Reducing Earthquake Casualties: An Overview
Shiono	A Computer Model for the Recovery of Trapped People in a Collapsed Building
Tiedemann	Casualties as a Function of Building Quality and Earthquake Intensity
Wenger	The Study of Volunteer and Emergent Organizational Response
Zensinger	Federal Urban Search and Rescue Capabilities in the United States

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KEYNOTE

CORPORAL DAMAGE AS RELATED TO BUILDING STRUCTURE AND DESIGN

The need for an international survey

Michel F. LECHAT, M.D., Dr P.H.

'104'

1. EARTHQUAKES AS A PUBLIC HEALTH PROBLEM

Earthquakes have caused some one million deaths over the last two decades. Such an event as the Tangshan earthquake in Northern China, 1976, has been responsible for several hundred of thousands in a matter of minutes. The growing urbanization of the planet, including in quake-prone areas, with as a result vulnerable megapolis of up to 20 millions, forewarns of disasters to come. Engineers on their side design anti-seismic structures - the only conceivable mitigation measure at present - at a cost of billions. This "International Workshop on Earthquake Injury Epidemiology" intends to tackle the problem of mitigation of and response to earthquake, bringing together widely diversed expertise, from the structural engineer conceiving safe designs to the epidemiologist scoring the end-results.

2. MITIGATION VS RESPONSE

For the purpose of preparedness and management, disasters in general, including earthquakes, may be considered as a time-sequence in five phases :

* the anticipatory phase
* the pre-disaster phase
* the impact phase
* the relief phase
* the rehabilitation phase

The anticipatory phase is the time for planning and for such preparedness activities as hazard mapping, preventive technology, disaster training and public education. The pre-disaster phase commences when there are indications of an impending disaster and a prediction based on a probability judgment can be made. It involves the activation of preset warning systems identified during the non-disaster phase which are appropriate for key groups in disaster response and for the general public. The impact phase involves a major disruption of the local community. Though it is characterised by initial chaos, it often includes a remarkable degree of self organisation whose effectiveness can be increased by suitable programmes during the anticipatory phase. The

relief phase begins when assistance arrives from outside the disaster area. The effectiveness of such aid may be increased by preparedness and planning. In the rehabilitation phase, short-term relief is progressively replaced by more specific assistance based on an assessment of local conditions. It ends with the restoration of, or an improvement on the conditions prevailing before the disaster. This framework is common to all natural disasters, and to some extent can also be applied to man-made disasters. Intervention can thus be envisaged at various points of entry in the system.

In recent years, the emphasis in disaster management has definitely shifted from post-facto improvisation to pre-disaster planning and preparedness, including prevention and prediction whenever possible. Floods for example are amenable to prevention by appropriate land use, soil conservation, construction of dykes. While hurricanes, typhoons and other strong wind phenomena cannot at the moment be prevented, prediction is possible. Provided the technology is applied and the population is educated to response to warning signals, evacuation or other preparedness measures can be implemented.

It may however happen, and it often happens, that even when the technology for prevention and/or prediction is available, it cannot be applied. Cost and social factors have to be taken into account. It might be too expensive to build dykes against tsunamis. There are also very good reasons for people living in flood-prone areas or on the slopes of volcanoes. Some countries can support a large population because they have floods which irrigate the lands; in countries with an accelerating population growth volcanic soil is good for agriculture, and anyway people may have no other places to go. Then, often, rescue and relief, that is response once the disaster has occurred, is still essentiel to save what remains to be saved.

Regarding earthquakes, prediction cannot be operational at present. Earthquakes prone areas are well mapped, but neither the time of occurrence nor the exact place can be predicted with sufficient accuracy. Long-term prediction is neither sensitive nor specific. Would less unreliable prediction become possible, it would raise excruciating dilemmas for the decision maker, apart of the perspective of horrendous

lawsuits in case of false positive or false negative warnings. Major earthquakes may also occur in low-risk areas where for centuries no disaster has occurred, the more damageable so that the population is not prepared for it. The Eastern United States (Charleston, South Carolina, 1886) is such an area. Short-term prediction is the subject of much talk. Some success has been claimed in China. It is however doubtful that a prediction with a lag time of a few minutes can reach the population in time to prompt effective escaping behaviors, especially in high buildings and in large cities. It also requires an efficient system of communication. Not every country, especially in rural areas, can afford warning system based on computers linked to the national telephone network, like Iceland, or radios and televisions systems delivering emergency messages even when the units are turned off, like Japan.

It means that with respect to earthquakes, we are left with two points of entry into the system, i.e. mitigation of effects, through anti-seismic buildings, and efficient rescue after the impact, that is response and rescue.

3. MITIGATION : ANTI-SEISMIC BUILDING

Anti-seismic building aims at modifying the interaction between the habitat and its occupants. It is reported to be most effective at least in saving lives and preventing casualties, provided the building codes are actually adhered to. It is reported that in Japan, the number of deaths due to earthquakes has steadily decreased since the ediction of the Disaster Countermeasures Basic Act in 1966. Time series however are generally not matched for the number and magnitude of earthquakes.

Anti-seismic building techniques have made tremendous progress over the last few decades. Buildings of 50 or more stories sheltering thousands of people are build in highly hazardous areas. They are reputed safe in case of earthquakes of high magnitude. Anti-seismic design have been tested through computer simulation, on mechanical models, and to some extent, in real life situations. The experience of Mexico City, 1985, has clearly demonstrated that such buildings, when the coding codes are applied, can resist an earthquake of magnitude 8.4.

That is a remarkable achievement. One may however wonder whether the primary purpose of these engineering developments is to protect people, or rather to overcome the challenge of pursuing the necessary modernization of very large cities which happen to be constructed in hazardous areas. Thus, whereas there is no doubt that anti-seismic design confers protection on an individual building basis, what the protection is in terms of population-coverage remains questionable.

Three types of situations should be considered :

(1) The enforcement of anti-seismic building code should be enforced for all new structures, especially public facilities, offices spaces and housing, in earthquake prone areas. Can it be afforded everywhere, especially in poor countries, while it is known to increase the building cost by 10 or 15 percent ? Often, antiseismic building measures are enforced for the reconstruction of a town which has suffered a recent earthquake or has been repeteadly destroyed in the past. There is no guarantee however that the next earthquake will occur at the same place (although it may be the case as in Orléansville/El Asnam, Algeria, 1954 and 1980). One would like to krow, world-wide, and by country or disaster-prone areas, (a) the proportion of people who are effectively protected at the moment by anti-seismic buildings, both at home and in the working place; (b) what would be the cost to afford complete protection. One could of course conceive of a scheme which should make foreign loans or grants conditional to the implementation of anti-seismic measures, on the model of what is now recommended for environmental protection. This conditionality is however pure anathema for a number of developing countries. In conclusion, in many places, in the next future, anti-seismic building will be reserved to a limited number of major buildings, the more the better.

(2) In most earthquake exposed cities, structures, modern or ancient, built with no antiseismic techniques whatever, represent the majority. Antiseismic fitting of old buildings raise additional issues. Beyond the cost, the mere number of buildings to be renovated may require setting priority, which in turn could lead to delicate ethical and political choices.

What about the existing old houses ? Should they be renovated, destroyed, replaced ? The question is particularly relevant for the Mediterranean countries. Cost of renovation for making them anti-seismic would be considerable. It could be carried out on an individual basis, and probably not on a large scale.
The most extreme irremediable situation consists of those buildings which are supposed to be antiseismic while actually the antiseismic codes were not adhered to.

(3) The earthquake resilience of traditional housing varies according to the style and shows large geographical variations. In most developind countries, traditional housing is gradually replaced by new styles.
The study conducted by R. Glass in Santa Maria Cauque, Guatemala, following the 1976 earthquake, provides a well-documented example of the relationship between deaths and casualties and the type of housing (1). In a 1918 earthquake, at a time when all houses were built of cornstalk and mud-covered, no death occurred. The first adobe houses, with dried bricks held by weak mud mortar, were built around 1925. In 1971, 85 percent of the houses were built in adobe. In the 1976 earthquake, 5 per cent of the village's population were killed. Clearly, in 50 years, the risk of quake-related trauma has gone from minimal to maximum.

The unregulated wild mix of traditional building methods and new materials is a characteristic of economic development in poor countries. In Turkey, people are extending their houses by building additional floors, placing a large concrete slab on insufficiently supported walls. Such procedure is calling for disaster at the first tremor.

The problem is an usual one not dissimilar to the Green Revolution in which irrigation without proper sanitary engineering brings water borne diseases, and insecticide poisoning is the price paid to protect the crops. Introduction of new technologies must go together with corresponding education as a package. For earthquake protection, it calls for research on the housing factors as related to traumas, in view of edicting simple minimal building codes at no or minimal cost, and education at the community level.

One conclusion is that, whatever the great success achieved in anti-seismic design, in many areas, emergency and rescue will most likely remain a prime component of disaster management.

4. RESPONSE : SEARCH ANS RESCUE

At the moment, rescue is most often unplanned. The population is generally ill-prepared, yet ready to help. It is only recently that the potential of the local community for self help has been fully realized by health managers, with its implication for preparedness of the population and training of personnel. The concept is not yet fully accepted. Too often too large a reliance is still placed on external help.

Three sets of observation points to the central role that the disaster stricken community can play in search and rescue.

(1) Social scientists have been much more eager than health managers in studying the reaction of disaster-struck populations. Observations suggest that the response of the local community is quite effective, if not always efficient. In Japan, it was observed that within half an hour after an earthquake (Niigata, 1964), 75 percent of the non-affected survivors were engaged in some kind of rescue activity. In another more recent earthquake, Southern Italy, 1980, the proportion of survivors who remembered participating to rescue was lower, around 20 percent (3,4).

In earthquake prone areas, this capacity for search and rescue should be improved by adequate preparedness and training.

(2) Studies on the survival of trapped victims according to the delay in rescue show that immediate rescue is what counts. It has led to the concept of the "Golden twenty-four hours". In the Tangshan, China, 1976 earthquake, the proportion of trapped people who survived declined from 99 percent within half and hour to 81 percent for those extricated later but before 24 hours after the impact, and 37 percent for those extricated on the second day (Fig. 1). Similar figures were observed in the Campania-Irpinia earthquake, Italy, 1980 where a retrospective survey of some 3.600 survivors in the 7 worst affected villages (overall casualty

rate 19.7 percent) has shown that the proportion of people extricated alive among all extricated was respectively 88 percent for the first day, 35 percent for the second day, and 9 percent on the two following days. Of all the trapped victims extricated alive, 94 percent were rescued within the first 24 hours (3,4).

For all trapped victims which were extricated, dead or alive, 471 in total, 25 percent were extricated within half an hour, 44 percent within 3 hours, and 56 percent within 12 hours (Fig. 2). Within two days, 80 percent of all the trapped people were extricated. The time within which 50 percent of the victims had been extricated, dead or alive, (Time Lib_{50}), was 8 hours.

Such studies however have severe limitations. The observations may be partly due to a selection bias, since the less affected victims screaming for help or easily located are likely to be extricated first.

In addition, in Italy, 95 percent of the trapped survivors later evacuated to a medical center, were extricated with local means such as shovel, spikes, or bare hands. While it does not mean that more people could not have been saved would adequate equipment be available, this observation shows at least that the local population can play a determinant role in rescue.

This was confirmed by comparing death rates, ratios of injured to death, and delays for extrication in single and multiple households. People living in single households had a death rate 2,4 times higher than those living in households with one or more members of the household present. When trapped, their death rate was approximately 1.5 times higher. Injured to death ratio was 2.6. for single households victims vs 1.8 people in multiple households. Proportion of people trapped who were extricated, dead or alive, within 24 hours was 46 percent only in simple households as compared to 61 percent in multiple households (Table 1).

Whatever the limitations of these studies, they indicate that the local community is quite effective in search and rescue, which as an essential component of disaster preparedness should be part and parcel of primary health care.

(3) External rescue teams, with an arrival delay on the spot of 2 to 4 days if not more, come generally too late to have a significant impact on the saving of life. While they may achieve isolated brilliant results well publicized by the media, their impact population wise needs to be properly evaluated. It is likely to be minimal and should be properly evaluated. This is not to say that external aid is not needed, far from it, since one life saved is worth every effort. It just does mean that investments are likely to be more productive in terms of the total number of lives saved when the local population is properly educated in search and rescue. That technologically advanced equipment can achieve what the local population is not able to perform with the local tools concerns only a small fraction of the victims surviving long enough to benefit from it.

5. RESEARCH

Research is therefore needed in two directions, i.e. (1) to identify the hazards of different types of housing structures as related to earthquakes, in view of providing planners, architects and structural engineers with a quantitative assessment of risks; (2) to determine the response of trapped victims.

These studies are complementary. The dual objective is to provide a basis for the design of safer structures, and to contribute to a better planning of emergency and rescue services. This approach does not have to be restricted to earthquake, and could be extended to other types of natural disasters where the interaction of houses and occupants play a major role, mainly atmospheric hazards such as wind storms, tornadoes, hurricanes and tropical cyclones.
Such studies have been carried out extensively for automobile and traffic accidents, aircraft crashes, and industrial accidents, but to no significant extent for habitation.

(1) Regarding the identification of hazards associated with building structure, some data are available from the litterature.

An interesting observation is that previously, following earthquakes, the ratio of casualties requiring medical care to deaths was approximately (within a large range) 3 to 1. Now, as shown in Armenia, it could come close to 1 to 3 (5). It seems that earthquakes in the ecology of large industrialized or developing urban areas is becoming a killer, with few casualties and many deaths.

In Guatemala, 1976, the adobe houses especially when overcrowded were the most lethal. No relation was observed with the type of roof or the number of doors and windows. The worst houses were those with heavy adobe block held by weak mud mortar. The best were those with non-adobe lightweight cornstalk walls supported on a wooden frame; if the walls collapse, the frame and the roofs remain intact. Houses older that 7 years had a higher risk, with 1.6 times more casualties, than newer ones, since age tends to dry out the bricks and make them brittle. The size of the adobe blocks had no relation with the severity of injuries (1).

In Jalapa, Guatemala, after the same earthquake in 1976, a survey of the survivors showed that 11.5 of the admitted in the hospital casualties had fractures of the clavicle, suggesting that they were hit by falling roofs, walls, or beams (6).

In China, a large number of pelvic fractures were reported after the Hsing Tai earthquake, totalizing 30 % of all cases admitted to hospital (7), while only 32 cases of such fractures were noted in Tangshan estimated at 240.000 dead.

High rates of crush syndrome in the rescued survivors are at times reported (16 % in Agadir, 5.5% in Skoplje) (8,9), whereas in other occasions none is mentioned, what suggests that either rescue was quite fast or more probably came too late.

Such data are scarce, and most of the time they were collected in a haphazard manner or are just chance observation. No systematic survey of deaths and casualties associated to building structure have been carried out. There are of course good reasons for this lack of data, since at the site of an earthquake all efforts are directed to immediate rescue.

Two research programs should be envisaged, one on a macrolevel, the other more on a more detailed scale.

The first research should assess the probability of death and casualty according to the type of housing (style, type of material, number of floors, age).

The second research should aim at identifying individual building characteristics responsible for deaths and casualties (ornaments, material, design). It will require a careful evaluation of the body damages, and to the extent possible should include forensic determination of the immediate cause of death.

Surveys on body damage and structures will have to take into account other major variables, mainly behavior at the time of impact, and rescue procedures. Such data will incidentally have a bearing for defining the appropriate protective behaviors that the population should be taught, as well as improving training for rescue and designing appropriate non counterproductive rescue procedures.

Studies should also be conducted on the hazards associated with antiseismic structures. It may happen that people survive well in building damaged beyond any repair, and conversely. The correlation of damage to antiseismic structures and casualties should therefore be further investigated, in order to develop failure models compatible with prevention of human losses.

(2) With respect to search and rescue, the response of trapped victims surviving the impact determine their chance to be extricated alive in a given period of time. Since it is obviously impossible to conduct cohort survival studies from the time of impact, chances of survival can only be estimated indirectly, by comparing the proportion of victims extricated death or alive at different times after impact. Data should be collected on the absolute number extricated dead or alive by periods of time (hours or days), or as cumulative figures over time after impact. Different patterns may emerge, which will give indication on the effectiveness of rescue and on the efficiency of extrication procedures.

Such observations however do not provide indication on when the dead victims actually died, and how much time the ones alive would have survived further. Still included among the deaths will be those victims who were killed at impact, and for whom earlier rescue would have made no difference. Determination of the cause of death, including wherever possible autopsies in at least a subsample, could provide some indication on the size of this group.

Since the objective of such studies is to determine delay in rescue for effective emergency health care, it should take into account the long term survival of the victims which were finally extricated alive, making provision for those who are beyond chance of survival at time of rescue.

6. IDNDR

A study on "Earthquake Injury Epidemiology and Search and Rescue in Collapsed Buildings" is presently undertaken under the sponsorship of NCEER, the National Center of Earthquake Engineering Research.

IDNDR, the International Decade for Natural Disaster Reduction, with its large international interdisciplinary research programs, provides an unique opportunity to extend this study in different geographical contexts, especially in earthquake prone areas in developing countries (10).
It should be one of the outcome of this workshop to prepare a preliminary protocol and set up a task force for such a study.

	One person of household present	Two or more persons of household present	X^2
number of people	285	3,334	
death rate	11.2 %	5.1. %	($p < 0.05$)
injury rate	20.7 %	13.6 %	($p < 0.05$)
injured/death (ratio)	1.8	2.6	
proportion of persons trapped	23.9 %	14.4 %	($p < 0.001$)
death rate amongst trapped	45.6 %	33.6 %	($p < 0.05$)
proportion of trapped extricated (dead or alive) within 24 hours	46.5 %	61.0 %	($p < 0.05$)

TABLE 1 : MORTALITY RATES, INJURY RATES, INJURED TO DEATH RATIOS, AND DELAY IN RESCUE, IN SINGLE AND MULTIPLE HOUSEHOLD, ITALY, 1980

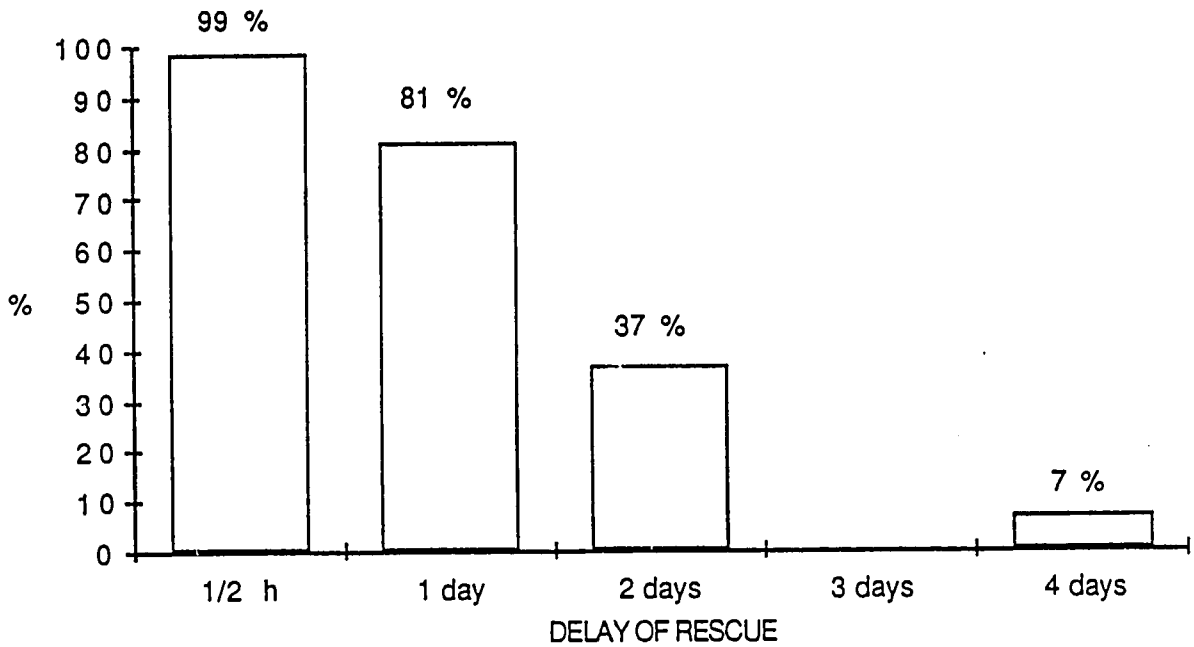

Fig. 1 : SURVIVAL OF PEOPLE RESCUED FROM DEBRIS IN RELATION TO THE DELAY OF RESCUE, TANGHSAN (CHINA) 1976

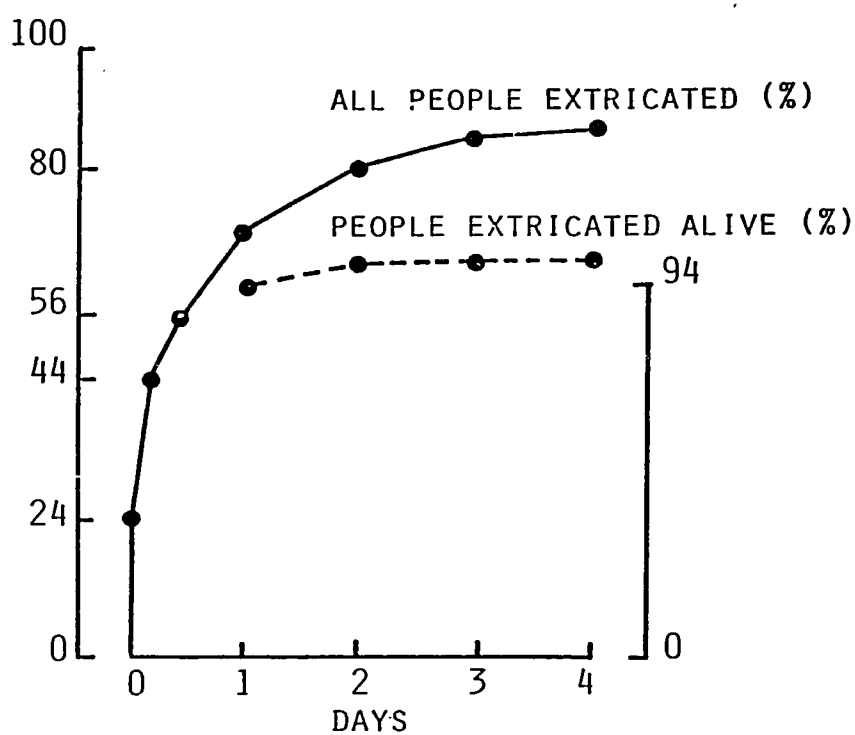

Fig. 2 : CUMULATIVE NUMBER OF PEOPLE EXTRICATED, TOTAL AND ALIVE, ACCORDING TO DELAY IN RESCUE, ITALY, 1980

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PRESENTATIONS 1

Earthquake Casualty Estimation and Response Modeling

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Introduction

This workshop was organized as a part of the mobilization of the research community to respond to the appalling loss of life in recent earthquakes. The world has been shocked to witness the massive fatalities caused by the catastrophic failure of large, modern, engineered structures in Mexico City in 1985 and in Armenia in 1988.

The organizing group for this workshop has initiated a program of research on earthquake injury epidemiology and search and rescue in collapsed buildings. The focus of our work has been on the improvement of survival rates after building collapse.

In the pursuit of that work we have faced the problem of attempting to understand the relationships of building damage and occupant casualty. One is soon faced with the problem that there is very little useful data available on the mechanism of injury in building collapse and there are very few cases of comprehensive injury investigation following earthquakes. Such data has been very difficult to collect because it must be collected in the immediate post impact period when conditions are most chaotic and all qualified manpower is directed to the primary lifesaving effort.

We face the dilemma that while the events with which we are concerned are too frequent and too serious to be tolerated, they are still too unpredictable and too infrequent to offer themselves for ample study. We must make use of all available global experience. We must develop the means to make useful and accurate transfer of experience between events taking into account differences in seismology, building practice and social and economic factors.

The problem of earthquake casualty reduction necessarily involves several disciplines. We must consider both aspects affecting the physical performance of buildings and factors affecting the physiological status of building occupants. Further, in terms of operational response, we must consider the factors which affect organizational capacity in post-collapse search and rescue, transportation and treatment.

To address this complex set of issues, we have attempted to assemble a multidisciplinary group of people from around the world who have distinguished themselves by taking initiatives in the study of some aspect of the building collapse/casualty problem.

Though earthquake damage estimation and earthquake loss estimation have been considerably elaborated over the past twenty years, the topic of earthquake casualty estimation is relatively new and less developed. In this group we hope to develop some consensus on:

- The current definition of the topic earthquake injury epidemiology
- definition of the principal problems of the field
- review of recent work, sharing those descriptive and analytical models which have been developed to date
- sharing references and access to relevant data which is in very short supply

Before this meeting is over we hope to develop some agreement on research priorities for the advancement of the field.

Earthquake Casualty Estimation

Casualty estimation in earthquake may be used in a variety of ways. In pre-earthquake mitigation planning:

a. As a part of general loss estimation. Measurement - the quantification of death and dollars: material and life loss estimates have proven to have a critical function in the provision of political motivation to initiate pre-disaster mitigation activities. For the most part, general estimates based on judgement with little specific reference to the mechanism of death and injury in buildings have been adequate.

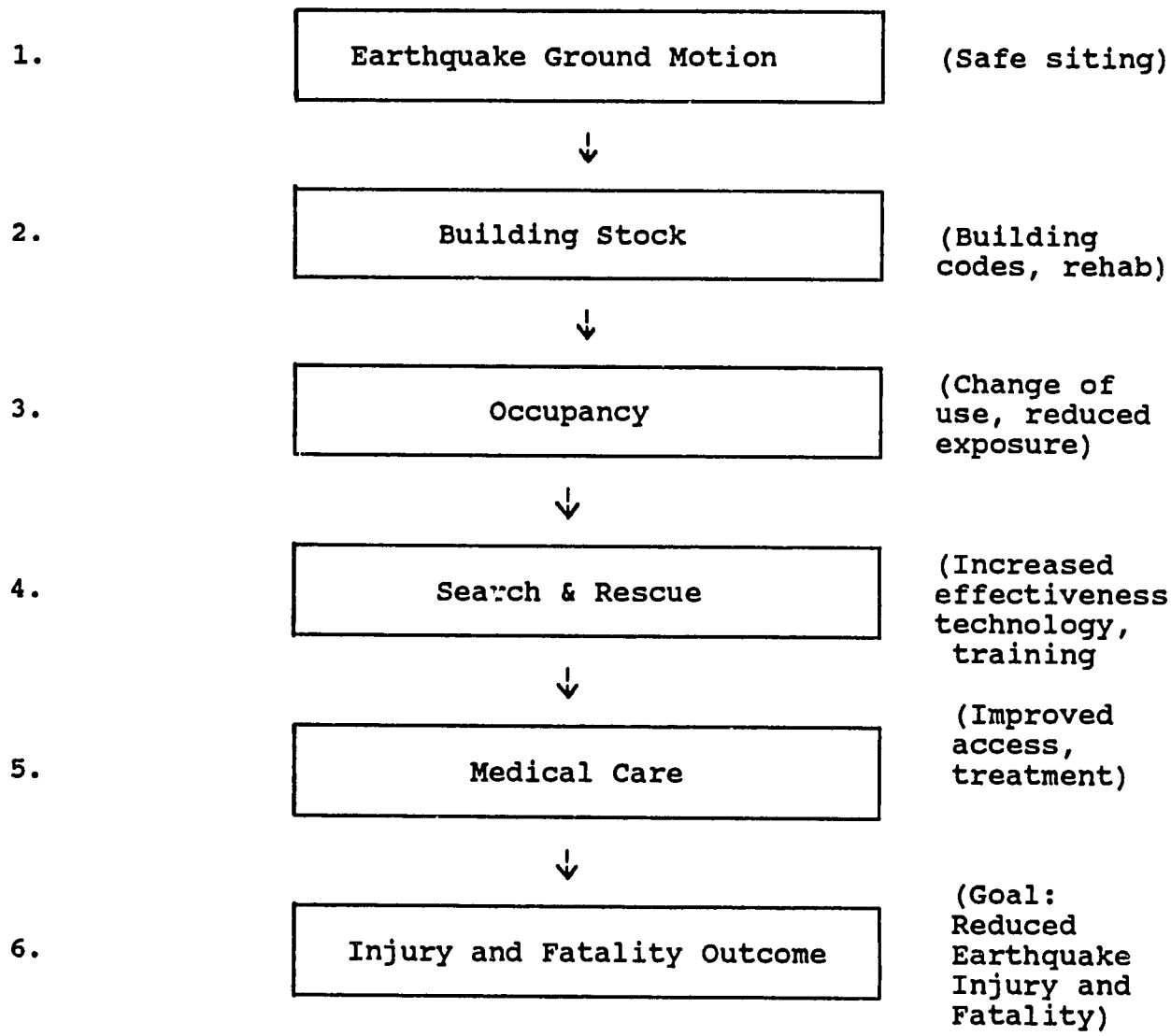
b. As a part of "life safety" based mitigation measures, as in the case of the University of California System. Prioritization of retrofit measures on the basis of life safety requires an understanding of the lethality of particular structural types and the relationship of lethality to occupancy. This application also relies heavily on judgement. The estimation of collapse potential is still very premature. In spite of all of our contempt for URM, unreinforced masonry, in normal times, it does not appear to have been the major culprit in recent severe earthquakes in Mexico and Armenia.

c. As a part of emergency response planning and response exercise scenarios. This is a more recent development. Specific organization of structural search and rescue capability has only begun to develop as a major concern in the U.S. since the Mexico City earthquake in 1985.

In post earthquake response, we face a much more severe test. While an error in estimates for mitigation planning may lead to some inefficiency in resource allocation, errors in response

Figure 1.

Earthquake Casualty Estimates



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organization and execution cost lives. Casualty estimation in the response phase is not just a function of building type. Relevant factors affecting search and rescue must be considerably more elaborated. Factors affecting survival of collapse victims include:

1. initial injury severity score
2. individual pre-collapse health status
3. discovery time
4. extrication difficulty
5. fade-away time
6. effective rescue manpower
7. time of extrication
8. site stabilization status
9. transport time

These factors affecting survival involve a complex interweaving of physical factors relating to building collapse environment and physiological factors relating to the health status of the victim. There are also critical variables relating to the organization of response capabilities of search, rescue and medical services.

The modeling of earthquake casualty mechanisms has the benefit of making explicit the relationship of key variables. It allows us to better understand the significance of new information and allows us to assemble what may initially be fragmentary information in a constructive way to facilitate appropriate response.

Principal uses of casualty estimation modeling in the post disaster phase are:

1. estimation of manpower and equipment needs for search, rescue and medical treatment - gross

2. Optimization of initial deployment of SARTAT response over affected area

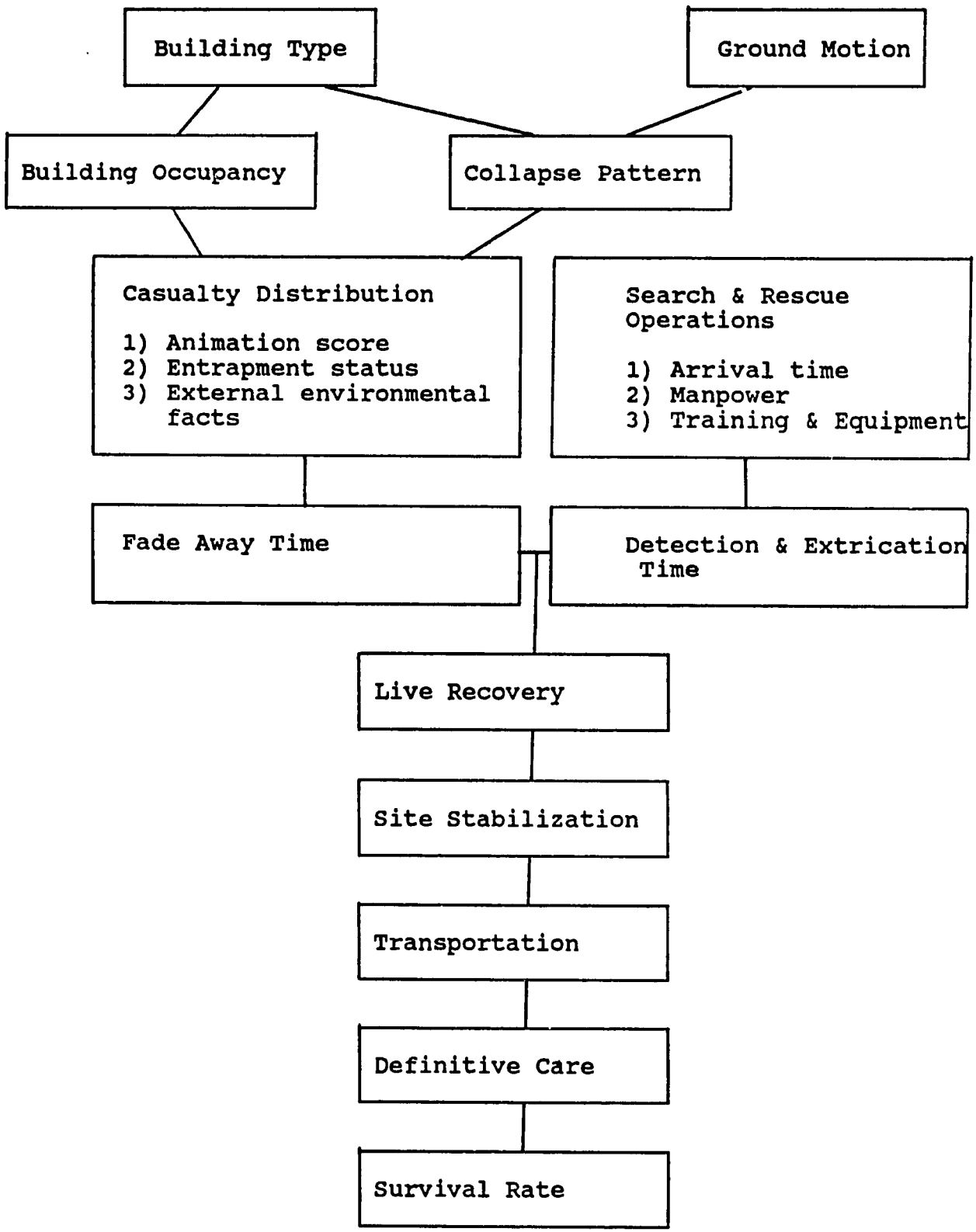
3. Dynamic optimization of active SAR period as resources increase and opportunities for rescue decrease.

Modeling of Response

To date only fragmentary information is available on the critical factors which affect the survival rate of victims in collapsed buildings. There is very little systematically collected data which allows the comparison of building damage and resulting occupant injury. Data collection has been ad hoc and rarely preplanned. There has been no commonly accepted model of the process of building failure, occupant injury, search and rescue and medical treatment. As a result, we lack comparable observations

Figure 2.

Rescue Operations Model



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from different events. Variables relating to building type, environmental factors, and rescue operations are not typically adequately distinguished to make cross event or event multiple site (from the same event) comparisons feasible.

It is necessary to develop a model in which key variables are identified and plausible relationships of these key variables are represented. The development of such a hypothetical model of the building collapse/rescue process is helpful in attempting to make sense of data collected in past events and it may be helpful in organizing the protocols for collection of data from future events.

While pre-event casualty estimation modeling is focused on the potential loss from the entire population affected by an earthquake, response modeling is focused on the operational unit of response which is typically the collapse site. This is particularly true of recent major urban earthquakes where casualties and rescue efforts have been concentrated in large, high occupancy buildings. The pre-collapse input variables to the site response model include attirbutes relating to the building and the occupancy:

Building attributes: Type of construction
Size (floor area and number of floors)

Occupancy attributes: Number of people
Age
Sex
Mobility
Function
Distribution

The immediate post-collapse variables include:

Collapse Pattern: Volume loss
Floor area compromised

Occupant Status: Injury severity (animation score)
Extrapolation status (extrication difficulty)
External environmental factors

These variables will not be typically subject to on-site observation. Immediate on-site observation is typically not feasible. However, a hypothetical determination of victim status immediately following the collapse (t_0) is important in estimating the optimum feasible search and rescue operation. It is in theory possible to estimate the time that a victim may survive in the rubble on the basis of the following variables:

Pre-collapse victim health status
Animation score
External environmental factors
Entrapment status

Rescue operations may be represented by a set of variables relating to the following factors:

Time of arrival
Volume of manpower
Effectiveness (training and equipment)

Victim status can be estimated at several critical points during the rescue process:

Point of detection
Point of access
Point of extrication
Point of transport
Point of definitive care
Point of release from health care

This tracking of building occupant status through the process of collapse, injury, rescue and subsequent care allows the analysis of relationships of a number of factors from building attributes to rescue response and medical treatment to ultimate patient outcomes.

The elaboration of this model of site response will help in the clarification of the process of occupant injury as a function of building attributes and victim attributes. Such information will contribute to prioritization of building modifications for earthquake safety. It also may lead to possible reassignment of occupancies to reduce injury exposure. Improved understanding of the distribution of injury and severity and associated fade-away time may help optimize the applications of rescue resources in the post-collapse period. Tracking of victims through the extrication, stabilization, transport and definitive care stages is also very important in order to evaluate the ultimate value of measures applied to particular categories of victims.

The development of an elaborated model of the collapse response process also makes possible more appropriate reference to experience from other parallel activities such as mine rescue operations and aircraft crash investigations. Detailed field investigation and data collection procedures have been developed in both these areas which can readily be adapted to the purposes of earthquake injury epidemiology. It is now important that the initiative be taken and that we agree on the most effective means to expand our collective understanding of the factors affecting survival in earthquakes.

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Charge to the Conference

It is the task of this conference to consider the following questions:

1. To what extent can the initial estimate of manpower needs be made automatically - that is based on minimum event information. Is an automatic mobilization or call-out possible on the basis of magnitude and location data?

2. To what extent can a casualty estimation model serve to optimize immediate post event reconnaissance? To identify specific collapse sites and to generate detailed estimates of victim distribution in terms of injury severity, and extrication difficulty.

3. To what extent can a casualty estimation model serve to evaluate the value of specific inputs. What is the value of added rescue and medical capability at various points during the rescue period in terms of victim survival.

Finally, what we are asking of you:

What the active part of this workshop is asking of participants:

1. Review of existing data

2. Development of field research protocol

3. consideration of research application needs

4. development of broad multidisciplinary and specific disciplinary research agendas

We want to reach some consensus on where we stand, what we know on:

- the current definition of the field
- the current definition of principal problems
- a sense of appropriate, feasible, promising approaches to dealing with principal questions

We hope to share descriptive and analytical models which have been developed to date

We hope to develop some agreement on research priorities for the advancement of the field to provide practical support to a range of functions related to reduction of life loss in future earthquakes.

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Engineering for Earthquakes: Redefinition of the Original Roles

By Nicholas P. Jones,[1]

Abstract

For most of this century, engineers have been aware of the effects of earthquakes on constructed facilities. The development of building codes has reflected the concern for the threat to public safety resulting from the severe damage or collapse of buildings and other structures. In the past several decades, great advances have been made in techniques for the analysis, design and construction of new buildings, resulting in a generally safer product. However, as recent earthquake events have shown, there is still the possibility, in the U.S. and elsewhere, for great loss of life and injury from inadequate structures. In response to this observation, it is suggested that the definition of earthquake engineering, or perhaps more appropriately "engineering for earthquakes," be redefined in a broader context which addresses more directly the public safety issue, and where necessary, the search and rescue problem. This paper summarizes the development of the current field of earthquake engineering, and outlines suggestions for a global framework into which earthquake engineering, architecture, medicine and epidemiology may fit to reduce the large potential losses in future earthquakes.

Introduction

Since ancient times, societies, however primitive, have been aware of the effects of earthquakes on their habitat, even though the source of the shaking and the mechanism of the destruction were often not understood. The Corinth, Greece earthquake of 856 AD is estimated to have killed 45,000; the Shensi, China event of 1556 about 830,000; the 1737 Calcutta, India earthquake: 300,000 (Bolt 1978). Most of these victims were killed by low-rise, poorly-constructed structures which had little or no lateral load resistance.

The effect of major earthquakes on large urban areas in the industrialized world was really first felt in the earthquake and subsequent fire in San Francisco in 1906. While

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the death toll of 700 was small in comparison to historical events, and actually many subsequent events in the 20th century, the potential for a larger disaster in terms of loss of life and economic consequences was evident. Contrasting the historical events, society questioned the adequacy of the structures in which it worked and lived, and engineers were called upon to produce structures which could resist earthquakes in a manner which reduced economic loss and improved life safety.

The development of building codes which reflected the lateral loads of wind and earthquake was started around that time as a result of the 1906 earthquake. San Francisco adopted a uniform 30 pound per square foot (psf) lateral design load which was to provide resistance to both wind- and earthquake-induced forces[2]. Throughout the subsequent decades, codes were introduced, modified, appended to, and corrected, in most cases in response to catastrophic events which caused significant damage, with or without loss of life. (Examples: The 1933 Long Beach earthquake, which caused significant damage to school buildings, but occurred at a time when school was not in session; as a result, the Field Act, which required school buildings be design for seismic loads, was introduced. The 1971 San Fernando earthquake (Jennings 1971) led to significant changes in design practice for highway bridges and, as a result of the collapse of the Veterans Administration hospital – which accounted for 49 of the 64 deaths attributed to the earthquake – and partial collapse of the then unoccupied Olive View Hospital, a heightened awareness of the performance

[2]While consistent for wind loads, the "pressure" loading did not reflect the inertial load induced by earthquakes. Nonetheless, some lateral resistance was provided.

of critical facilities developed; the VA embarked on an extensive program to evaluate the adequacy of its facilities, which led to the extensive retrofit or demolition of many of its hospitals and the establishment of new design guidelines (VA 1973).)

A similar trend has occurred with what are commonly called secondary systems and nonstructural items. Secondary systems generally include large pieces of mechanical equipment which are attached to the building, or primary structure, in some way, but are not required for structural support. Dynamic interaction between these systems and the primary structure has often led to extensive damage, which often is, at least potentially, life threatening. The damage to the Sylmar electrical substation in the 1971 San Fernando earthquake (Jennings 1971) — many large transformers and other switchgear were destroyed — again led to the recognition of the importance of the performance of secondary systems. The effect of nonstructural walls and cladding on modifying the performance of the primary structure has long been a concern. More recently it has been recognized that building contents also pose a threat to life and limb and appropriate steps should be taken to secure them appropriately.

While current codes and suggested provisions (e.g., FEMA (1988), ICBO (1988)) estimate the seismic loads that new buildings are designed to withstand quite realistically (which includes allowances for building function, type of structural system, foundation effects, as well as the inherent dynamic properties of the structure and the location-specific seismic risk), there are still a number of unresolved areas which are of relevance here.

In this country and abroad, there are a large number of what may be termed "precode structures" which in some cities house a large proportion of the population. These buildings were constructed before the codes in effect at the time required consideration of seismic loads, and therefore offer little or no resistance to these lateral loads. The structural forms and the construction materials used are often highly unsuitable for seismic areas.

There are in some cases ambitious plans afoot to strengthen or remove these hazardous buildings (for example in California which has a "five-year plan.") However, there is often great economic, social and political pressure which hinders these actions. The result is that in this country, and throughout the world, there are thousands of buildings which are likely to collapse in moderate to major earthquakes. The recent examples in Mexico City, 1985 and Armenia, 1988 graphically demonstrate the hazard, and underscore the large human tragedy which results.

Also highlighted by the events mentioned above is the fact that when a building does collapse, for whatever reason, we are still not in a position to be able to effectively rescue trapped victims from the rubble. Systems for location of building inhabitants abound, but most are adaptations of technology developed for other applications, and virtually all are only marginally effective. Likewise, methods for the "delicate dismemberment" of a collapsed structure and the extrication of located victims are not well developed.

It is felt by the author that a major part of the problem is that there has not been a focussed research effort in this area. It is hoped that this workshop will be able to

define some of the necessary research goals which may then be studied in the future. The purpose of this paper is to highlight the engineering aspects of the problem in a framework which addresses its interdisciplinary nature. Summarized are some suggestions for specific research thrusts which will improve our capability to locate and rescue trapped persons in future building collapses, and thereby reduce the high cost – in terms of human life and suffering – of future earthquake events.

Problem Definition

Figure 1 presents a flowchart which outlines the "earthquake process" globally, in an attempt to identify the critical issues and clarify the potential contribution of a redefined "engineering for earthquakes." Indicated in the diagram are the professions involved in the analysis or study of the various stages in the process, as well as the relevant inputs required.

The figure may be divided into three basic phases:

1. the earthquake and its consequences,

2. the response to the earthquake at a particular location, and

3. the recovery after the event.

The first phase, given by the top line, presents what has traditionally been the earthquake engineering process. Included are contributions from seismologists, geologists and geotechnical engineers who, working together, estimate a realistic level of expected ground

acceleration at a site. The geotechnical and structural engineer then translates this information into a design load; analysis is performed and the structure designed accordingly. In many cases, these steps are handled in a simplified manner by the building codes and the services of a seismologist, geologist and sometimes even geotechnical engineer are not required.

Commonly, the job of the engineer is complete at this stage, save the supervision of the construction process. While due consideration has usually been given to the basic principles of seismic-resistant design[3], the engineer does not normally consider the possibility of collapse and the resulting consequences for occupants. For modern structures, this optimism may be justified but, as outlined earlier, collapse or severe damage of some older construction must be considered a certainty when a major earthquake affects an urban region.

Perhaps due to this "positive" attitude on the part of engineers with regard to their new construction (which is somewhat justified considering the performance of many newer buildings in both U.S. and worldwide earthquakes) that little study has been done which considers the actual collapse of structures. While the causes of earthquake-induced collapse have been identified in many structures over the years, and improvements in earthquake-resistant structural design resulted from their study, very little research has been directly

[3]That is: (1) the structure should suffer no structural and only minor nonstructural damage in a "minor" earthquake; (2) the structure may suffer nonstructural damage and minor, repairable structural damage in a "moderate" earthquake; (3) the structure may suffer significant damage but should not collapse in a "major" earthquake. While the definitions of "minor," "moderate," and "major" are variable depending on location, type of structure, type of facility, etc., the basic "three-level" design principle is fairly well established.

aimed at investigating the ultimate failure modes of structures, and the resulting effects on inhabitants. The recent heightened awareness of the threat posed by older structures has led to a big push to implement evaluation and strengthening programs, but again little thought to how to deal with collapses should a major event occur *tomorrow*.

Referring back to Figure 1, this observation is represented as the split box for "effect on structure". While the basic response of a structure to earthquake loads is well understood, collapse – particularly of older structures – and collapse patterns have received little attention. It is, however, study of this type which is needed to begin to understand box 5: the effects of structural damage on occupants.

As indicated in the figure, this understanding of human effects cannot be accomplished by structural engineers alone. While the engineer can make contributions in analysis and prediction of collapse patterns, other factors, best understood by other professionals, are also important. While the details will be provided by my colleagues, it suffices to say that required are the services of

- architects, to study building layout, occupancy, egress patterns, population distributions, usage patterns, etc.,
- medical personnel, to identify and study where necessary the precise causes of death and injury of trapped victims, and
- epidemiologists, to relate the observations and factors obtained above in such a way as to enable substantive conclusions to be drawn and recommendations made for the

management of and response to future events.

The second phase indicated consists of the response phase, and is concerned with the delivery of relief, rescue and treatment activities after the event. Of prime concern is the location and extrication of trapped victims in the rubble of collapsed buildings. Paralleling and following this activity is the appropriate medical treatment, both on site and off site.

At this stage, the necessity for effective emergency management is apparent. In most significant events over the past decade, it has been clear that there was a lack of an organizational capability not only in the affected region, but also on site. The reasons for this are manyfold. The infrastructure is usually severely disrupted; local management capability is often minimal, and disorganized. International relief efforts are often not coordinated, and search and rescue activities often end up competitive, rather than cooperative. Even within a national team, an organizational structure is not apparent.

A major, and pertinent, reason for the management difficulties is, however, that there is really no disaster management role which is clearly defined and based on a solid body of research and past experience. Difficulties outlined above compound the problem. The results of studies in earthquake injury epidemiology can influence directly the management aspect. Training programs require establishment, ensuring adequately trained[4] personnel are available, at least at the national level, and perhaps ultimately at the international level also.

[4]Adequately trained implies trained in principles of engineering, architecture, emergency medicine and epidemiology, as well as management aspects.

Details of the medical and search and rescue aspects will be covered by my colleagues in their presentations.

The third and final phase is the recovery from the event. This refers in this context to the long-term medical, engineering, architectural and societal recovery. Again, it is envisioned that studies in earthquake injury epidemiology will impact directly on many of these aspects. In a basic way, this is evident in the reconstruction in Armenia: considerable effort has gone into making the new structures more earthquake resistant.

Recovery can also be linked to prevention. Recovery from one event can lead to preparedness for another, not necessarily in the same location. For example, there is a significant effort to improve earthquake preparedness in Southern California in anticipation of a large event. We do not have to wait for the event to strike to learn our lessons!

The New Role for Engineering:

Where does the "new" engineering for earthquakes fit into the above picture? It is clear from the discussion that the current scope of earthquake engineering is not comprehensive. Presented below, in summary form, is a series of areas into which engineers must delve to assist in the enhancement of life safety in future earthquake events.

- What is the ultimate performance of an engineered structure? Given that the three-level design approach has been used, the possibility of collapse is made as small as possible. Should a sufficiently large event occur, however, what will be the collapse scenario for the structure? Can this information be used in the design to enhance

the possibility of survival even if a collapse should occur (e.g., safe corridors, etc.?)

- How should we characterize structural collapse from an epidemiological standpoint? Is a quantity such as volume fraction lost, etc., appropriate as an indicator of survivability potential?

- What are the most lethal building types from a structural engineering standpoint? Building on earthquake injury epidemiology studies, can we identify and those types of structure most likely to collapse in an "undesirable" manner and potentially killing or trapping large numbers of people? Information of this type can be used to assist in the prioritization of structures for retrofit procedures.

- What are the needs in search or location equipment? Can systems be developed which can penetrate the mixed environment of voids, concrete, masonry and steel to detect trapped victims. While some systems exist, none have been specifically designed for this environment, and as a result they are generally relatively ineffective.

- How should a collapsed structure be "dismantled" or penetrated in such a way as to rapidly reach trapped survivors, yet not risk the integrity of the remaining structure nor threaten the security of the victims? What are the stability characteristics of the collapsed structure?

The above list is not complete. There are sure to be other areas not specifically addressed which are of importance also. It is hoped that some of these will be identified in

this workshop.

Conclusions

Presented above is an overview of the global earthquake problem, couched in a "human effects" context. A brief history of traditional earthquake engineering has been given, and its place in this context indicated.

It is clear from the discussion herein that the current role of engineering for earthquakes is not sufficiently broad to address the entire scope of the earthquake death and injury problem. The infant field of earthquake injury epidemiology needs contributions from many disciplines, especially engineering, to enable it to make an impact in reducing the toll in future events. Structural engineering is necessary to assist in the categorization of collapse and collapse patterns which may be used in the identification of potentially lethal structures; design changes and retrofit priorities and procedures can result. Other engineering disciplines may become involved in the development of location and extrication devices for the collapsed building environment.

The aim of this workshop is to identify the multidisciplinary field of earthquake injury epidemiology. Multidisciplinary implies both interdisciplinary and intradisciplinary. New considerations for engineers fall in to both categories. The preceding paper outlines the author's view of some of the important engineering contributions required. Coupled with those of my colleagues, and the outcome of the discussions of the workshop, we hope we will be able to enhance significantly the development of a field which will reduce significantly

the loss of life and hardship produced in future earthquakes.

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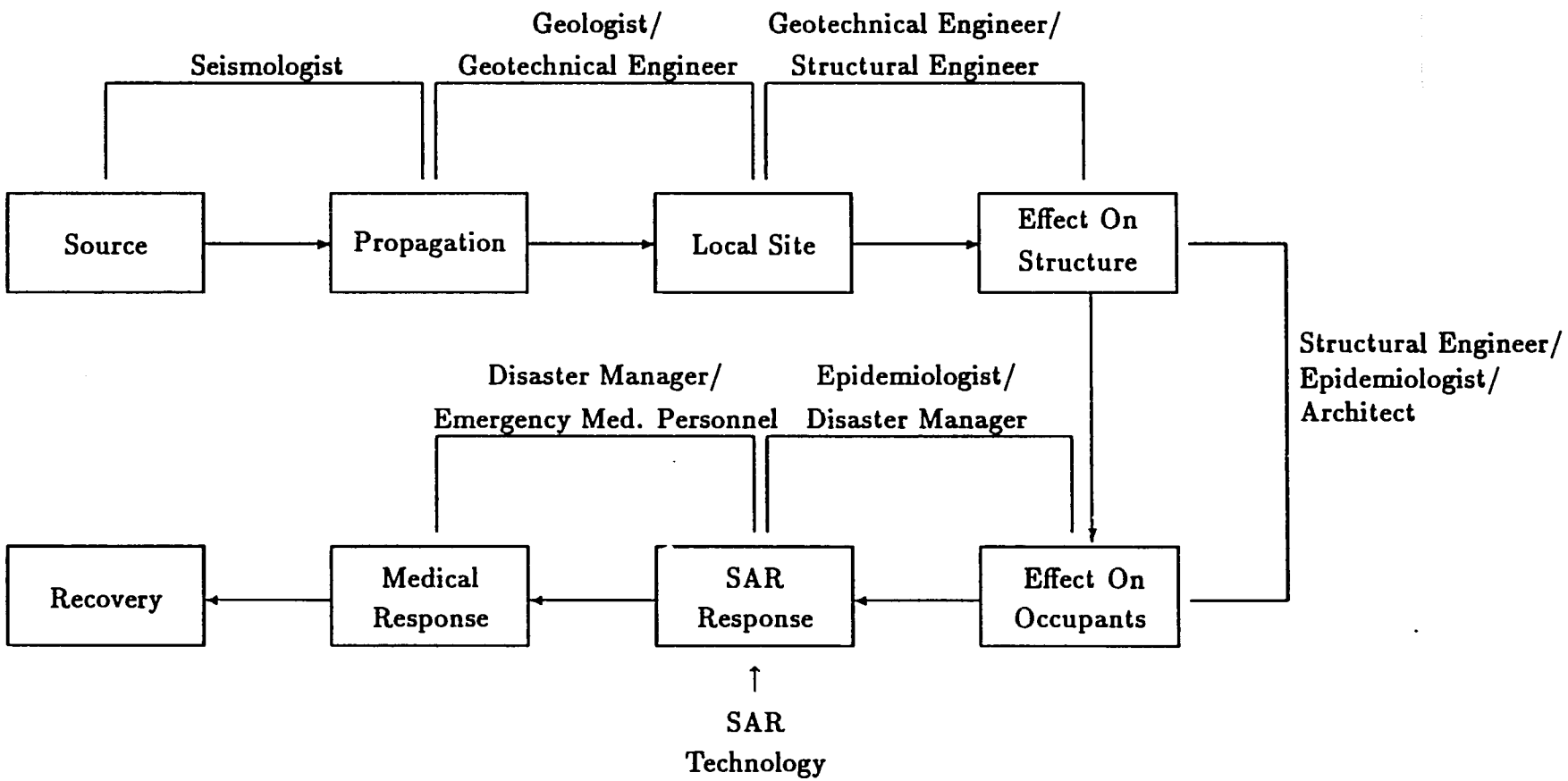

Figure 1: Flowchart of the "Earthquake Process."

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USE OF QUANTITATIVE MEASURES OF INJURY SEVERITY IN EARTHQUAKE RESEARCH

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INTRODUCTION:

A major effort in trauma research has been the development of methods to quantify severity of injury. Improved characterization of injury severity is required for the appropriate allocation of therapeutic resources, for prediction of outcome, and for the evaluation of the quality of care in different facilities or systems or in the same facility at different times. Unfortunately, such methods have never been used in earthquake injury epidemiology research. Past epidemiologic studies of earthquakes have characterized injuries only in the most descriptive fashion such as anatomic location of injury, age and sex-specific rates, etc. It is important that building stock in earthquake-prone parts of the world be described in terms of lethality as well as characterized in terms of potential injury severity case-mix.

This paper describes the application of methods to quantify the severity of trauma in the analysis of earthquake-related injuries (See Figures 1, 2). Such indices have enormous potential as an aid in planning for earthquakes, triage, the medical management of critically injured patients, in tracking a patient's condition from the scene of injury, during extrication and transportation, and during the patient's hospital course, post-earthquake evaluations of the efficacy of search, rescue and onsite medical care in eliciting and testing research hypotheses.

In the immediate post-earthquake period, information on injury severity can be used in several ways. First, it can describe the severity of injury at a particular point in time. This will allow

characterization of the injury severity case-mix resulting from the collapse of a given building type. The second application of a trauma assessment methodology relates to monitoring changes in injury severity over time.

Past papers describing earthquake injuries usually describe the severity of injuries in a very qualitative fashion, e.g., mild, moderate or severe. An assessment methodology such as the Trauma Score (TS), which results in the assignment of a numerical score to the severity of a patient's injuries will also permit the clear and concise communication of information to others. Words like "minor," "serious," and "critical" mean different things to different people. However, a numerical score (eg., a "5" on a 1-10 scale) derived from a standardized assessment technique is much more precise and facilitates the concise transmission of maximum medical information. This is particularly important when medically untrained personnel are attempting to describe the severity of injuries to a physician who will eventually be caring for the patient. By describing the severity of injuries sustained in a more quantitative fashion, it is also hoped that this will allow more valid comparisons of injury patterns from one earthquake to the next.

An approach which rates the severity of injury can also be used for triage, that is, the prioritization of treatment and evacuation for injured patients based on injury severity as well as probability for successful resuscitation. The latter requirement for use as a triage tool comes from the fact that

several quantitative injury severity scales allow prediction of ultimate outcome (i.e. survival vs. death). While experienced physicians frequently rely on their best medical judgement to triage patients, medically inexperienced personnel will benefit greatly from an algorithmic approach to assessment and triage. A trauma assessment based on physiologic variables could provide a relatively objective evaluation of the patient's condition and a rational basis for the allocation of scarce resources.

An effective trauma assessment tool indicates the severity of the injury according to some accepted standard and as mentioned above, can be used to predict certain types of outcomes, such as survival. Because of their predictive ability, quantitative measures of injury severity can also be used to evaluate the efficacy of search and rescue efforts as well as on-site medical care. This is critical, since currently there is little information available on the relationship between mortality in casualties and the time that elapses before discovery, extrication and treatment.

For example, injury severity scores should be calculated at specific points in time related to key events and interventions (eg. when victim first accessed, when extricated, when first seen by medical care provider, when transportation initiated, upon arrival at hospital, etc.). By applying injury severity scores in this fashion, we can determine if a relationship exists between mortality and morbidity and time elapsed before and between critical interventions such as extrication from collapsed

buildings. The only way that we can conclude that a certain percentage of persons could have been saved had they been extricated within a given time period, or had medical care been rendered within so many hours, or had transportation been faster is by calculating injury severity scores at each of these critical time periods.

Calculating injury severity scores at each of these key times, can also permit evaluation of effectiveness and efficacy of these interventions. For example, if the person's severity score worsens between discovery and extrication, this may mean there is a significant problem with rescue. On the other hand, if all patients successfully extricated have already sustained "lethal" injuries, search and rescue may not really be all that important after all. If a patient has a favorable injury severity score at extrication, yet dies, one must look closely at his subsequent management for such factors as prolonged transport time, inadequate hospital care, etc.

Calculating injury severity scores for persons injured in earthquake-related building collapse also has important implications for planning for future earthquakes. By incorporating our analysis of injury severity scores into a model of casualty estimation, we will be able to predict the percentage of deaths and injuries sustained for principal building types and occupancies as well as the range of injury severity. Analyses of injury severity case-mix for victims of the collapse of buildings of a given design and construction for past earthquakes may allow rapid estimation

of injuries and thus of emergency health care needs for future earthquakes where buildings of similar design and construction exists.

Quantitative measures of injury severity can be applied either in the time period immediately following a building collapse for purposes of triage or for immediate data collection purposes (eg. determination of time trends for morbidity and mortality), or retrospectively as a means of assessing overall patterns of injuries and for evaluation of search and rescue and medical care rendered. Determination of time trends for morbidity and mortality will require calculation of injury severity at various points in time. Physiologic scales such as the Trauma Score (TS) are ideal for this purpose since they are easy to calculate and reflect changes in the patient's clinical condition over time.

Unfortunately, data necessary to calculate physiologic scores have rarely been collected in past earthquakes and retrospective analyses will probably have to depend on anatomic scales such as the Abbreviated Injury Scale (AIS) or its derivative, the Injury Severity Score (ISS). Anatomic scales can rarely be calculated in the field since they may require information from the complete medical records or even from autopsy and medical records in order to calculate an injury score.

In summary, indices of trauma severity must be based on easily obtainable data and be proven to be reliable predictors of outcome and accurate discriminators of the severity of injury. We describe

below the quantitative measures of injury severity with the greatest promise of application to earthquake injury research.

INJURY SEVERITY SCALES WITH GREATEST PROMISE FOR USE IN EARTHQUAKE RESEARCH:

Generally, severity indexes may be considered either anatomic or physiologic. Anatomical scales quantify the injury according to the parts of the body affected and the amount of structural or tissue damage inflicted upon those parts. Physiological measures, on the other hand, quantify the body's response to injury, rather than the injury itself. Commonly utilized physiologic parameters include blood pressure, respiration and neurological response. There seems to be increasing interest in indexes which consider both anatomical and physiological components, as well as other contributing factors such as age of person and mechanisms of injury.

Since data required to apply an anatomically-based severity score are not usually available early in the casualty's clinical course, but only after surgery, diagnostic testing or autopsy, this type of scoring methodology is not well suited for in-field data collection, nor for triage. Scales used for triage or prognostic evaluation must be sensitive to the individual's response to injury and should therefore rely on detailed physiological information. Physiological scales, as opposed to anatomic scales are sensitive

to instantaneous changes in the patient's status over time and are therefore of particular utility in directing pre-hospital treatment and triage. Clearly, an index employed in field triage of patients must be easy to use by rescue and paramedical personnel and based on minimal data available at the scene of the injury.

Since the human body's response to trauma varies dramatically over time, the calculated injury severity score using physiologically-based scoring schemes is highly dependent on the interval of elapsed time between injury and the collection of data. This makes the physiological scores more subject to variation when used to control case mix. With increasing frequency, researchers are utilizing changes in severity scores as an outcome measure to evaluate the effects of treatment. In the case of earthquake research, such changes can be used to evaluate the efficacy of search and rescue techniques as well as the quality of medical care. Physiologically-based indexes are most appropriate for this purpose, since they rapidly reflect therapeutically induced changes in the patient's condition.

Because severity scores obtained via instantaneous physiologic scaling can vary depending on how long after injury the assessment is made, if they are to be used in retrospective evaluation, where ultimate outcome is of interest, there must be agreement as to which measurements, obtained over the course of treatment, should be used as fixed point indicators of severity.

Unfortunately, detailed information such as field vital signs,

and mental status required to calculate the Trauma Score are not often available for use in retrospective evaluation of earthquake-related injuries. Scales based on anatomical descriptors alone, on the other hand, are more often routinely available from medical charts (and in some cases from computerized data bases) and have been shown to be valuable tools for describing the extent of tissue damage.

Since physiologic indices based on observed outcomes reflect both the severity of tissue damage and the quality and quantity of medical treatment rendered, it will be difficult to use physiologic scales as a standardized method to characterize injury severity case-mix for victims of building collapse. Unless it can be assumed that all patients in the sample used to derive the scores received care of similar quality, the resulting scale will not only measure the varying severity but also the variable treatment. This will make it difficult to compare physiologically-derived injury severity scores from one earthquake to the next. Analysis of injury severity for purposes of comparison are probably better characterized by anatomic scales, since these reflect initial bodily insult and are one-time calculations. On the other hand, evaluation of search, rescue and medical care interventions which require the calculation of scores at several points in time to show improvement or decline in the patient's status are better served by physiologic scales.

The Abbreviated Injury Score (AIS) and its derivative for assessing overall severity, the Injury Severity Score (ISS) are

probably the most promising anatomical indices for analysis of earthquake-related injuries while the Trauma Score is the most promising scale based on physiological parameters.

PHYSIOLOGIC SCALES: THE TRAUMA SCORE

The Trauma Score is a physiological measure of injury severity. It is useful for triage and in-field calculation since it is simple, easy to calculate and rapidly obtainable. It is based on seven circulatory, respiratory and neurological parameters:

Respiratory rate
Respiratory expansion
Systolic blood pressure
Capillary refill
Eye opening
Best verbal response
Best motor response

The Trauma Score is fluid, changes over time, and provides a "snapshot" of the patient's clinical condition at a given point in time. The widespread application of the trauma score in research and evaluation will be limited, however, until certain issues regarding its application are resolved. First, the TS is not time invariant. As indicated in the overview of injury severity scales earlier in this paper, scales whose values are sensitive to change in patient status over time, while useful for triage and prognostic purposes, are applicable in retrospective studies only if measurements are made at standard points during the care process (eg. when victim first accessed, when extricated, when first seen by medical care provider, when transportation initiated,

upon arrival at hospital).

A second problem in applying the Trauma Score retrospectively involves the nonavailability, on a routine basis, of the data required to compute the Trauma Score. Although the data necessary to calculate TS is easily collectible, such data has not been routinely collected by rescue personnel and on-site medical personnel in past earthquakes. Unless search and rescue personnel or first responding medical personnel routinely measure and record the five parameters that constitute the Trauma Score, its utility in assessing the efficacy of search and rescue and in-field medical care will be seriously limited.

ANATOMIC SCALES:

Abbreviated Injury Scale/Injury Severity Score

On the other hand, anatomic measures of injury severity such as the Abbreviated Injury Scale (AIS) are measures of tissue damage. The AIS and its derivative, the Injury Severity Score (ISS) are the most widely used anatomical measures of injury severity. They are one-time measures of body injury and do not change with time. The calculation of anatomic scores may need information obtainable only from surgery, autopsy or from the complete medical record. Certainly, calculating AIS in the field is next to impossible. However, this data is often available through retrospective review of the medical record.

To calculate the AIS, the body is divided into seven regions: 1) external, 2) head and face, 3) neck, 4) thorax, 5) abdomen and

pelvic contents, 6) spine and 7) extremities and bony pelvis. Each individual injury can therefore be classified according to location and severity. Injuries are assigned scores ranging between 1 and 6 in each of the body regions as follows:

Points:

1	Minor
2	Moderate
3	Serious
4	Severe
5	Critical
6	Maximum/Unknown

The higher the score, the poorer the patient's condition. The AIS was designed to assess single, isolated injuries, but was not as useful in describing the multiply injured patient. Simply adding the AIS scores of various injuries did not account for the synergistic effect of multiple injuries. Injuries in second and third body regions tended to increase the risk of death more than would be expected if the affects of the injuries were truly independent. Baker et al, introduced the Injury Severity Score (ISS) which made possible a numerical description of the overall severity of injury in patients with injuries to multiple body regions. The ISS is defined as the sum of the squares of the highest AIS grade in each of the three most severely injured areas. Thus:

$$ISS = a^2 + b^2 \quad c^2$$

where "a" is the AIS value for the most serious injury, "b" is the AIS value for the most serious injury in a body region different from that of "a," and "c" is the highest AIS value for an injury

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occurring in a region different from both "a" and "b." Including more than three injuries did not significantly improve the correlation between the ISS and mortality. Baker suggests that the ISS not be computed for anyone with an AIS injury of 6, since these injuries invariably result in death. Therefore, the highest attainable ISS score is 75 (AIS injury of 5 in each of three body regions) and this score is automatically assigned to anyone with an AIS 6 injury. A number of studies have validated the ISS as a predictor of mortality and morbidity. Bull introduced the concept of using the ISS to determine an LD_{50} for trauma. The LD_{50} is the injury severity "dose" which is lethal to 50% of the patients being studied.

While limited in scope and generalizability, these studies indicate that the ISS may be a reasonably valid predictor of the surviving patient's prognosis. It should be noted that an anatomical index, such as the AIS, is better insulated from the effect of changes or improvements in medical care than other types of indexes, such as those based on physiological parameters. This is because the AIS relies on the amount of tissue damage- which is not affected by post-injury interventions, rather than the body's response to injury, which can be affected by subsequent care.

On the other hand, the major drawback to the widespread application of the AIS, especially in large epidemiological or system evaluation studies, is the need to review the entire medical record for adequate scoring. As noted earlier, this process can take, on the average, between 10 and 25 minutes per patient,

depending on the clinical training of the rater and the extent of injury.

PRESENT APPLICATIONS OF QUANTITATIVE MEASURES OF INJURY SEVERITY IN EARTHQUAKE RESEARCH:

1. Retrospective Application of Quantitative Measures of Injury Severity to Patients Hospitalized as a Result of the 1988 Earthquake in Soviet Armenia

Currently under way as a collaborative study between the Johns Hopkins Medical Institutions and the Ministry of Health of the Soviet Socialist Republic of Armenia is a longitudinal study of 12,000 patients who sustained injuries severe enough to require hospitalization following the December 1988 earthquake. The objective of this study is to characterize injury severity case-mix for the collapse of buildings in Armenia of a given design and construction using anatomic descriptors of injury such as the AIS and/or ISS. This will require retrospective review of medical records and results of autopsies. Secondly, this study hopes to test the utility of the AIS/ISS in predicting outcome (eg. death, degree of permanent disability) for victims of building collapse. This will allow us to choose those parameters which predict mortality best for earthquake-injured patients. In other words, results from this study should indicate what revisions to the AIS and/or ISS are necessary to render them more applicable to the study of earthquake-related injuries.

The validation phase will be a step-wise process designed to answer important questions about the appropriateness of the proposed changes in the AIS/ISS. The relationship between the modified AIS/ISS severity scoring methodologies and mortality will

be explored. Mortality is a widely used measure to test the goodness of a severity scale. It is hypothesized that as severity increases, mortality also increases and several appraisals of the ability of the modified AIS/ISS to predict outcome will be considered. If the changes made have improved the scales' ability to characterize building collapse-related injuries, then mortality predictions derived from these modified scales should also be improved. Perhaps factors postulated to influence injury severity may need to assume a variety of values or weights depending on their importance, as well as uncertainties in the data and/or various interpretations of the data.

Ultimately, we hope to incorporate our analysis of injury severity patterns in the Armenian earthquake into a model of casualty estimation that will allow us to predict the percentage of deaths and range of injury severity sustained for principal building types and occupancies.

2. Development of Simple, Rapidly Applied Physiologic Methods to Assess Severity of Injuries for Victims of Building Collapse

Evaluation of the efficacy of search and rescue and medical care rendered, as well as determination of time trends for morbidity and mortality will require calculation of injury severity at various points in time. This will require the use of physiologic injury scales such as the TS or a modification thereof since physiologic scales are the only ones that reflect changes in the patient's clinical condition over time and which are also easily calculated with information available in the field.

We are currently investigating the utility of an injury assessment tool called "RPV Assessment Method" which is a rapid and simple method to determine the severity of a casualties that can be performed by non-medical personnel under adverse conditions and which also has prognostic value.

The RPV Assessment Method utilizes the three physiologic parameters of Respirations, Pulse, and best Verbal response based on the Glasgow Coma Scale. A person with absolutely no health care background can determine the RPV score of an injured person simply by measuring the respiratory and pulse rates and determining the best verbal response to specified questions, then summing the coded values assigned to those rates and responses.

The underlying assumption is that the human body responds in specific ways to injury, depending on the severity of the trauma. More severe injuries result in physiologic changes from normal which are greater than those associated with less serious trauma. This relationship is reflected in the assignment of coded values to various degrees of physiologic derangement, as seen in Figure 3. There is also indication that RPV has excellent predictive value regarding the ability to estimate the probability of survival after injury. As with all physiologically based severity indexes, the time interval between injury and assessment can affect the score, since the response of body systems to trauma is not instantaneous, but worsens or improves over time. The value of serial assessments and charting of changes over time is obvious for reasons outlined previously.

The RPV Assessment Methodology is a rapid and simple way to determine the severity of a casualty's injury. It can be performed by non-medical personnel, under adverse conditions, with a minimal amount of training. Ultimately, we hope to be able to apply the RPV Methodology at specific points in time (eg. when victim first accessed, when extricated, when first seen by medical care provider, when transportation initiated, upon arrival at hospital), in order to assess the efficacy of search and rescue and medical care rendered.

3. **Development of rapid assessment methods for establishing the cause and approximate time of death of a body removed from a collapsed structure.**

These techniques are already used by medical examiners and pathologists in post-mortem examinations to determine cause and time of death. We hope to analyze autopsy results to estimate time of death for victims of earthquake-induced building collapse. This estimate should then be correlated with length of entrapment. In addition to the above, the location of the body in the particular structure will be ascertained. Calculation of the AIS may also require autopsy results on those killed by building collapse to determine precise description of anatomic/tissue damage.

The aim of the above three data collection strategies is to ascertain the nature and severity of injuries throughout a structure as a function of time. It is noted that existing earthquake epidemiology studies probably make some attempt to at least pinpoint the location of each survivor or body found. The

above study attempts to add the time dimension and information on injury severity to this data base.

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Figure 1.

Objectives in Using Quantitative Measures of Injury Severity in Analyzing Injury Patterns in Earthquakes

1. Characterization of injury severity case-mix for the collapse of a building of a given design, construction
2. Rapid prediction of emergency health care needs given knowledge of types and numbers of buildings in a given geographic area.
3. Development of triage guidelines
4. Development of casualty estimation models based on damage estimation for principal building types and principal occupancies. These casualty estimation models will include injury severity discrimination.
5. Evaluation of efficacy of search and rescue, and medical care delivered.

Figure 2.

Questions about the quality and timeliness of care for victims of building collapse that will require the application of quantitative measures of injury severity:

1. Are patients being triaged correctly?
2. Is search and rescue effective?
3. Is medical care effective?
4. Which on-site and hospital treatment are more effective?
5. Does efficient search and rescue and emergency medical care influence mortality and morbidity rates?
6. How can new techniques of search and rescue and medical care be tested?
7. Are there a number of late deaths following earthquakes or do most deaths occur within a very short space of time? Could many of the deaths have been prevented by more effective search and rescue, better emergency services, or better long-term definitive care.
8. What happens to survivors after rescue? To they get better before dying, or vice versa? Did the victim survive for a significant time, and if not, why not?

Figure 3.

Coding of Physiologic Variables Used in RPV

Respiratory Rate	Coded Value
0	0
1-9	1
10-24	4
25-34	3
35 and greater	2

Pulse	Coded Value
0	0
1-40	1
41-60	2
61-120	4
120 and greater	3

Best Verbal Response	Coded Value
None	0
Incomprehensible Sounds	1
Inappropriate Words	2
Confused	3
Oriented	4

Figure 4.

Probability of Survival as Function of RPV Score *

R	1	0.089
P	2	0.157
V	3	0.265
	4	0.409
S	5	0.571
C	6	0.719
O	7	0.832
R	8	0.905
E	9	0.948
	10	0.972
	11	0.985
	12	0.992

* BASED ON WASHINGTON HOSPITAL CENTER PATIENTS

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RESEARCH ISSUES IN THE EPIDEMIOLOGY OF INJURIES FOLLOWING EARTHQUAKES

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Introduction

The purpose of this paper is to identify and discuss the research issues involved in studying the epidemiology of injuries following earthquakes. It will first review some basic principles of epidemiology, particularly as they relate to injuries and disasters. Some of the lessons learned from disaster epidemiology are examined to illustrate how the systematic study of disasters has provided important knowledge about the prevention and management of the consequences of disasters, especially earthquakes. This paper does not claim to be a comprehensive review of the epidemiology of injuries following earthquakes or other disasters. Such reviews are available in the literature (Logue, et al., 1981; Seaman, 1984; Lechat MF, 1975, 1976, and 1979; Western, 1976). Nor does this paper seek to provide answers, but rather to raise the important questions that need to be addressed in future research. A review of potential methods to answer some of these questions is provided in an accompanying paper by Armenian. This paper will develop a framework for a systematic examination of the issues involved in understanding the epidemiology of injuries following earthquakes. Central to this understanding is an analysis of what data are necessary in order to better understand such disastrous events. To conduct such studies requires the collaboration of a variety of different disciplines including emergency care providers, search and rescue personnel, engineers, geologists, geographers, sociologists, and epidemiologists.

Epidemiology provides the scientific basis for prevention. It is the branch of medical science that studies disease in a population rather than in individual patients. It seeks to study in a systematic way patterns of disease that can be used to develop risk factors or predict disease outcomes. Epidemiologic principles have made significant contributions to our understanding of diseases and disease transmission. For example, long before the AIDS virus

was actually discovered, epidemiological studies had identified high risk groups, risk factors for the development of the disease, the means of transmission, and had suggested ways to prevent its further spread. Similarly, studies of the epidemiology of chronic diseases have identified factors such as the contribution of saturated fats to the development of heart disease. Central to the science of epidemiology is the belief that adverse effects do not occur at random, but have predictable patterns that can be studied and then be used to form the basis of developing prevention strategies.

Application of Epidemiology to Disasters

The application of epidemiologic principles to studies of disasters has led to some important preventive strategies. For example, a study of injury patterns following a large tornado in Texas found the lowest risk of injury to be among those who remained inside permanent housing (Glass, et al., 1980). Those who tried to flee in cars were at greatly increased risk of death or serious injury. Those who remained in mobile homes had the highest risk of being killed. These findings led to important recommendations with regard to decreasing the risk of injury during a tornado.

Epidemiology has also been applied to the assessment of health needs and disease surveillance after earthquakes. Studies of attendance at clinics following the 1976 earthquake in Guatemala showed that by the time international medical disaster assistance arrived, new trauma admissions had fallen off dramatically (Seaman, et al., 1984; de Ville de Goye, 1976). This finding has led to the realization that efforts should be made to increase the local capacity to respond to disasters rather than rely on outside assistance. Well-designed epidemiologic studies have also shown that contrary to popular belief, major outbreaks of food or water-borne

diseases rarely follow natural disasters (Spencer, et al., 1977).

Injury Epidemiology

The application of epidemiology to the study of injuries is relatively new. It is increasingly being realized that injuries occur in predictable patterns and are not simply accidents or acts of God (National Research Council, 1984). While some events such as natural disasters can be predicted by geologists and seismologists, they are difficult to prevent. However, the injuries that follow them can be prevented or at least reduced. Thus, the public health approach to disasters emphasizes injury prevention rather than disaster prevention. A building may still fail in an earthquake, but injuries may be prevented or reduced if those parts of the building likely to be occupied by large numbers of people can be designed in such a way that there is less risk of injury to the occupants. This approach to injury prevention has been very successful at reducing deaths and injuries from automobile crashes. It has not been possible to prevent all automobile crashes, but by improving vehicle design and the use of safety belts and airbags, the risk of injury to the occupants of the vehicle can be reduced considerably. Applying some of the same principles of occupant protection to building occupants may provide important new information for reduction of injuries and deaths from earthquakes.

Injury epidemiology and prevention has developed a framework for analyzing injury-producing events based on dividing the event into phases, each of which may suggest very different strategies for prevention. First developed by Haddon (1980), these phases are labelled pre-event, event or impact, and post-event (Haddon, 1980; Noji and Sivertson, 1987). Each phase represents a different segment of time in which injuries can be prevented (Table 1). In the pre-event phase, we can either prevent the earthquake from occurring or ensure people do not experience it. However, methods to predict an earthquake are generally unreliable, and

Table 1. Phases of earthquake where injuries can be prevented.

Phase	Strategy
Pre-event	Prevent earthquake from occurring or ensure people do not experience it.
Event	Reduce injuries during earthquake (antiseismic buildings).
Post-Event	Reduce consequences of injury following building collapse (rapid search and rescue)

needless to say, there is no way to prevent its occurrence. The event phase relies on preventing or reducing injuries during the earthquake. This phase is the focus of much attention and much can be done through better engineering of structures to prevent buildings from collapsing. The post-event phase deals with reducing the consequences of the injuries through better search and rescue methods and more effective emergency care. Some researchers have subdivided the post-event phase into the relief phase and the rehabilitation phase, to better separate the acute disaster relief from the more long-term recovery phase.

One of the first applications of epidemiology to the study of building collapse was an article in Science by Glass, et al., in 1976. He identified the type of housing construction as a major risk factor for injuries. All deaths and serious injuries occurred among those living in the newer style adobe houses, while those living in the traditional mud and stick construction houses had no injuries. Some other interesting findings were that increasing age of the house was a risk factor, and that injury rates were higher in large families. This study however, was written only by epidemiologists. Little use has been made of engineering and architectural principles. If such disciplines were included in the study design, more useful relationships

between building design and injury patterns could have been developed (Jones N & Krimgold F, personal communication, 1989). More useful information for understanding injury patterns and developing prevention strategies can be obtained through an interdisciplinary research program that draws on the strength of different disciplines.

While the Glass study may have some problems, it illustrates that epidemiology can play a role in identifying risk factors relating to the building design and construction. However, careful attention must be given to the integration with other disciplines. The remainder of this paper outlines some of the potential research questions raised from a review of existing studies of earthquake injury epidemiology and how we can use these to develop the field of earthquake injury epidemiology, utilizing the input of other disciplines. Central to basic epidemiology is the description of diseases in time and place and the basic questions of how, where, when, and why these conditions occur. These questions provide a useful framework for determining the needs for further research on injuries following earthquakes.

Time and Place

Unlike most other health conditions, injuries and deaths from earthquakes are concentrated both in time and place. Earthquakes are massive catastrophic events that occur suddenly with long periods between events. They often cause little or no damage. In fact, over 70% of the approximately 1.3 million earthquake-related deaths since 1900 have occurred in 12 single events (Table 2). One single earthquake, the 1976 Tangshang earthquake in China was responsible for 19% of all fatalities in this century.

Earthquakes also occur in very predictable places based on the underlying geological structure of the earth's crust. In the United States, the most lethal earthquake was the 1906

Table 2. Major casualty earthquakes 1900-1988

No. Killed*	Place	Date
242,500	Tangshang, China	1976
200,000	Kansu, China	1920
142,800	Kanto, Japan	1923
66,800	Ankash, Peru	1970
58,000	Mossina, Italy	1908
40,900	Tsinghai, China	1927
32,700	Erzincan, Turkey	1939
32,600	Avezzano, Italy	1915
28,000	Chillan, Chile	1939
25,000	Quetta, Pakistan	1935
24,900	Armenia, USSR	1988
23,000	Guatemala City	1976
382,800 (29%)	Others	
1,300,000 (Total)		

* Rounded to nearest hundred.

San Francisco earthquake and fire that killed 452 people (Table 3) and was caused by a shift in the San Andreas Fault. The estimated 1.3 million people killed in earthquakes in this century represent about 14,770 deaths each year over an 88 year period. While this number may seem large, when considered in terms of rates per 100,000 population, it corresponds to a rate of only 0.34 per 100,000 population. Even China has reported only about 500,000 deaths since 1900, just double the overall rate (0.60 per 100,000 population using the 1980 population for calculations). More detailed studies which look at mortality rates for smaller geographic areas have not been done. The 1980 all cause world mortality rate is 1,000 per 100,000 population; the motor vehicle mortality rate in the U.S. is 19.4 per 100,000 population. Thus while the mortality rate from earthquakes is relatively low, it is their potential

Table 3. Five most fatal earthquakes in the United States since 1900

No. Killed		Date
452	San Francisco earthquake and fire	1906
173	Alaskan earthquake/tsunami hitting Hawaii and California	1946
120	Long Beach, California earthquake	1933
117	Alaskan earthquake/tsunami	1964
64	San Fernando Valley, Los Angeles, California earthquake	1971

Source: National Oceanic and Atmospheric Administration

for massive overwhelming number of casualties and injuries within a very concentrated time and place that leads us to be so interested in the problem.

How are people killed or injured in a building collapse?

Understanding of the mechanism by which people are killed is essential to developing prevention strategies. Injuries are caused by the transfer of energy to the body in amounts or at rates that exceed the bodies threshold or ability to withstand the energy transfer (Haddon, 1973). Thus, the etiologic agents of injury are forms of energy which may be mechanical, thermal, electrical, chemical, ionizing radiation, or the restriction of energy transfer which occurs during suffocation or drowning, by preventing oxygenation of the blood. In most earthquakes, people are killed by mechanical energy as a direct result of falling building materials. However, surprisingly little is known about the exact mechanisms. For example, anecdotal evidence from Armenia suggests that suffocation from dust inhalation may be a significant factor in many people who die without apparent injury (Noji E, personal communication, 1989). There is a

need for detailed autopsy data on a sample of cases to determine the exact cause of death, especially for those with little evidence of external trauma. It may be that developing methods to reduce dust release in building collapse could prevent many deaths.

In some earthquakes few people may be killed by the building collapse but die due to post-earthquake fires. In the big 1923 earthquake in Kanto, Japan over 143,000 people were killed, most of whom died not by the earthquake directly, but by the post-earthquake fire that swept rapidly through the damaged area immediately after the earthquake (Seaman, et al., 1984). Similarly the large fire that occurred after the 1906 San Francisco earthquake was responsible for much of the death toll following that event. Some earthquakes produce massive waves or tsunami and have caused a proportion of the deaths in the five largest U.S. fatal earthquakes (Table 3). Another factor that may affect the number of people killed is exposure to cold. In Armenia, for example, it is believed that some of the people who could otherwise have been rescued may have perished due to the intense cold (Noji E, personal communication, 1989).

A clear understanding of the exact causes of death can provide valuable information for understanding how people actually are killed following earthquakes. Autopsy information has provided invaluable data for analyzing automobile crashes and making appropriate modifications to automobile interiors. Such information could also provide useful information upon which to suggest modifications to buildings to prevent death.

Some of the most important questions which need to be addressed are as follows:

Where are victims located?

Is there a difference in the locations in a building between the survivors and those who are fatally injured? Determining where people are located when they are injured or killed can provide valuable information to both assist in locating potential survivors, and in making recommendations to building occupants as to what to do during an earthquake. An analysis of successful rescue efforts could provide valuable data on where the survivors were located and what factors contributed to their survival. For example, one women was rescued 13 days and 8 hours following the Tangshang earthquake (Sheng, 1987). She was trapped underneath an iron bed in a collapsed hospital building. The bed created a void space in the collapsed building and prevented her from being killed by falling material. Other anecdotal stories from search and rescue personnel describe situations where survivors are located many days after the earthquake trapped in small spaces such as bathrooms. The walls hold up collapsing material and water can be trapped for drinking. Individual rescues such as these raise a number of epidemiologic questions. Can we learn from the collapse of buildings where potential void spaces are created? Is it possible to design buildings not only to stand up, but also if they sustain a sufficient force that the building "fails," can they be designed to collapse in such a manner that they create the maximum potential for rescue of the building occupants?

The study of injury patterns from previous earthquakes also may help predict those characteristics that are related to survivability of building collapse. It may not be cost-effective or possible to strengthen older buildings to prevent collapse, but relatively simple modifications may increase the probability that collapse will cause fewer injuries; for example, strengthening stair wells, bathrooms, or creating "safe" corridors. Research efforts such as these will require the cooperation of engineers, architects, search and rescue personnel, medical staff, and

epidemiologists.

An important issue for search and rescue personnel is locating trapped survivors. Little scientific research has been done to predict where trapped survivors are likely to be located in a collapsed building. Can we approach the rescue of people in a damaged building in a scientific manner? As part of search and rescue efforts, data should be collected on the successful rescue efforts, particularly relating to the parts of the building where survivors were at the time of collapse. Another research question is whether or not studies of the epidemiology of injured survivors can lead to advice as to the best way to dismantle a collapsed building. What approach will provide the highest likelihood of a successful rescue without doing more damage to those trapped?

The behavior of building occupants during an earthquake is another area for research. No good guidelines exist for what is the best plan of action once a building begins to shake. Foreshocks may provide valuable warnings that can affect behavior. For example, the Montenegro earthquake of 1979 came in two shocks with enough time between them for people to get outside their houses (Tiedeman, accompanying conference paper). Studies from the 1980 Italian earthquake suggest that those who immediately ran outside were less likely to be injured or killed (de Bruycker, et al., 1985). However, while running outside may be good advice in rural areas, it may not necessarily be the best thing in densely populated urban areas. Narrow streets provide no protection and can rapidly fill with debris falling from collapsing side walls or roofs of buildings; whereas inside the building major parts of the building may be left standing and provide protection. Reports from the Chilean earthquake suggest that a number of people were killed from falling building overhangs as they tried to escape (Aroni S, personal communication, 1989). The anecdotal stories of people surviving under desks or beds suggest

that such behavior may prevent injuries. However, only by developing accurate studies of the location of injured and non-injured persons can we develop sound advice as to the best behavior to reduce the likelihood of injury. The advice is likely to be specific for certain types of buildings and may be different for densely populated urban areas versus rural areas.

When do people die following building collapse?

Understanding when people die following building collapse can provide important information for planning rescue efforts. However, little is known concerning the effectiveness and appropriateness of the different levels of search and rescue, because no formal evaluations of these efforts have been carried out. Evidence from the few studies that exist suggest that most people who are successfully rescued are excavated by local survivors immediately after the quake occurs.

Studies of acute blunt trauma as represented by motor vehicle trauma have shown that rapid extraction, resuscitation, and transportation to hospital can dramatically affect survivability following injury (Sacco, et al., 1984). In fact, much is made of the "Golden Hour." This concept suggests that the probability of survival is greatly increased if persons can be transported to definitive care within one hour of injury. Such rescue times are unachievable in most earthquake situations. Even if they could be achieved for limited numbers of people, the patients would rapidly overcome available medical resources, which themselves are probably heavily affected by the earthquake. However, the limited earthquake rescue literature to date suggests that rapid rescue is essential to increase survivability.

Olson (1987) has defined the "Golden 24 Hours" as the period of time during which the victim in a collapsed building has the greatest chances of surviving if rescued. However, little

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data are available to support this concept. A study of the 1976 Tangshang earthquake in China (Sheng, 1987) however, found that 99.3% of those extracted by rescue squads within one-half hour survived, whereas only 81% of those extracted between one-half hour and one day survived. Only 7.4% of those who were extracted on the fifth day survived (Table 4). Similar findings of rapidly declining probability of being alive at extraction were found in the 1980

Table 4. Survival rates vs. Rescue time
Tangshang Earthquake, 1976

Time of Extraction	Number of Persons	(%)	Number Surviving	% Surviving	Cumulative % Surviving
1/2 hour	2,277	(21.3)	2,261	99.3	29.9
1 day	5,572	(52.1)	4,513	81.0	89.6
2 days	1,638	(15.3)	552	33.7	96.9
3 days	348	(3.3)	128	36.7	98.6
4 days	395	(3.7)	75	19.0	99.6
5 days	459	(4.3)	34	7.4	100.0
0-5 days	10,689	(100)	7,653	70.8	

Adapted from: Sheng ZY, 1987.

Southern Italian earthquake (de Bruycker, et al., 1985). However, these rather crude calculations do not taken into account that the less severely injured may be rescued earlier or that those people showing signs of life are easier to locate, and thus will be extracted earlier. Future studies need to consider factors such as the severity of injury, as discussed in the accompanying paper by Noji.

Information needs to be collected on those that die so that the time of death can be predicted. This may help predict the potential for rescue. The predictive models for survival

time are based largely on blunt trauma such as that due to motor vehicles. Anecdotal stories are told of large numbers of victims surviving for days after an earthquake. Some people may be trapped in voids in the building, but are relatively uninjured. Thus, the severity score and other models used for classical blunt trauma injuries may not be appropriate for use in disaster situations. There is a need for more research to develop more appropriate tools for assessing severity of injuries related to earthquakes.

In planning research on the efficacy of search and rescue, the distinction must be made between light search and rescue conducted immediately following an earthquake, and heavy urban search and rescue. Most people are rescued with light rescue methods using untrained, uninjured survivors who use simple tools such as shovels and axes. In the 1980 Italian earthquake it was estimated that about 97% of the trapped survivors taken to one medical center were extracted using primitive tools such as shovels or bare hands, and only 3% were rescued using tractors or cranes (de Bruycker, et al., 1983). More research is needed to determine the needs for expert outside assistance with search and rescue. Often such help can only be of assistance for heavy urban rescue where there is a likelihood of survivors trapped in voids within buildings.

Why do people die following earthquakes?

Earthquakes themselves do not kill people, but rather the majority of injuries are caused by the building or its components. Seaman, et al. (1984) found a direct linear relationship between mortality and the number of houses destroyed for 19 earthquakes in Turkey during the period 1912-1976 (approximately 8.5 people killed per 100 houses destroyed or badly damaged). Few studies, however, have looked at exactly what components of a building cause the injuries,

particularly in those situations where some people are killed and others only injured or escape without injury. To date most antiseismic building designs have been engineered to preserve the integrity of the building with variable attention to the effects of non-structural components on injury risk. Falling light fixtures, other equipment such as wall-mounted x-ray machines or even overhanging verandas, may become lethal weapons even when the integrity of the building remains intact. Analysis of previous building failures may lead to the development of simple effective retrofit prevention strategies. Engineers generally tended just to look at degree of structural collapse in analyses of collapsed buildings. However, some collapses may be more "friendly" to its occupants than others. Analysis of previous earthquakes may provide useful information to the retrofitting of existing buildings and the design of buildings with an eye toward massive earthquakes that exceed the ability of the building to remain intact. Other factors to be considered include the likelihood of the building to burn or catch fire -- which was a problem following earlier Japanese earthquakes.

Predictive models

There is a need to develop better methods to predict the number of people killed and injured following an earthquake. This information is essential for both rapidly assessing the magnitude of the problem and for planning rescue and other relief efforts. In the absence of such data the relief effort may not be appropriate for the needs (de Ville de Goyet, et al., 1976; Zeballos, 1985). In one earlier model, Lechat (1979) proposed using a ratio of injuries to deaths as a useful guide to predict the number of injuries. This information could then be used to assess medical needs after earthquakes, and predict the amount of supplies and personnel needed in a disaster relief effort. However, the ratio of 3:1 injuries to deaths only applies to

the sample of 3 earthquakes used in the initial analysis, and a limited number of other earthquakes (de Bruycker, et al., 1985). A more comprehensive analysis by Alexander (1985) found it was not a useful predictor when studying other earthquakes. Even if such models could be refined, taking into account various other factors such as building type, intensity of earthquake, etc., accurate estimates of fatalities are often not available. It may take days or weeks before reasonable estimates of the number of fatalities become available. There are often large discrepancies in the number of fatalities reported by different sources for the same earthquake. For example, three different estimates are available for the number of people killed in the Nicaraguan earthquake in 1972 (Coultrip, 1974; OFOA, 1988; Whittaker, et al., 1974).

Another possible approach is to develop a predictive model based on earthquake risk. While geologic maps that outline the earthquake prone areas are available, they do not relate to risk of death or injury. A predictive model could possibly be developed based on a combination of factors such as risk of earthquake of defined magnitude, the particular building construction of the area at risk, and the population likely to be affected. To be able to develop such a model, there is a need to develop simple measures of the lethality of the injury producing potential of different types of buildings, particularly as they relate to different severities of earthquake. A simple classification system for building types should be based on their potential to both cause injury, and also with regard to their potential for creating void spaces upon collapse.

Definition of variables for research studies

It is impossible to compare injury patterns for different disasters without establishing common definitions. Even if broad definitions are available it is essential to have more exact measures of severity in order to enable more detailed comparisons to be made. The accompanying paper by Dr. Noji, illustrates this point well. It is essential to develop simple scoring systems to quantify the extent of trauma. These are usually based on prediction of survivability. However, detailed medical information is often not available in the acute disaster situation.

As discussed earlier there may be problems counting the number of people killed. However, the problems of measurement are even more acute when trying to measure the number of injured. There is no standardized definition of injury in use. Most studies to date have only classified injuries as fatalities and non-fatalities (persons injured). Others have used uninformative terms such as minor, serious, or critical. There is a need to develop standardized definitions since there is a huge difference between minor contusions and life-threatening injuries requiring hospitalization. Future developments of earthquake injury severity scores as discussed by Dr. Noji (accompanying paper) will greatly assist in this but may be difficult to use in all situations. The practicality of a simple definition which separates injuries into those that would require inpatient hospitalization (if available) and those that can be managed safely as outpatients needs to be determined. This definition would at least allow separation of minor from serious injuries. The low ratio of people injured to killed in Tangshang is probably due to their only recording cases of "severe injury" (Tiedeman, accompanying paper).

The data needed for comparative studies is often lacking even for such basic information as the magnitude of the earthquake (Mercalli or Richter scales), the number of deaths, number

injured (using standard definitions) or the size of the affected population. In most areas of the world where major earthquakes have occurred official census records are poor. Other problems include uncounted urban migrants, or other groups such as the refugees from other republics, who were living with relatives in Armenia.

Even when good census data are available, as in California, other factors such as the proportion of people commuting to and from the affected area may greatly affect the population present at the actual time of the earthquake. Thus, even to estimate the population at risk may be difficult. The risk of injury may vary greatly by the type of building a person is occupying, which changes depending on the time of day that an earthquake occurs. For example, the 1933 earthquake in Long Beach, California caused significant damage to school buildings, but no deaths because it occurred at a time when school was not in session (Jones N, accompanying paper). Wooden, single family homes, such as suburban houses in California, are reasonably earthquake resistant. Even if they did collapse their potential to cause injury is much less than that of an unresistant old stone building, like those often used for businesses, offices, or schools.

Time of day can also affect the ability to escape. In Guatemala, the 1976 quake occurred at 3:05 in the morning while everyone was asleep. If the same quake had occurred later in the day many more people would have been outside and thus uninjured. The 1988 Armenia earthquake occurred at 11:41 in the morning, and thus many people were trapped in office buildings or factories. If it had occurred at another time of day, very different patterns of injury and places of injury would have occurred.

Conclusion

Despite the inherent difficulties in conducting studies of injuries following earthquakes a number of studies have already shown that it is possible to collect valuable information that can be used for prevention. However, more refined methodologies will need to be developed. These will include the development of appropriate sampling frames, the use of case-control studies, and the use of multivariate techniques for analysis. The integration of epidemiologic studies with those of other disciplines such as engineering, architecture, the social and other medical sciences is essential to the provision of suitable variables for analysis. Interdisciplinary studies are necessary if we are to develop improved understanding of injuries following earthquakes and the development of effective strategies for reducing injuries from earthquakes.

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PRESENTATIONS 2

SPATIAL ASPECTS OF EARTHQUAKE EPIDEMIOLOGY

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A Rationale for Spatial Models of Injury Caused by Earthquakes

In many respects the geographical or spatial dimension is a neglected factor in disaster epidemiology. Few general spatial models have been proposed and the prevailing emphasis on the temporal dimension, although it is compelling, has not led to a clear understanding of the relationship of casualty patterns to distance and place. In the case of earthquake disasters this has left several vital questions unanswered: is the pattern of injuries nucleated or dispersed? Does its concentration diminish in an orderly manner with distance from the epicentre? Are concentric models appropriate when considering spatial variations in the incidence of casualties? This paper will review these problems and offer some preliminary hypotheses concerning the expected pattern of deaths and injuries resulting from earthquakes. Unfortunately, although the appropriate data are not scarce, few attempts have been made to test their reliability or to subject them to rigorous geographical analysis, and hence the conclusions reported here must necessarily be tentative.

There are several reasons why spatial analysis is relevant to earthquake epidemiology. On a theoretical level, space may be considered as a unifying variable, a framework in which to place other factors. Hence phenomena such as injury severity, building collapse and seismic acceleration all have locational connotations. Moreover, dynamically evolving situations such as earthquake aftermaths may be considered as continuously adapting spatial processes and patterns. On the practical side, the lessons of many earthquakes (for example, Guatemala, 1976, and southern Italy, 1980) indicate that perception of space can be a serious obstacle to the provision of aid and relief. During the immediate aftermath of a seismic disaster in which there is a large number of casualties aid is a very scarce resource. If the lives of the injured are to be saved it needs to be distributed with maximum efficiency, yet experience shows that lack of information on the pattern of building collapses, the location of casualties and the extent of the disaster area may seriously inhibit early attempts at providing relief to the survivors. Spatial models therefore have a potential logistical value in the prediction of casualty patterns and the direction of primary search and rescue.

Existing Spatial Models of Earthquakes and Other Disasters

Remarkably few general spatial models have been reported in the literature on disasters. Wallace (1956) presented a diagram of the generalized relationships among impact and aid zones in disaster, and De Ville de Goyet and Lechat (1976) refined it slightly (Fig. 1). Alexander (1986a) appears to be the only author to have investigated this model further: he found no difficulty in identifying the five spatial zones and noted that in the 1985 Val Stava (N. Italy) mudflow disaster the radii of the zones (which are concentric circles only in a hypothetical sense) followed an approximately logarithmic progression.

Manni (1982) presented a simple model of the spatial organization of medical units in and around a disaster area and related this to transportation modes and the level of treatment required by injured victims. First aid and evacuation centres should be located at the scene of the disaster, emergency surgical posts 3-5 km away from it and hospitals for general treatment at greater distances. Geipel (1982) made a very thorough social and economic study of the 1976 Friuli (N.E. Italy) earthquakes, but although his monograph has a strong element of regional analysis it does not offer any explicitly spatial models that can be applied more generally. Alexander (1986b) plotted the percentage of populations evacuated from settlements damaged by the 1984 Abruzzo (central Italy) earthquakes against distance from epicentre. He found that in some settlements precautionary total evacuations were carried out regardless of the distance while in others the percentage of the population that was evacuated declined exponentially outwards from the epicentres (i.e., only the occupants of those dwellings presumed damaged were evacuated). This probably resulted from the differing attitudes of municipal mayors: total evacuation served to draw the attention of the regional government to the plight of damaged agricultural settlements, while the mayors of villages with a significant tourist presence attempted to minimize the apparent impact of the earthquakes in order not to discourage holiday bookings.

Foster (1980, Ch. 5) described a simulation model for earthquake damage in the city of Victoria, British Columbia, in which the pattern and seriousness of effects varied with the intensity and magnitude of the physical event and with the distribution of vulnerability in the built environment. Rendell (1985) used nearest neighbour analysis to demonstrate clustering in levels of damage to buildings in a southern Italian village that was affected by seismic shaking and landsliding in November 1980. She concluded that the earthquake damaged or destroyed buildings that were already dilapidated or weakened by previous landsliding.

Purely inductive spatial models of earthquake disaster

abound in the form of microzonation and macrozonation studies. The former usually involve mapping of the seismic response of different terrains with particular reference to the architectural and engineering structures located on vulnerable soils and also to secondary hazards such as landsliding and seiching. The latter involve mapping the distribution of damage in particular earthquakes in order to arrive at a generalized seismic risk map based on the expected effects of earthquakes of different magnitudes, intensities and recurrence intervals (Foster, 1980, Ch. 3).

These and similar studies indicate that spatial analysis of disaster impacts often depends upon scale: in other words, that the models or modes of analysis cannot be transferred with ease from one scale to another. Hence, the seminal study by Glass et al. (1977) of earthquake injuries in relation to housing type and the behaviour of house occupants offers far more scope to architects and social anthropologists than it does to spatial analysts.

Mortality and Morbidity in Earthquakes

There is little doubt that building collapse is the principal cause of death in earthquake disasters (Page, Blume and Joyner, 1975). In fact, using data from a series of Middle Eastern earthquakes, Seaman, Lievesley and Hogg (1984) found strongly significant correlations between mortality and number of houses destroyed. Lomnitz (1970) found that the death rate is closely related to the time of day at which the earthquake occurs (and hence to human activity patterns). Seaman et al. (1984) also noted that mortality rates vary with the age and sex of the victims. The patterns are complex but it appears that females, pre-teens and the over 60s are particularly vulnerable groups.

The nature and incidence of earthquake injury have been discussed by Seaman et al. (1984) and Alexander (1985). Lack of standardization in the injury data reported for seismic disasters (indeed, lack of adequate definition in many of the statistics reported) inhibits comparison between events. However, it appears that the ratio of light to serious injuries, or of outpatients to hospitalized victims, varies from about 9:1 to 30:1. The proportion of head injuries among significantly injured patients could vary from 4 to 37% while the proportion of polytraumatized patients might vary from 3 to 66%, and hence there are substantial differences in the nature of the morbidity caused by each earthquake (Alexander, 1985).

Seismic magnitude appears to explain mortality and morbidity only where the total of injuries is high (Alexander, 1985), but in each case earthquakes that affect large areas of heterogeneous urban and rural settlement seldom kill more than 10% or injure

more than about 25% of the population of towns and villages (Alexander, 1982a; Romero et al., 1978). The ratio of one death to every three significant injuries mooted by Lechat (1979) and reiterated by PAHO (1982) appears to be valid only for a minority of earthquakes, predominantly those with a Richter magnitude in the range 6.5-7.4 (Alexander, 1985).

Spatial Disaggregation of Seismic Mortality and Morbidity

Work by, among others, Howell and Schultz (1975) and Brazee (1979) indicates that relatively simple exponential models can be used successfully to characterize the loss of seismic energy with distance from epicentre. It is clear that through the mechanism of seismic acceleration building collapse will be correlated with available seismic energy and hence with distance from epicentre (Page, Blume and Joyner, 1975), although the relationship will be heavily qualified by factors such as the areal density of buildings, their state of maintenance and the degree to which appropriate anti-seismic building codes have been applied locally. It follows therefore that injury patterns should respond to distance from epicentre, but within the compass of each qualifying factor.

Before considering this assumption further the concept of 'epicentre' needs to be examined. The epicentre of an earthquake is the point on the earth's surface above the place where fault slippage begins (i.e., above the hypocentre). There are several reasons why it should be regarded as a relative, rather than an absolute, concept. First, the instrumental determination of epicentres is subject to locational errors of up to 10 km and hence it is strictly more proper to map not a point but an elipse within which the epicentre has a given probability of actually being situated. Secondly, fault slippage occurs on a plane, and hence the source of seismic energy is areal rather than one-dimensional. In many cases the plane is inclined rather than vertical, so that the surface trace of the fault, if there is any such thing, is at one remove from the epicentre (see Bolt, 1988). For this reason, isoseisms are frequently elongated and irregular in shape rather than being strictly circular.

Using data from the 1980 southern Italian earthquake (Alexander, 1982a; De Bruycker et al., 1985a) and 1978 Tabas-E-Golshan Iranian earthquake (Berberian, 1978), Slosek (1986) employed parametric and non-parametric statistics to derive a relationship between distance from epicentre and mortality and morbidity. She found that crude death and injury rates are correlated with distance only if data on the percentage of housing damaged or destroyed are used as partial variables (i.e., the epidemiological rates depend upon damage to housing which is related to distance from epicentre, and there may be statistical interaction between these two relationships). The scale of her

analysis did not merit considering the epicentres of these earthquakes as elipses rather than points but, interestingly, using a 'line epicentre' (i.e. calculating distance from a line corresponding roughly to the location and orientation of fault breakage) yielded no better results than using a point source.

On the basis of data on crude death and injury rates, undifferentiated as to injury type or age and sex of victims, I have generalized the impact of the 1980 southern Italian earthquake into the concentric model shown in Fig. 2. This model is intended as no more than a working hypothesis concerning the basic pattern of casualties considered on a settlement-by-settlement basis. In an area of perhaps 20-40 km radius around the epicentre damage will be severe and the number of deaths will exceed that of injuries. Hence in southern Italy 75% of the deaths and 38% of the injuries occurred in 14 municipalities from among the 637 which reported damage. Most of the 14 were located very close to the epicentre. On the periphery of this zone there may be a few municipalities where the number of deaths is approximately equal to the number of injured victims (five such communities were identified in the southern Italian case). Further from the epicentre there will be communities where the death and injury rates are small with respect to the population size (less than 2% in each case) and injuries predominate over deaths. This will be particularly true of large and medium size cities in which people are injured by falling masonry or by actions taken under the duress of panic, but where outright structural collapse is severely localized and infrequent. Such was the case in the cities of Naples and Salerno in 1980. Still further outwards there will be towns in which injuries but no deaths are reported and finally communities that receive damaged but no casualties. It is intended that this model be considered as concentric only in conceptual terms, and hence we will now consider modifications that may increase its reliability.

Anisotropic spatial models of mortality and morbidity

Slosek (1986) found that seismic mortality and morbidity variables performed better in spatial analyses if they were transformed to logarithmic form. This improved the normality of their distribution and tended to equalize their variances with those of the damage data and distance variables. At the scale of the macroseismic field it is unlikely that data sets are available which give detailed information on the age and sex of victims, the severity of injuries received, and the level of damage sustained by the housing stock. To be useful such data would need to be obtained as reliable averages for each settlement in the earthquake impact zone. Hence it is better not to seek more sophisticated procedures of statistical analysis but simply to make a few qualifications to the basic concentric model. These are illustrated in the lower quadrants of Fig. 3.

In the left quadrant axial variations in the concentric pattern are shown. These would be appropriate where isoseisms and damage to buildings are elongated around a fault trace with a definite surface manifestation that can be related to the seismic response of the ground. This model would also apply to cases in which the settlement pattern (which also determines the location of damage) is elongated; for example, where settlements occur in a linear valley. In the right quadrant nodal variations are depicted. These represent the effect of anisotropic variations in the settlement pattern, thus allowing for the presence of cities of different population sizes at various distances from the epicentre. Differences in the nature, density and seismic resistance of buildings in these cities would determine the particular nodal relationships between death and injury rates that are superimposed upon the general concentric pattern.

Other sources of mortality and morbidity

Apart from death or injury in building collapse, it has been hypothesized that earthquakes may cause increases in the incidence of acute miocardial infarction, or heart-attack (Trichopoulos et al., 1983). The medical conditions for this have been confirmed by Trevisan et al. (1986). However, my own analyses of a variety of earthquakes that apparently provoked this sort of mortality in Italy during the 1980s (unpublished) indicate no significant increase in the rate of seasonally adjusted deaths from miocardial infarction. This is perplexing in that the ages of the 36 heart-attack victims caused by the November 1980 earthquake in southern Italy ranged from 18 to 84, with a remarkable proportion of relatively young adults. The only spatial variation apparent in these and other data sets is that a major earthquake will cause tens of heart-attack victims in the area close to the epicentre (radius ≤50 km) and only a handful at greater distances (Fig. 3, upper right quadrant). Even this generalization must be treated with care: Slosek (1986) observed that epidemiological data form a continuum with distance such that it is difficult or impossible to think realistically in terms of discrete 'epicentral' and 'extra-epicentral' areas.

The disease epidemiology associated with earthquakes has been investigated by Beinin (1981), Greco et al. (1982), Alexander (1982b, 1982c) and Gueri and Alzate (1984). In general, earthquakes are not followed by large increases in the incidence of communicable diseases, although minor changes in certain endemic complaints are to be expected (a contrasting view is presented by Gomez and De Sarmiento, 1987). However, both Beinin (1981) and Trevisan et al. (1986) reported that cardiovascular diseases increase during the weeks and months after earthquake disasters. Hence, there may be a time delay in death from miocardial infarction as a result of earthquake-

induced stress. In any case, more longitudinal studies of the medical impact of disaster are called for (Logue, Melick and Hansen, 1981).

It is not easy to give a spatial expression to these observations. Outbreaks of respirory disease, gastro-enteritis and ailments related to cold conditions may occur on a localized basis as a result of locally insanitary or hostile conditions. But given the scope and magnitude of modern international disaster relief efforts, it is improbable that they will be allowed to spread. Hence, the vector diffusion of diseases is unlikely unless there is already an uncontrolled vector channel for the pathogens to follow. Disruption to health care and public hygiene may be a likely consequence of earthquakes, but it is just as likely to be followed rapidly by a major effort to supply medical and sanitation resources to the disaster area. This will probably include hyperchlorination of potentially contaminated water supplies, thus preventing another vector for the spread of disease. The evidence suggests that major population migrations are not a likely consequence of earthquakes and hence there is little opportunity for the translocation of serious illness by this means (PAHO, 1982). For these reasons there have been virtually no attempts to construct a geography of earthquake-induced disease epidemiology (Alexander, 1982b).

Conclusions

Work by De Bruycker et al. (1985b) has demonstrated that significant reductions in mortality can be obtained if trapped victims are rescued promptly during the immediate aftermath of an earthquake disaster. On the other hand, earthquakes in Guatemala in 1976, southern Italy in 1980, and Armenia in 1988 have made it clear that one of the most imperative problems immediately after the event is to clarify the geography of the disaster area, including the location of injured victims and the configuration of the impact zone. It is probable that, even though the available data are not of the highest quality, any advance in theoretical modelling that might give some a priori grounds for assuming a particular distribution of deaths and injuries will be welcome, especially in cases where the disaster area is large, heterogeneous and troubled by problems of accessibility to remote settlements.

Research that might facilitate this goal has tended to be far too inductive in character. Case studies abound with few attempts to search for common ground or to see whether data yield regularities that are comparable between countries and events (cf. Logue, Melick and Hansen, 1981). The unreliability of field data has probably discouraged the more theoretically minded researchers from constructing, testing or elaborating models such as the ones proposed in this paper. However, unless good use is

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made of the data that are available, there will be no incentive to collect and verify better data. Good, widely applicable theoretical models will lead to better predictive capability after disasters. I therefore end this paper with a plea for more attention to the comparability and theoretical content of studies in disaster epidemiology, and, of course, more attention to the spatial and not merely the temporal dimension of events.

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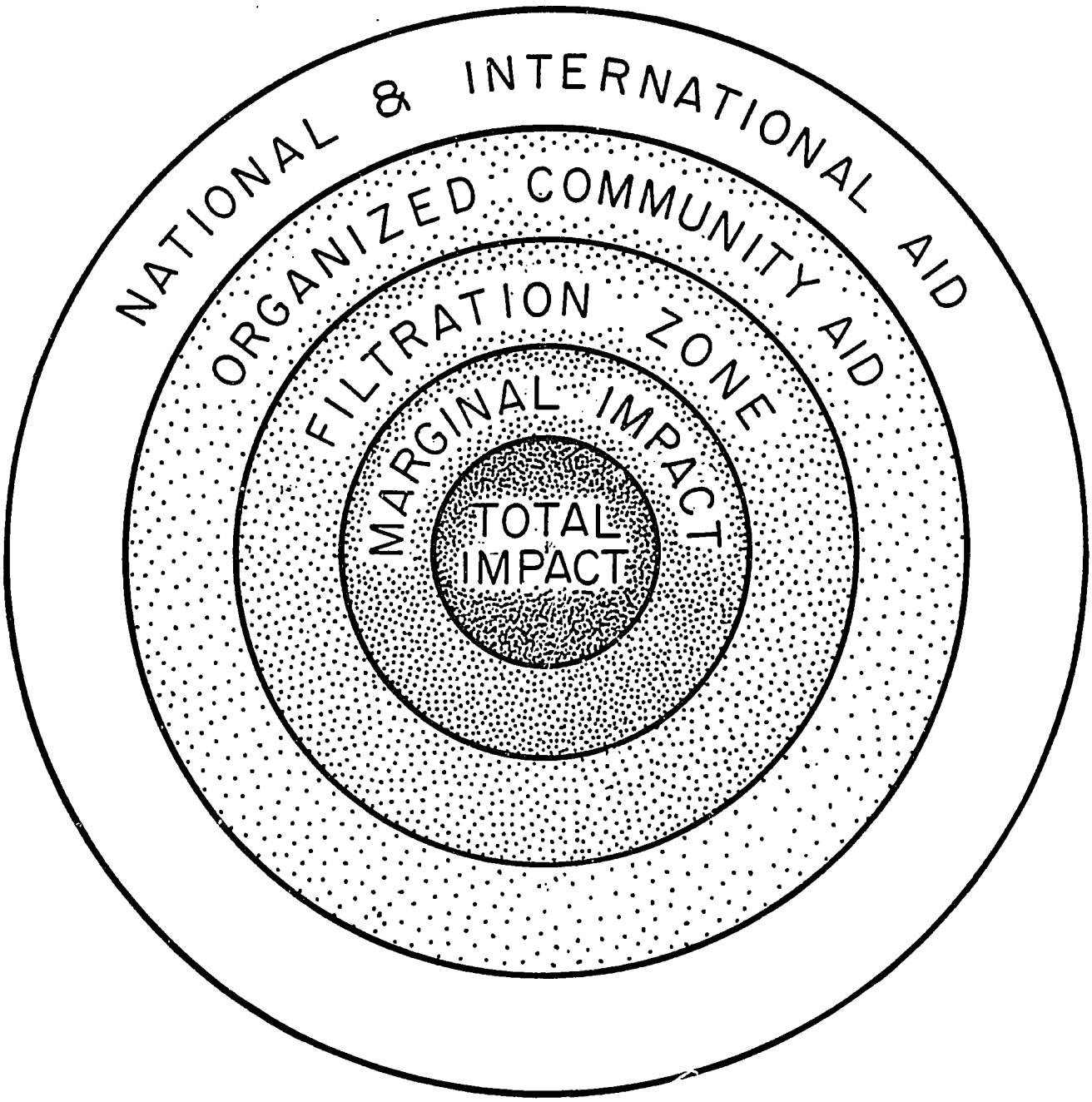
Fig. 1 Spatial model of disaster (after Wallace, 1956).

Fig. 2 Spatial model of casualties in earthquake disaster.

Fig. 3 Four hypotheses for the spatial distribution of casualties in earthquake disaster.

SPATIAL MODEL OF DISASTER



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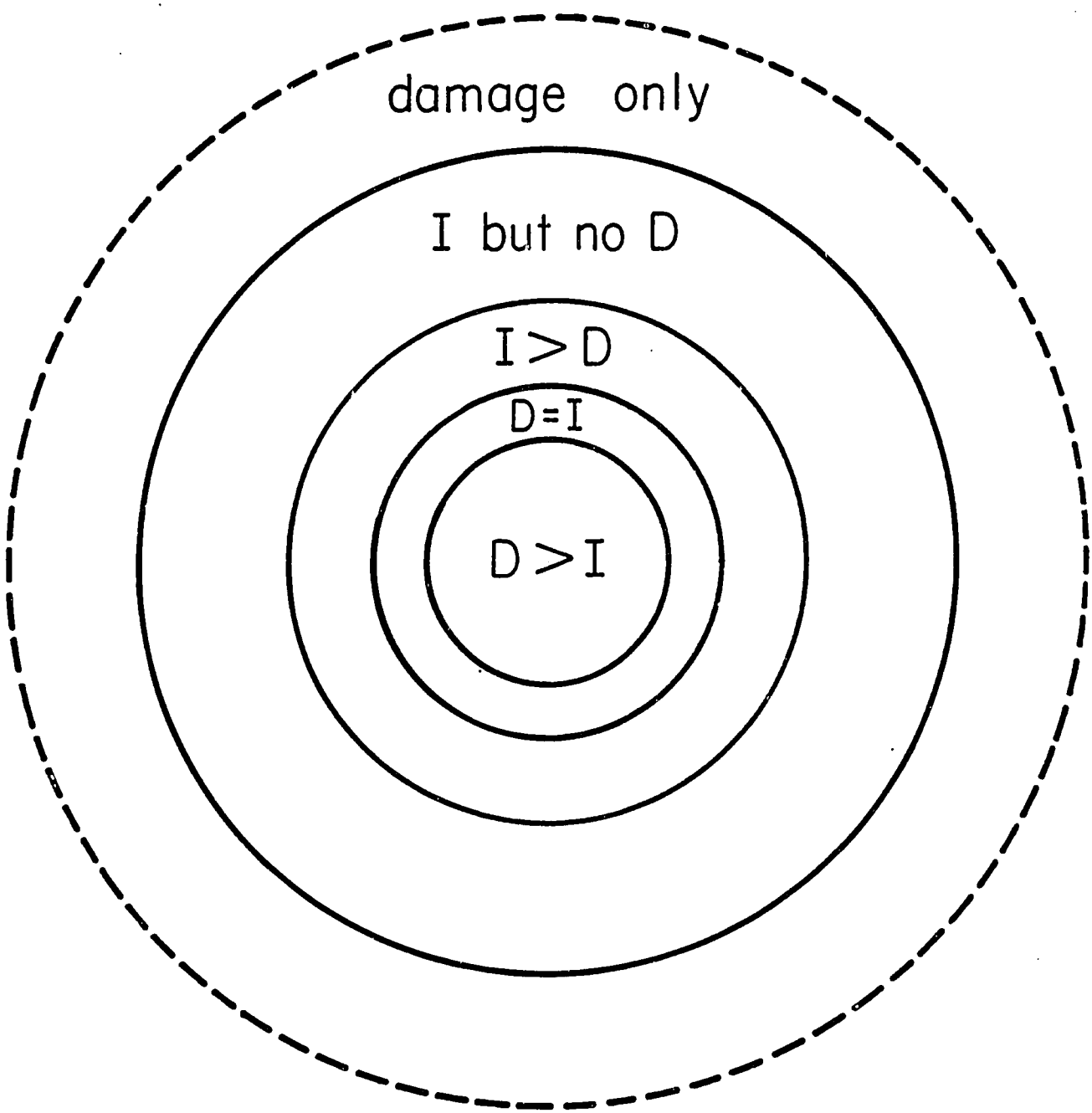
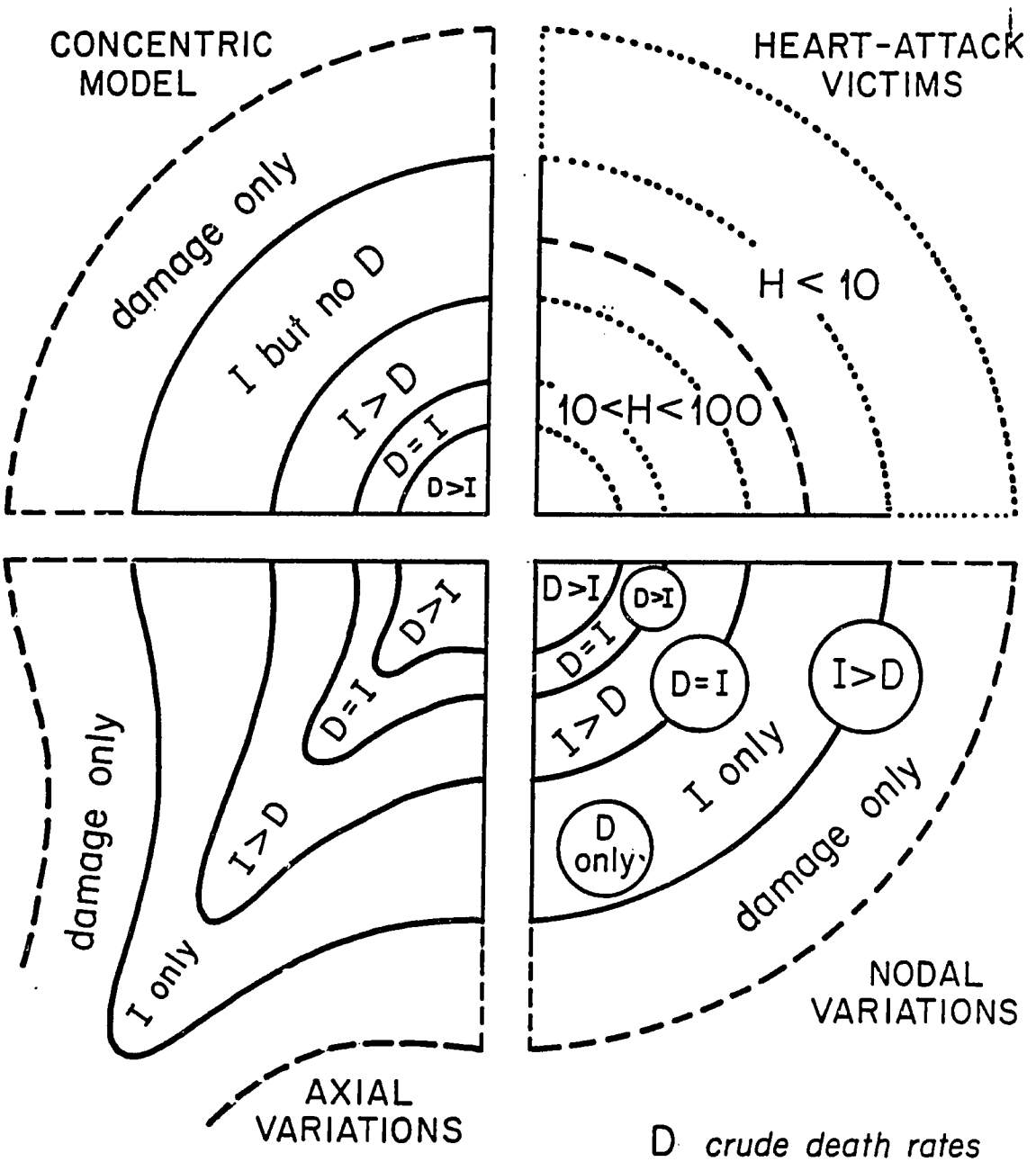
SPATIAL MODEL OF CASUALTIES IN EARTHQUAKE DISASTER



D *crude death rates*
I *crude injury rates*

FOUR HYPOTHESES OF THE SPATIAL DISTRIBUTION OF CASUALTIES IN EARTHQUAKE DISASTERS



D *crude death rates*

I *crude injury rates*

H *number of cases of acute myocardial infarction*

METHODOLOGIC ISSUES IN THE EPIDEMIOLOGIC STUDIES OF DISASTERS

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APPROACHES TO THE USE OF EPIDEMIOLOGY IN DISASTERS

The uses of epidemiology in disaster situations have been reviewed in a number of reports (1-3). As listed on table 1, the role of epidemiology in such situations could include a broad framework of activities spanning from surveillance to etiologic research.

Saylor and Gordon (4), in one of the earliest reviews on the role of epidemiology during natural disasters, have considered disasters as epidemics and have used well-defined epidemiologic parameters like time, place and persons to describe disasters. Using a similar approach, Lechat (5) has classified the time frame for studying problems of disasters as during impact, post-impact and in the long-term.

A multidimensional approach to problems during disasters has been developed over the past few years (6). Considering that epidemiology has an action-oriented role and that by necessity, such action should be multidisciplinary, we developed, a few years ago, a conceptual model that could be useful in the organization and evaluation of epidemiologic action during disasters (7). As illustrated in figure 1, the three dimensions to be included in such action include the following:

1. Level of Action - The ecologic level is concerned with policy and government action while at the personal level the concern may be for prevention and rehabilitation in individuals.

2. Type of Action - This could vary from prevention to clinical-curative activities to rehabilitation.

3. Timing of Action - In addition to the impact and post-impact phases of Lechat (5) we have considered a pre-impact phase of epidemiologic activities.

There are a number of problems faced by epidemiologists involved in disaster situations. These include problems related to the political environment, the rapidly changing social and demographic perspective, issues of relevance to the realities, etc. (8). The current paper will not address these general problems but it will focus on the more specific issues of methodologic problems of epidemiologic investigations of disaster situations.

INFORMATION NEEDS AND SOURCES OF DATA

It is important to view the generation and utilization of data by epidemiologists during disasters within an information-decision system perspective. It is hoped that data is generated so as to provide information for decision making and action. During the Israeli invasion of Lebanon in 1982, in addition to a surveillance of health care facilities for ongoing information on morbidity, we conducted a separate household survey to assess the health problems as they occurred in the community so as to direct relief and action to the neediest groups (9). A Special surveillance program established during the 1988 floods of Khartoum, Sudan, did not identify any outbreaks of typhoid or cholera, thus, vaccinations for these conditions were not carried out and as a result attention was focused on the prevention and management of the common diarrheas and respiratory infections (10).

An organized approach to data collection in disaster situations assists us to improve decision making and predict a variety of options we need to face. Based on the previously presented three dimensional conceptual model, one could develop three two-dimensional matrices that could be used to list the various decisions one may need to make at the different phases of a disaster (table 2). Thus, at the pre-impact phase the decisions are concerned about delineating the at-risk populations and assessing the emergency preparedness

and the flexibility of the existing surveillance systems. During impact, characteristics of the affected population and the need for services have to be assessed quickly, while the post-impact phase needs information on long-term rehabilitation and health services reconstruction. The epidemiological investigation has to cater to the information needs of the decision-action process of the specific disaster and, thus, it can not be detached from it.

Over the past few years various efforts have been made to develop rapid and valid epidemiological assessment techniques. Although one may compromise a certain amount of scientific rigor in order to achieve efficiency and speed, one needs to do the best possible effort under the circumstances of a disaster and hopefully achieve the best possible decision-action. Guha-Sapir and Lechat have developed useful attributes for indicators for needs assessment in earthquakes (11). These have highlighted simplicity, speed of use and operational feasibility.

In assessing sources of data, epidemiologists have traditionally focused on issues of validity and reliability. No systematic effort has been made to assess these characteristics of data in a disaster situation. In addition to these characteristics, other aspects of data sources that need to be addressed in such a situation include completeness, accessibility, timing, etc. The following is a classification of data sources that may be used during disasters:

1. Traditional sources of data. These are usually controlled by governments and are in various levels of development. The deficiencies in surveillance programs in most countries make it difficult for these information systems to cope with the acute stresses of the disaster situation.

2. Existing facilities. An active surveillance and data collection system could be developed using the available facilities of health services for

information. However, sometimes, as in Mexico City, these facilities may be the first to be destroyed by the earthquake and thus can not be depended upon (12).

3. Nontraditional sources of data. A number of communities may have church and other records that may be useful to assess the impact of disasters retrospectively. We have used such an approach to study mortality from Armenian parish records from 17 countries (13).

During disasters an epidemiologist must be innovative and adapt to new situations. Following the 1978 earthquake of Thessaloniki, Greece, Katsouyanni et al (14) have used the available death certificates to study earthquake related stress and cardiac mortality. For the post-earthquake assessment of the affected population in Armenia, an active surveillance and a data base management program have been proposed (15).

ASSESSMENT FOR INTERVENTION AND RESEARCH

A variety of epidemiologic methods can be used during disasters and in the assessment of impact in the post-disaster phase. In addition to a descriptive data base, a number of specific issues need to be researched. Johnson et al (16) in a study of Khmer refugee children in Thailand have elucidated a number of researchable issues related to enteritis necroticans occurring in this affected group.

1. Cross-sectional surveys are the most commonly used approach in the investigation of morbidity and health problems in disaster situations. As stated previously rapid assessment techniques have recently been developed for such a purpose. However, surveys need to go beyond a descriptive concern and address more analytic issues of etiologic relationships. Also, surveys need to collect data that is detailed and specific enough to be useful for

interventions. The availability of questionnaires prepared prior to the disaster and that can be adapted and modified quickly will assist in an efficient data collection operation. Available programs for analysis may provide rapid feedback within hours of data collection.

2. Case-control studies. It is unfortunate that the case-control method has not been used very frequently in the investigation of health problems during disasters. In the absence of well defined population denominators it is the method par excellence to identify risk factors, eliminate confounding and study the interaction of a number of factors. However, a faulty and indiscriminate use of this method may lead to wrong inferences and decisions that may be critical for the victims of disasters. As listed on table 3, there are a number of problems that one needs to address in implementing a case-control study in a disaster situation. As a first step one needs to define clearly the outcomes of interest. In the vast majority of disasters, injuries are the most immediate outcome of concern. These need to be quantified and qualitatively defined. The quantification of injuries may lead to a study where there are different levels of "caseness". Although the exposure may be easily identified in a disaster, however, the details of the exposure circumstances are essential for analysis. All cases and potential controls are exposed (qualitatively) to the disaster, but the differences between the two groups need to be studied in terms of differentials in circumstances and amount of exposure. The issues related to the selection of controls need to be assessed clearly. In addition to establishing the internal validity of the observations, one needs to be concerned with the external validity or generalizability of the findings to the affected population. Thus, controls have to be representative of the community under study. The case-control method could also be used in a sequential manner within the framework of the surveillance of long-term health problems of disaster victims.

3. Cohort and longitudinal studies are difficult to initiate and conduct in populations affected by disasters. These cohorts have to be identified in retrospect and early in the post-disaster period not be miss medium term effects of the exposure. A number of these cohort studies are in progress currently involving populations exposed to man-made disasters. In the absence of a continuous follow-up system, one may generate longitudinal information based on periodic cross-sectional assessments of the same population over time as attempted by Lima et al (17).

CONCLUSIONS

Disaster epidemiology provides the opportunity for the public health professional to be involved in acute problem-solving situations and to be instrumental in having a direct impact in relieving human suffering. Such an involvement, as stated previously, could be at various levels. The epidemiologic data base can have a major impact on public policy provided it is valid, reliable and timely.

In assessing the epidemiologic data base the inferences that can be made about the observations have to be biologically plausible and be confirmed within a number of studies that use a variety of methods. Following a classification of epidemiologic issues in disaster situations, a systematic protocol needs to be developed on the international scene to bring about a stronger scientific base to disaster epidemiology. However, we need to keep reminding ourselves that the primary concern of epidemiology is public health action and as such, we should quantify attributable risk as much as we measure relative risk.

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Table 1

The Role of Epidemiology in Disasters

1. Surveillance and Action-oriented Information Systems

2. Disease Control Strategies for Well-defined Problems

3. Assessment of the Use and Distribution of Health Services

4. Etiologic Research on the Causes of Morbidity & Mortality Due to Disasters

5. Efforts for the Long-term Development of Epidemiologic Activities for the Affected Populations.

Table 2

Information-Decision Matrix at the Preimpact Phase

	Level of Action	
Type of Action	Ecological	Personal
PREVENTION		
CLINICAL CURATIVE		
REHABILITATION		

Table 3

Problems with Case-Control Studies in Disaster Situations

CASE SELECTION	- Specification and quantification of injuries
	- Potential unidentified outcomes
	- Geographic delineation of cases
CONTROL SELECTION	- Representativeness
	- Overmatching
	- Process of selection
	- Migration away from disaster area
EXPOSURE ASSESSMENT	- Differentials in circumstances of exposure
	- Quantification of exposure
	- Misclassification
	- Recall bias
	- Interviewer bias

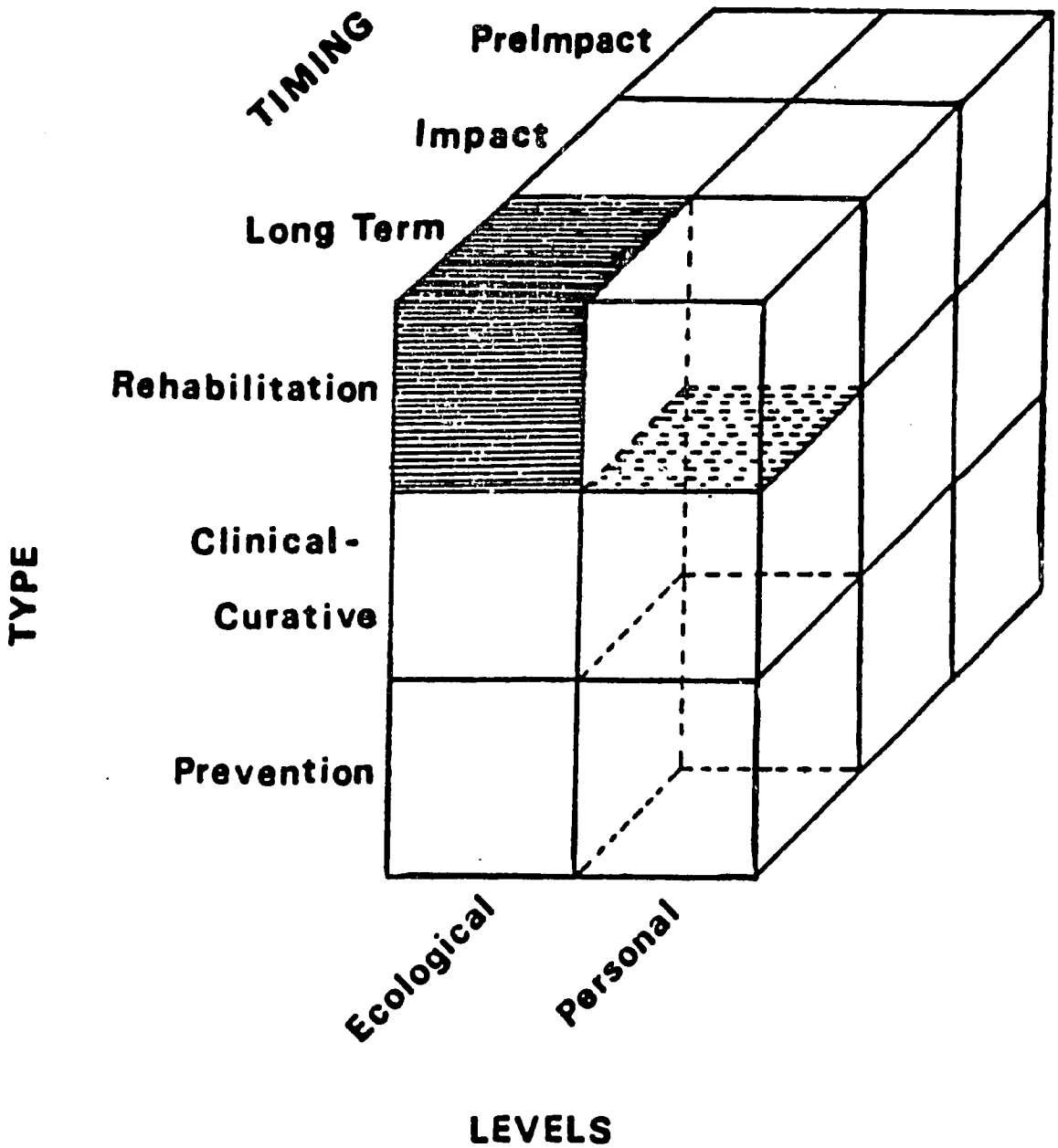

FIGURE 1: Conceptual model for the organization of epidemiologic action during disasters.

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Assessing Strategies to Reduce Fatalities in Earthquakes

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Introduction

The most important priority in earthquake protection planning is the saving of human life. However, current knowledge about the way that people are injured in major disasters and the factors that affect it is small, compared with the knowledge of many of the other processes involved, for example the stress patterns induced in structural systems by ground motion and the causes of building failure.

This workshop is attempting to focus on that knowledge gap by pulling together work on the study of injuries in earthquakes. Its title: *Earthquake Injury Epidemiology* suggests that the study of earthquake injury could bring about its eventual eradication in the same way that other diseases and injury causes have been targeted worldwide.

The first part of this paper considers how to make a significant reduction in earthquake fatalities worldwide. There have been at least 650 lethal earthquakes from 1900 up to mid 1989,[1] with a total of over 1,300,000 officially reported deaths due to earthquakes. Will the next 90 years see more or less deaths than this and what will be the factors that determine it? What actions would make a significant impact on that global score? The actual actions that will effect earthquake fatalities will, of course, be carried out piecemeal at individual sites as part of programmes to upgrade or provide civil protection for specific communities. In the second part of the paper the policies for reducing fatalities in any given place are discussed and evaluated. Five different strategic options for reducing fatalities are considered, and the circumstances governing their effectiveness are discussed. Some attempt is made to quantify their effectiveness in particular circumstances, mainly through case studies carried out by these authors. The conclusions show that not all of these stratgeies are applicable to all cases, but by careful integration of the most appropriate, significant reductions in earthquake fatalities can be achieved with even minimal resources.

1. Priorities For Reducing Earthquake Fatalities Worldwide

1.1 Reduce Hyper-fatality Earthquakes

Only a few earthquakes are responsible for most of the fatalities: In fact the five largest events are responsible for over half of the total earthquake fatalities this century, and almost 80% of the total occurred in only 20 earthquakes (figure 1). However, earthquakes of this sort need not result in such large scale human losses.

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1 Database on significant earthquakes published by NOAA (1980) and updated 1980-1987 from personal files.

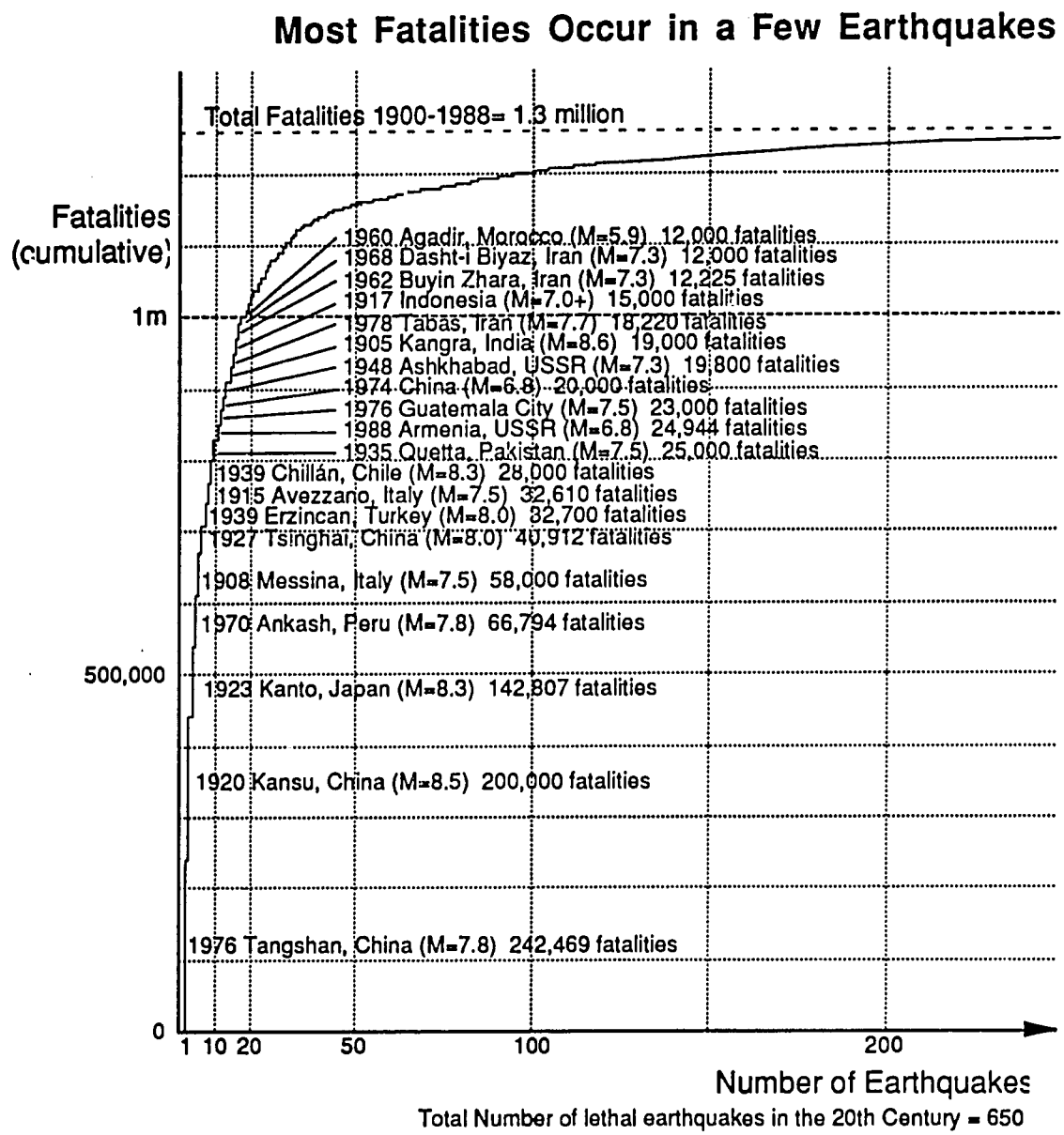

Figure 1
The Worst Fatality Earthquakes of the Twentieth Century

During the 20th century there have been over a thousand large magnitude earthquakes (M>7.0), but only 30 of them, less than 3%, have resulted in over 10,000 fatalities. What are the reasons for an earthquake resulting in a hyper-fatality disaster? It is evident that these disasters are the result of combinations of circumstances that lead to the death toll escalating far beyond the proportions of other earthquakes.

The circumstances giving rise to a hyper-fatality earthquake include:

- A 'direct hit' by a high intensity earthquake on a city or region of dense human habitation
- Extensive building collapse
- A severe secondary disaster (fire, landslide, flood, mudflow) enveloping the affected area
- Severe loss of the capability of the local population to help themselves

These circumstances, occurring to greater or lesser extent in each of the worst 20 earthquakes, suggest that effective casualty reduction could be achieved by reducing the tendency of disasters to compound themselves; i.e. to raise the threshold at which escalation of casualties begins. Mass building collapse disasters compound themselves because the local population is largely incapacitated: people are either trapped themselves and therefore unable to rescue other people, or they are traumatized by their narrow escape and the loss of their families, friends and houses. In events where only a proportion of the population is affected, the administrative and social organization remains effective and unaffected people rally to the aid of those in need, pulling people out of the rubble before they die, suppressing fires and avoiding tsunamis and other dangers. It may be that there is only a fine line between an incapacitated population and a capable one, but to reduce hyper-fatality events, the objectives must be to 'harden' the self-capability of the affected population. A critical factor may be the ratio of affected people to unaffected, and there may be thresholds of destruction level at which social incapacitation occurs. At present there are few models of the way that mass casualties occur, and little understanding of the way that this escalation of casualties begins. However, from consideration of these worst 20 events, it is possible to suggest general guidelines that may reduce hyper-fatality events.

a. Increase the Thresholds of Casualty Escalation

It is obvious that to reduce casualties in disasters, the numbers of buildings collapsing must be reduced. This is considered more generally in part 2, Safer Building Stock. The cost of building safer buildings is high, and it will be a long time before everyone living in vulnerable buildings can be housed in earthquake-resistant structures. If, as is argued here, the critical factor in the escalation of disasters is the ratio of affected people to unaffected, then the potential for mass-casualty occurrence may be greatly reduced as soon as a certain percentage of the population are living in safer housing. Thus small changes may make a big difference. The prevention of collapse of a building in highly vulnerable areas will save more than the life of its occupants: It may also save the lives of the people those building occupants are able to rescue. Programmes to bring about modest improvements in the resistance of buildings targetted in the areas of highest casualty risk may bring about significant reductions in the potential for a mass disaster.

b. Ensure Effective Emergency Management

Good emergency management is needed to prevent the escalation of a disaster into a super-disaster. In Japanese earthquakes, the failure to suppress a conflagration after an earthquake appears to lead to casualty levels of up to ten times the number that would be expected from an earthquake without a fire.[2] Suppression of individual fire outbreaks at source to prevent them combining into a conflagration is critical and implies a capability of the local population to react after the event, beyond the capability of the regular emergency services. The administrative and organizational capability of the social group must survive. In addition to increasing the destruction thresholds at which social incapacitation occurs, the organizational facilities for the society must remain intact. Physical buildings like fire stations and police buildings are already considered as critical emergency facilities which merit higher standards of protection, but additional facilities for social organization should also be considered, such as chains of command, key personnel, information and communication channels. An emergency plan for the involvement of the whole population in a catastrophic event is essential, both to raise public awareness of their expected role and to plan effective protection for the organizational capacity needed to sustain it.

c. ReduceSecondary Disasters

The effects of secondary disasters triggered by earthquakes have understandably received less attention than the primary effects. But it is evident that their effects are potentially far more lethal. The mudslide triggered in the Ancash earthquake in Peru in 1970 buried a town of 20,000 people, of whom very few escaped or were rescued alive. Even if the earthquake had reduced every house to rubble it would not have killed anything like the number buried under 50 metres of mud.

2 Coburn, Ohashi Murakami, Ohta (1987).

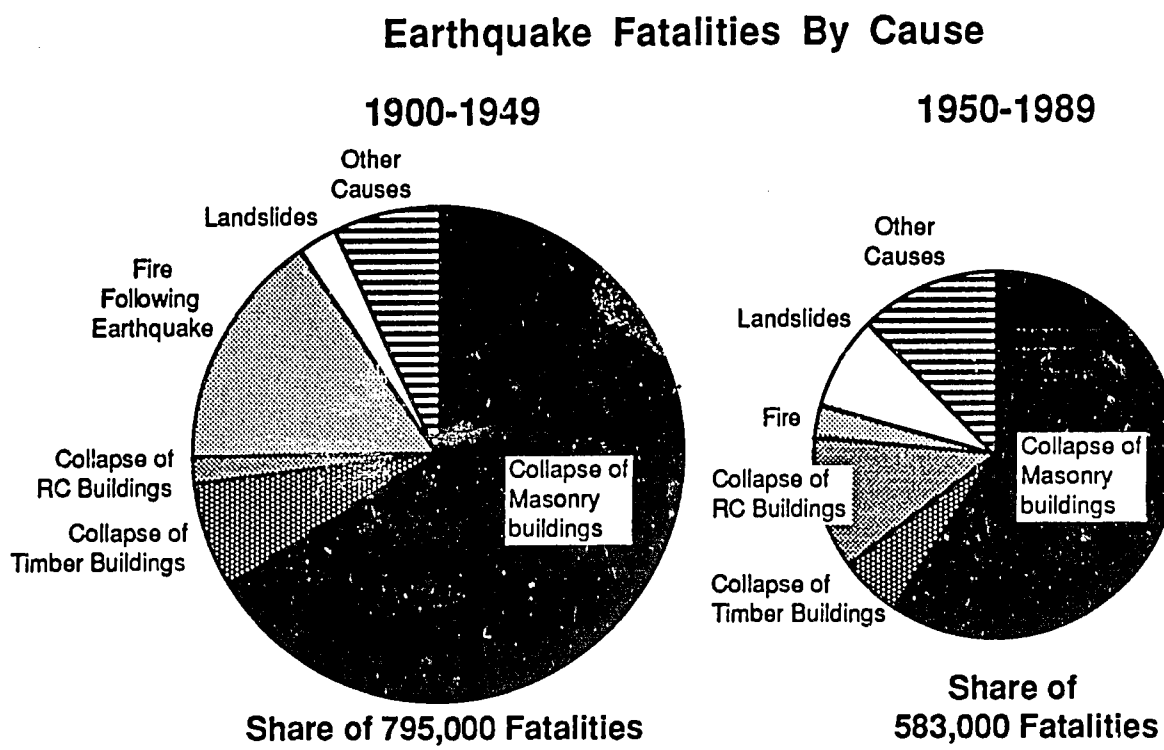

Figure 2
Breakdown of Fatalities Attributed to Earthquake by Cause

Against such forces, no amount of building strengthening or emergency preparedness would save the population. These types of disaster can only be prevented by mitigation planning based on carefully pre-analysis of potential hazards. The probability of these catastrophes may be too low for action on a global scale, but the analysis of their potential should become part of the standard risk mitigation methodology for earthquake protection planning.

1.2 Concentrate on the Most Fatal Building Types

About 75% of fatalities attributed to earthquakes are caused by the collapse of buildings. Figure 2 shows the breakdown of earthquake fatalities by cause for each half of this century. This shows that by far the greatest proportion of victims die in the collapse of masonry buildings. These are primarily weak masonry buildings (adobe, rubble stone or rammed earth) or unreinforced fired brick and concrete block masonry that can collapse at low intensities and collapse very rapidly at high intensities. These building types are common in seismic areas around the world and make up a very large proportion of the world's current building stock.

Increasing populations in developing countries will continue to be housed in this type of structure for the foreseeable future. However, there are increasing changes in the types of buildings being constructed in very many of the countries most at risk. Modern building materials, commercialization of the construction industry and changes in the aspirations of town and village dweller are bringing about rapid changes in building stock. Brick and blockwork are common building materials in even the most remote areas of the world, and the wealthier members of rural communities that 20 or 30 years ago would have lived in weak masonry houses now live in a concrete framed house.

Concrete framed houses are generally safer - i.e. they are less likely to collapse - but when they do collapse, they are considerably more lethal and kill a higher percentage of their occupants than masonry buildings. In the second half of this century most of the urban disasters have involved collapses of

reinforced concrete buildings and the proportion of deaths due to collapse of concrete buildings is significantly greater than earlier in the century.

Is the World Becoming Safer or More Dangerous?

It is difficult to assess the global extent of changes to the building stock in seismic areas. There is little doubt that the number of elements at risk, the buildings and population living in areas of high hazard, is increasing. Figure 2 shows that the total number of fatalities in the last forty years of this century has averaged 14,000 a year - down from an average of 16,000 a year in the first fifty years. Some of this reduction is undoubtedly due to beneficial changes: the reduction in fatalities from fire is largely due to changes in the Japanese building stock and successful measures taken by Japan to avoid conflagrations in its cities. However, the sporadic nature of earthquake occurrence and the random hit-and-miss nature of their consequences means that the lower death toll in the second half of this century is more due to luck than improvements in safety levels. The seismicity of the two periods, in terms of the average number of earthquakes in each magnitude range per year, is almost identical, but their distribution - occurrence on land or in the sea and their proximity to population centres - is not. In the first half of the century, earthquakes scored more direct hits: eight of the ten highest fatality earthquakes were pre-1950. A single hyper-fatality earthquake occurring in the last decade of this century could make the second 50 year fatality total higher than that of the first half of the century, and there are undoubtedly more earthquake disasters to come before the end of the century.

Changes in building practices in some areas are making a significant proportion of buildings stronger than they used to be, but it is unlikely that reductions in vulnerability are sufficient to offset the inexorable increase in population at risk. The world's population is growing at around 1.6% annually, i.e. doubling every 40 years, so the average vulnerability of the world's building stock needs to be reducing at a reciprocal rate, i.e. halving every 40 years, for the average annual loss just to stay equal. The average vulnerability of building stock is unlikely to be reducing that quickly, and the world is almost certainly increasing its risk of future fatalities. A more complex analysis of land area affected by different intensities of earthquakes, building typologies and population is needed to quantify trends of world casualty risk. What is certain is that risk is polarizing, with first-world countries obtaining increasing levels of safety standards in their building stock while the increasing populations of developing countries become more exposed to potential disasters.

1.3 Concentrate Efforts on a Few Countries

Despite the unwillingness of earthquakes to be constrained by political boundaries, the effects and organizational response to earthquakes is largely contained within individual countries. The framework for mitigating earthquake disasters will ultimately fall upon national administrations. The situations that give rise to a hyper-fatality earthquake disaster appear only to occur in a limited number of countries. Nine countries account for 80% of all fatalities and almost half of the total number of earthquake deaths in the world have occurred in China. China is exceptional in many ways in having a high density of population living in a relatively weak building stock, and with considerable concentration of its population into densely populated cities.

Japan has suffered a number of very high casualty events in the past, and has concentrated considerable efforts to protecting its population from the effects of earthquakes. It appears that Japan's protection strategies are achieving results. Other countries, like Italy, Iran, Peru, Turkey and USSR have all had a recurrence of large earthquake disasters and are now committed to some degree of disaster mitigation. The scale and extent of disaster preparedness varies considerably from country to country, as does the amount of resources allocated to the problem. In a number of cases, earthquake protection has not yet progressed beyond emergency preparedness measures - seismometer networks, research institutes and crisis management plans. Others, like Italy, have a national policy on civil protection from earthquakes, which involves education policy, public awareness programmes and shelter planning to link with emergency plans.

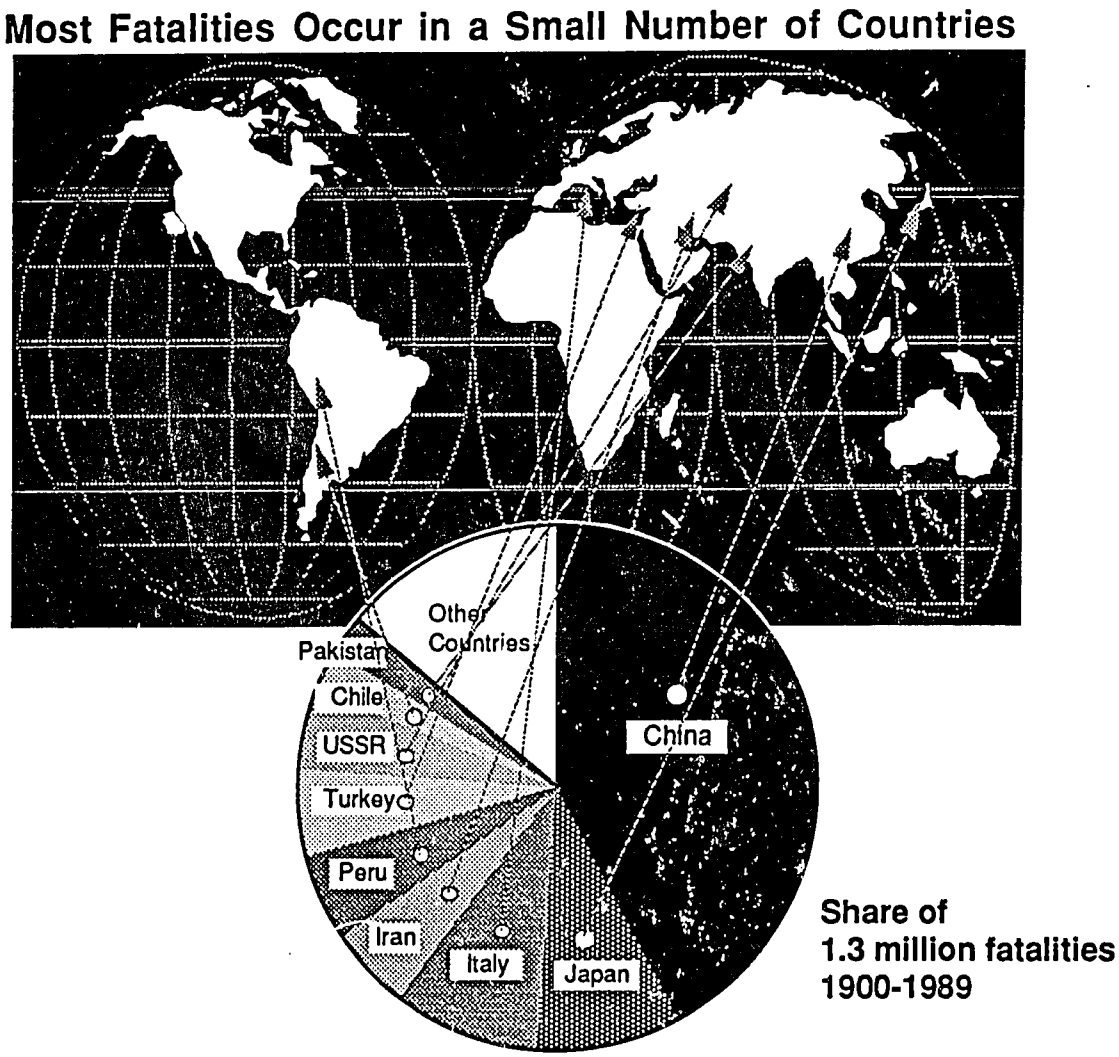

Figure 3
Location of Earthquake Fatalities Across the World

Few countries however, have yet established a coordinated, long term programme for earthquake risk reduction, integrating policies on building stock management, land use and emergency preparedness of the sort that will be necessary to achieve genuine reductions in earthquake casualties into the next century.

The situation in each country is quite different - Italy and Japan have relatively stable population levels and are now facing problems of dealing with risk in existing building stock. These industrialized economies have, by comparison with other countries, considerable resources to deal with the problem. China and Iran have high population growth and limited resources. Turkey is dealing with an unprecedented change in its building stock and demographic distribution. The Soviet Union is restructuring its socialized building industry at a time of national economic reform and a spate of recent disasters.

There is no single formula for reducing earthquake fatalities that can be applied by all of these countries. Ultimately each must coordinate a set of policies from a toolbox of strategic options that are technically viable. The effectiveness of the individual strategic options is considered in the second part of this paper.

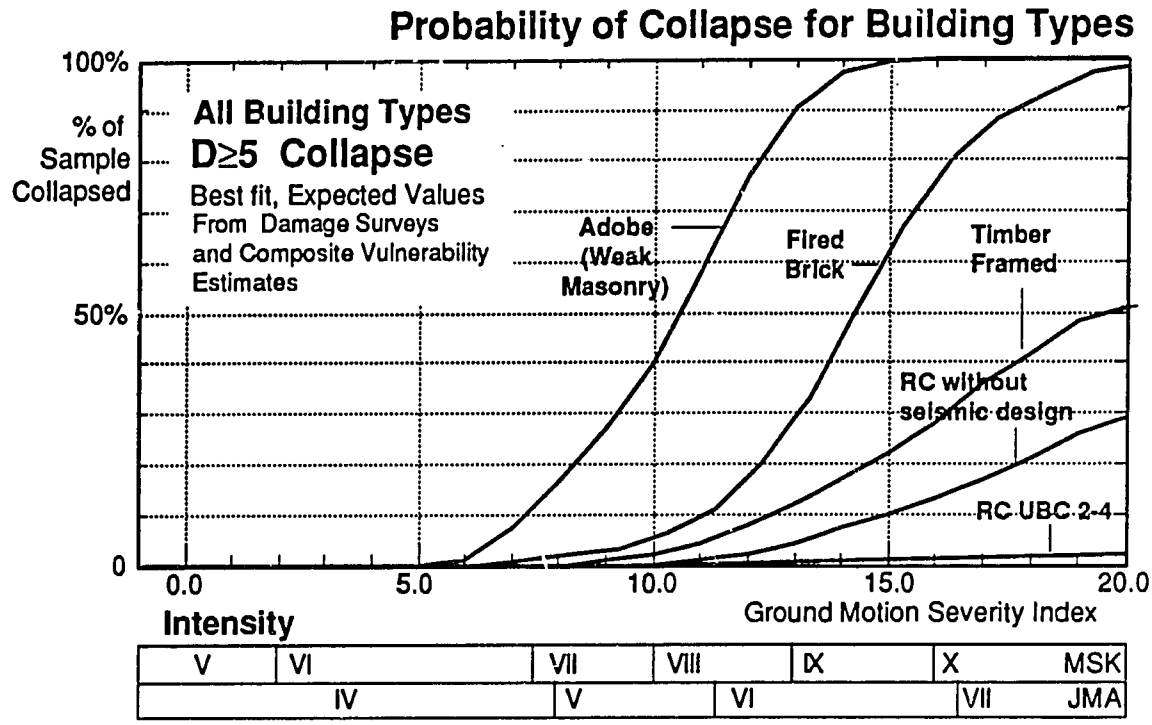

Figure 4
Vulnerability of Different Building Types in Shallow-Depth, Near-Field Earthquakes

2. Reducing Casualties at a Site

The reality of casualty reduction is that it will be carried out on a case-by-case basis in individual cities, regions or communities with mitigation programmes, preparedness and emergency management activity. A better way to consider casualty reduction is therefore to examine the basic policies available for casualty reduction in a comparative way. A policy maker at national or regional level is faced with a number of choices and policy decisions. He may have a specific budget to spend on mitigation and preparedness. How could those funds be most effectively used to reduced casualties? What other considerations are important in deciding which options are preferable? This section attempts to compare different approaches to casualty reduction, and considers some of the implications of each. The policies considered are:

A. Making a Safer Building Stock
B. Building on Safer Land
C. Reducing Occupant Densities
D. Evacuation of the Population Before an Earthquake
E. Rescuing More People Alive After the Earthquake

These will be considered in turn.

A. Safer Building Stock

One of the most obvious ways to decrease the risk of casualties is to ensure that buildings are less likely to collapse. The quality of buildings, measured by their seismic resistance, is of fundamental importance. Figure 4 shows the average probability of collapse of different building types against severity of ground motion shaking in the near-field areas of shallow-depth earthquakes, from the earthquake damage database of the Martin Centre, Cambridge University.

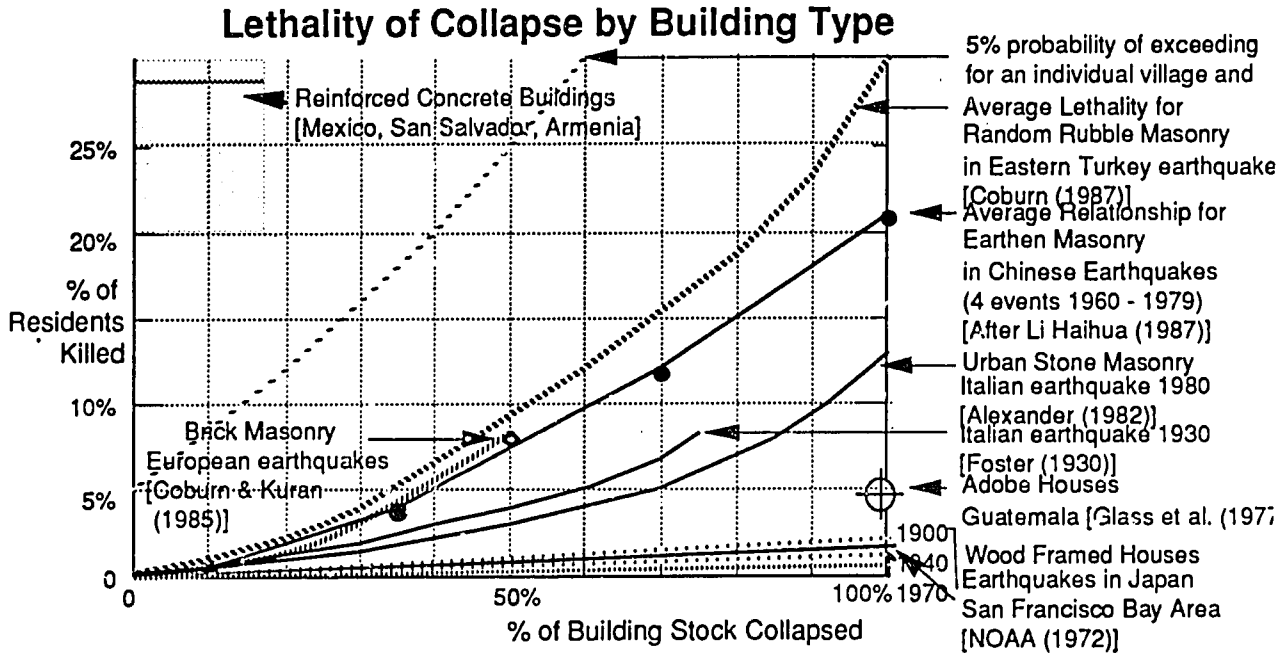

Figure 5
Numbers of People Killed per Building Collapse for Different Building Types

The lethality of collapse for different building types is highly variable, depending on the differences in mechanism of failure, speed of collapse and the different type of injury inflicted[3], but average values taken from the compilation of studies shown in figure 5 can be used to obtained expected mortality of population living in different building types at increasing levels of earthquake intensity, figure 6.

Figure 6 illustrates that in a district shaken by an intensity IX earthquake, somebody living in an adobe or weak masonry building is 20,000 times more likely to be killed than someone living in a reinforced concrete frame building properly designed for a minimum level of seismic load (UBC2 or more).

In terms of factors that affect mortality levels in earthquakes, there is no doubt that building quality is the primary controlling factor. Unfortunately it is also the most expensive and difficult factor to change. The total cost of building a concrete framed building to seismic code standards is $5,000 to $20,000 per head. Currently the earthen buildings that house 80% of the worlds population may cost their owners $5 to $500 per head in cash costs to build (essentially earthen buildings are built using free labour and collected building materials rather than cash expenditure). So by increasing investment in per capita building stock in the worst seismic areas by a factor of somewhere between ten and a thousand, the earthquake fatalities problem would disappear.

Changing from traditional weak buildings to engineered or modern buildings also requires a major restructuring of the building industry in these vulnerable areas, and a transition away from the owner and community building that is the practice at present, to a professional, contracting building industry, closer to the structure of building practice in urbanized societies. This effectively implies a change in the overall economic structure of these communities, away from their subsistence, agro-domestic economy to a cash-crop, wage economy and interdependency of skills, i.e. the effective urbanization of rural societies, together with the expectations this brings for infrastructure and other high-investment services. In many places these changes are already occurring, in some cases extremely rapidly, for many different reasons. There are opportunities for earthquake risk to be diminished along with these changes, by ensuring that the naturally occurring increasing investment in building stock is used effectively, to build stronger houses as well as more prestigious houses.

3 Coburn, Ohashi Murakami, Ohta, ibid.

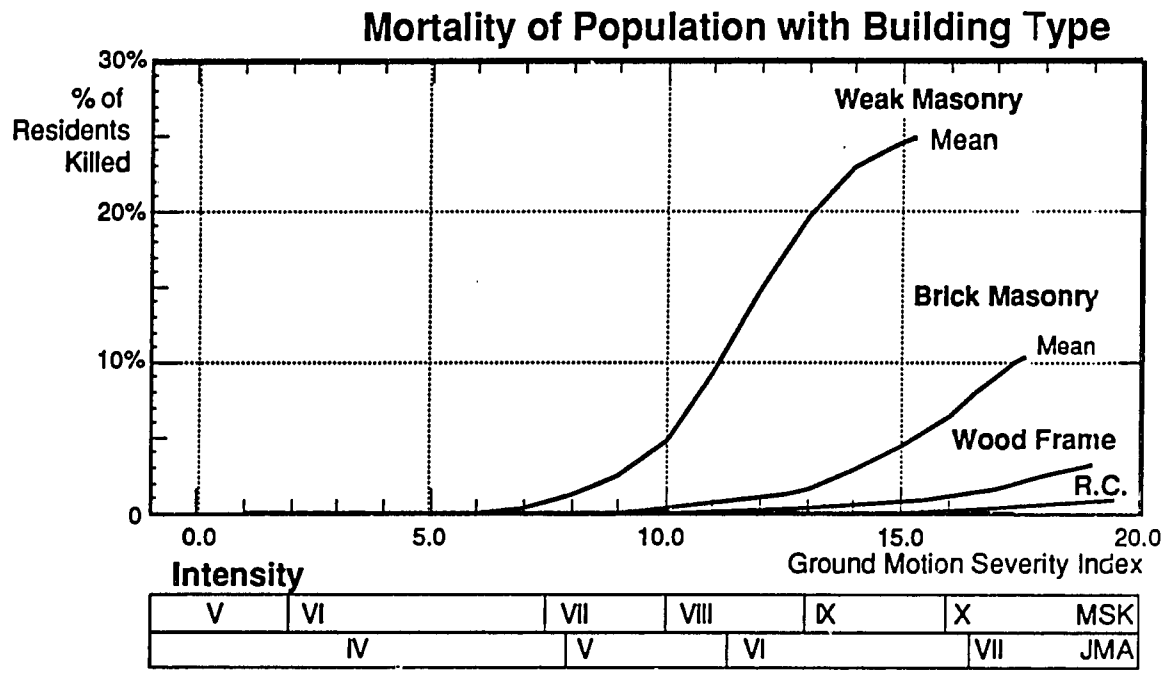

Figure 6
Probability of Being Killed in an Earthquake Living in Different Building Types

The achievement of seismic resistance in a building is not achieved merely through increasing the cost - the methods of building a stronger structure need to be understood. The quality of workmanship is vital in obtaining a safer building. Given this understanding of the process of achieving stronger buildings, the weakest building stock can be targetted for improvement at relatively low levels of cost.

Strengthening Traditional Buildings in Eastern Turkey

A study of the improvement of weak masonry buildings in the Alpine-Himalayan seismic belt, taking Eastern Turkey as an example showed that even relatively modest improvements to the structural integrity of owner-built houses could result in significant reductions in expected fatalities[4]. Simple structural improvements within the technical capability of village builders, like constructing timber ringbeams and increasing the connections of roof members to improve structural continuity would considerably reduce the likelihood of collapse of weak masonry buildings. These low-cost techniques were constructed in trials by village builders and tested under dynamic loads. A major improvement achieved was the length of time that the building could withstand shaking before collapse, improving the chances of occupants escaping before collapse and making the building considerably less prone to collapse in lower magnitude events and at moderate intensities.

The performance of improved weak masonry buildings would make a considerable impact on expected casualty levels over, say a 25 year period. Figure 7 shows that if all the traditional weak masonry buildings of Eastern Turkey had a single timber ringbeam, at a cost of an additional 50,000 Turkish Lira (approximately US$100 in 1983), the expected fatalities would be reduced from 8,000 to somewhere in the region of 6,000. The one million houses in the region would all need to be built with strengthening during their initial construction and the additional total capital investment would be 50 billion TL (US$100 million). This means a cost per saved life of around 25 million TL (US$50,000). This cost per saved life would be considerably reduced if the targetting of strengthening was improved. If only half the number of houses, or say, the10% in the most seismic areas were improved and still achieved similar life savings, the cost per saved life would be reduced to half or 10%.

4 Spence and Coburn (1987) and Coburn (1987).

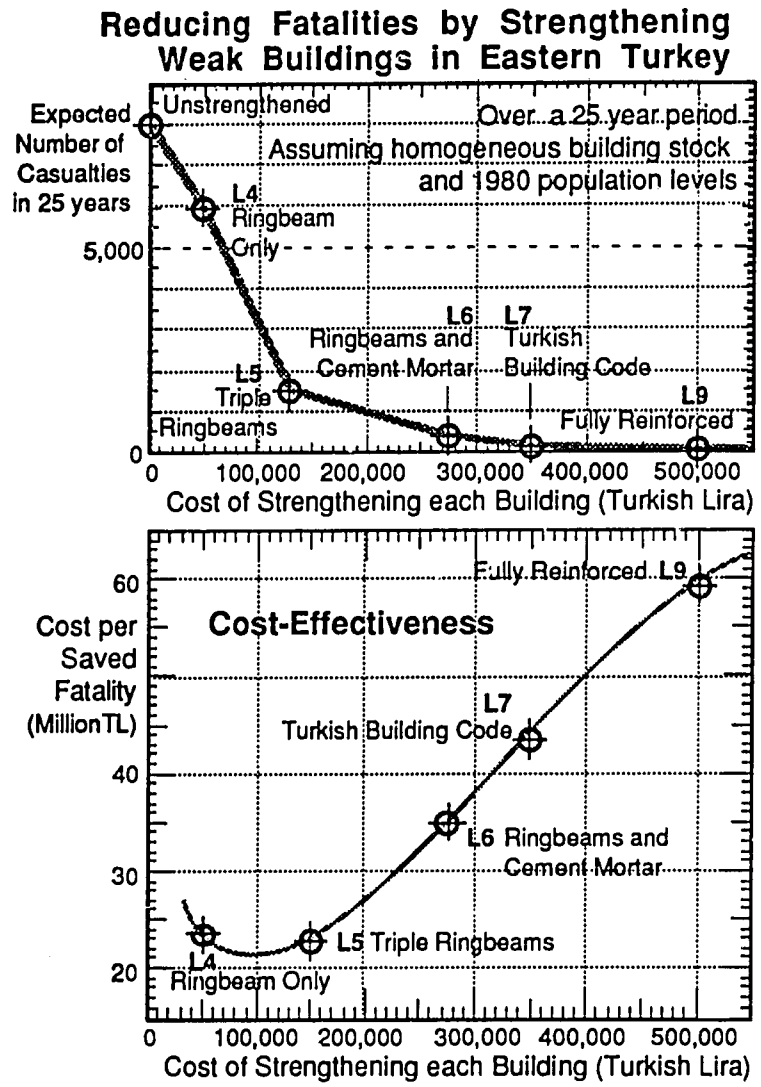

Figure 7
Cost Effectiveness of Building Safer Traditional Buildings in Rural Areas

More savings of life could be made if each building was stronger still. Three timber ringbeams at every one metre height up the wall would tie the structure together even more effectively and reduce expected fatalities from 8,000 down to around 1,500 - a very major decrease - and the cost effectiveness of such strengthening would be even better than the single ringbeam, although the total capital investment needed is almost three times as large.

As the level of strengthening goes up, the buildings become safer and the cost increases. The most cost-effective strengthening measures, measured in terms of the expenditure necessary to save a life, are the lower cost ones, and the better the targetting of structures at risk, the more cost-effective the strengthening measures become.

Village Builder Training Projects

These types of analyses raise a number of questions about what levels of expenditure are justified to save a life, and who should pay. This study in Eastern Turkey.was concerned with looking at the differences between pursuading villagers to protect themselves and pay for their own safety (using public awareness campaigns and builder training programmes) and using government grants or

subsidized materials as an incentive for building strengthening. Building safer has a number of other benefits in addition to saving lives; it reduces the costs of reconstructing houses for the homeless, it reduces losses of building contents and it reduces the costs of emergency relief operations. These expected savings can be offset against the capital costs of strengthening if a case is made for investment in structural safety by the central authorities.

Involvement in a village builder training programme after an earthquake in 1982 in the Yemen Arab Republic[5] - in which many of these low-cost improvements to weak masonry buildings were disseminated and further developed - indicates that outside agencies can, under the right conditions, bring about improvements in traditional building processes. In the Yemen case, no grants or materials were made available but builders were encouraged to pursuade house owners commissioning new work from them, to pay slightly higher costs for adding strengthening to protect their own families. In the first two years of the programme about 40% of owners were successfully pursuaded. Lessons from these and other pilot studies could be used to instigate building upgrading, particularly where the building stock is changing rapidly for other reasons.

The opportunities needed to bring about a higher quality building stock quickly and effectively may be limited. A buoyant property market and booming building industry will mean that buildings are replaced rapidly; the average life of a building is shorter and demand for new buildings is quickly satisfied. A stagnant market means that existing buildings are forced to last longer and population expansion is housed within existing buildings, forcing up occupancy rates.

Reducing Risk in Existing Buildings

Building strengthening costs less and is most easily carried out during the initial construction of a building. However, the problem being faced by many disaster preparedness planners in established cities is that the large proportion of buildings that constitute the risk to the population over the next few decades already exists. Risk reduction in the existing building stock is an increasing subject for concern and the focus of a project in Mexico City[6]. Options available include changing the use and occupancy patterns (see section C below) of vulnerable buildings and targetting buildings for retrofit strengthening.

Retrofit strengthening of existing buildings is expensive. In Mexico retrofit strengthening of buildings costs15 to 40% of the total cost of new construction. It is being carried out to reduce earthquake risk in all major public buildings and government-owned structures. For the wider risk to residential buildings, the key to casualty reduction is the identification of buildings likely to contribute to future earthquake fatalities. Screening of the building stock to target residents most at risk has been carried out in a pilot study which identifies the worst 1%, 5% and 10% of the building stock in terms of its potential contribution to future casualty levels. The concentrations of population in high occupancy buildings in Mexico makes this approach relatively effective. In the event of a severe earthquake, expected fatalities in the pilot study area would be reduced by almost 50% if the worst 5% of buildings had been strengthened, giving a cost per saved life in the order of 11 million Mexican pesos (US$5,000).

This figure of cost per saved life is also dependent on the probability of earthquake occurrence. Such a severe earthquake occurring within the lifetime of the strengthened buildings is by no means certain. Less severe earthquakes are more likely, and an earthquake with a return period of only 25 years would cause less casualties, the strengthening would save the lives of fewer people and so the cost of per saved life would work out at 100 million pesos (US$50,000) or more.

A larger scale programme involving the strengthening of over 10% of the pilot area building stock would reduce expected fatalities by over 80%, at a cost per saved life of 16 million pesos (US$7,000). The total costs of such programmes is high and capital intensive because they involve strengthening all of the worst 5% or 10% of buildings in the city to be effective. Depending on the definitions of worst (which seismic areas it includes and which building types) this may involve many tens of thousands of buildings and billions of dollars worth of investment.

5 Coburn and Leslie (1985).

6 Davis et al. (1989)

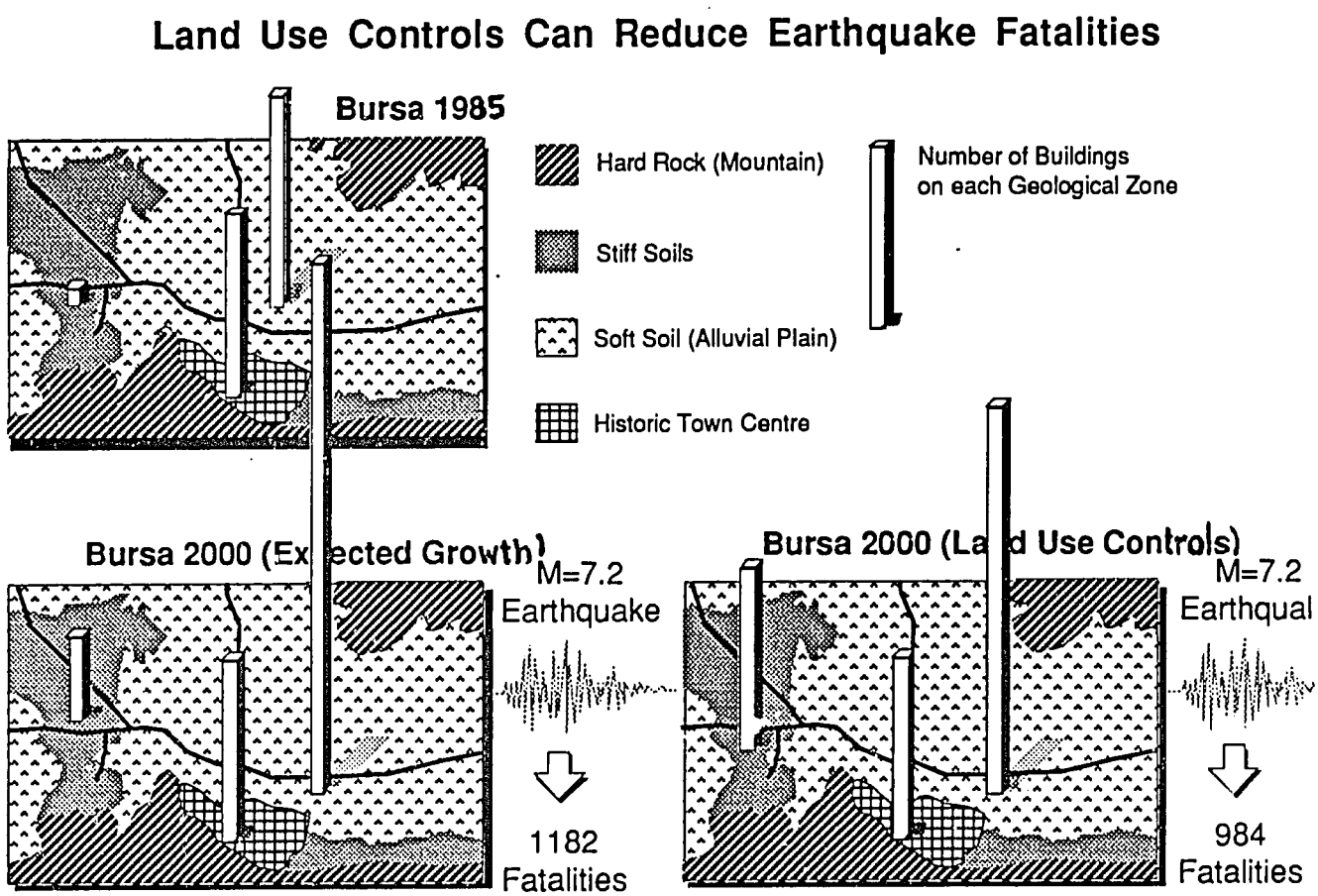

Figure 8
17% Reduction in Fatalities Achieved by Locational Planning of New City Suburbs in Bursa, Turkey

Planning With Limited Resources

To obtain a safer building stock the total capital investment that makes a significant improvement has been shown to be large. This investment has to be found either by the owners of the buildings individually, or by an outside agency - in each case resources are likely to be limited and spending on earthquake safety has to compete with other needs. Some other strategies are less capital intensive and could be considered in conjunction with building stock upgrading to help reduce fatalities.

B. Build on Safer Land

Some types of ground are safer than others in earthquakes. In addition to the numerous ground failures caused by earthquake vibrations, such as landslides, slope failures, liquifaction and rockfalls, it is well known that different types of ground vibrate more severely in earthquakes and so cause higher damage levels to the buildings built on them.

By avoiding building on areas of potentially higher hazard, future earthquake damage can be reduced. This method of damage reduction has the advantage that if locational planning is possible, there is no direct capital investment required to bring about increased safety. There are a number of indirect costs involved - land prices may be higher in one area than another, or there may be increases in transport costs or needs for additional infrastructure - but in many cases the costs can be far less than those involved in upgrading building stock.

The effectiveness of land-use planning for safety will vary considerably from case to case. Different types of ground affected by the same earthquake waves may vary in their severity of ground shaking and consequent destructiveness by a whole degree of intensity. Stiffer soils, like hard rock, may be shaken with ground motion of intensity VIII while softer ground close by, like deep alluvium, is shaking more severely, closer to intensity IX. In this case around 75% of weak masonry buildings built on the soft ground might collapse (see figure 4) killing 14% of their occupants (figure 6), wheras only 40% of the weak masonry buildings built on the rock would collapse, killing 5% of their occupants. There is generally more difference between the performance of different ground types at higher intensities, so for moderate levels of earthquake shaking locational planning is less effective in reducing losses. But where high intensities are expected this could play an important part in casualty reduction.

In a case study of the effectiveness of strategies to reduce losses in the rapidly expanding city of Bursa in Turkey,[7] one of the options considered was locational control over the expected future growth of the city suburbs, illustrated in figure 8. The constraints on development are considerable, but if much of the predicted expansion of the suburbs could be redirected away from their expected sprawl across the alluvial valley, and instead encouraged onto the stiff soils at the neck of the valley floor, the city would be significantly safer against a future earthquake. A magnitude 7.2 earthquake occurring 30km or so away from the city in the year 2000 would be likely to cause an estimated 1200 deaths in the city. If by then land use controls have redirected the expansion, fatalities would be only 984 - a reduction of 17% in life loss. This increase in safety would be independent of any changes in the quality of the building stock, which would of course, give further safety.

Unfortunately the science of microzoning ground conditions and predicting their likely performance in future earthquakes is not yet perfected. Estimates of likely response characteristics of different ground types are only approximate, and detailed knowledge of the sub-strata underneath sites is difficult to obtain. There are only a few places where earthquakes have recurred and where detailed observations have been made of how the ground conditions affect the intensity experienced. In most other places, the detailed effect of ground condition on surface wave severity can only be estimated.

Uncertainties about ground conditions and their likely performance in an earthquake may be too great for major decisions on location to be influenced by seismic safety considerations. The spatial distribution of elements of a city, its infrastructure and facilities is complex and critical for economic and other activities. Earthquake risk may rank very low in the considerations of locational development, but if other things are equal, earthquake risk should be an influencing factor that could make a significant contribution to safety at relatively low cost.

There are a number of other important restrictions to land-use planning as a tool of the earthquake protection planner. The first is that land-use planning is essentially opportunistic: there has to be a need for the location of new buildings (e.g. an expanding city), a choice between areas onto which location is possible, and a difference between the expected earthquake performance of the different areas. The second and possibly greater restriction is that land use has to be controllable. In many very rapidly expanding cities, principally in developing countries, urban planning authorities have almost given up attempting to control detailed land use, because the administrative framework for planning controls is impossible to maintain. The more stable cities, for example in the developed world, have well established planning control mechanisms but the opportunity for changing their risk through land use is very limited because the city already exists and will largely retain its historical layout.

Within existing cities however, other factors may be changed that also may reduce fatality levels in future events. The most important of these is changing building occupancy.

7 Akbar (1989).

The Number of People per House Affects Lethality of Collapse

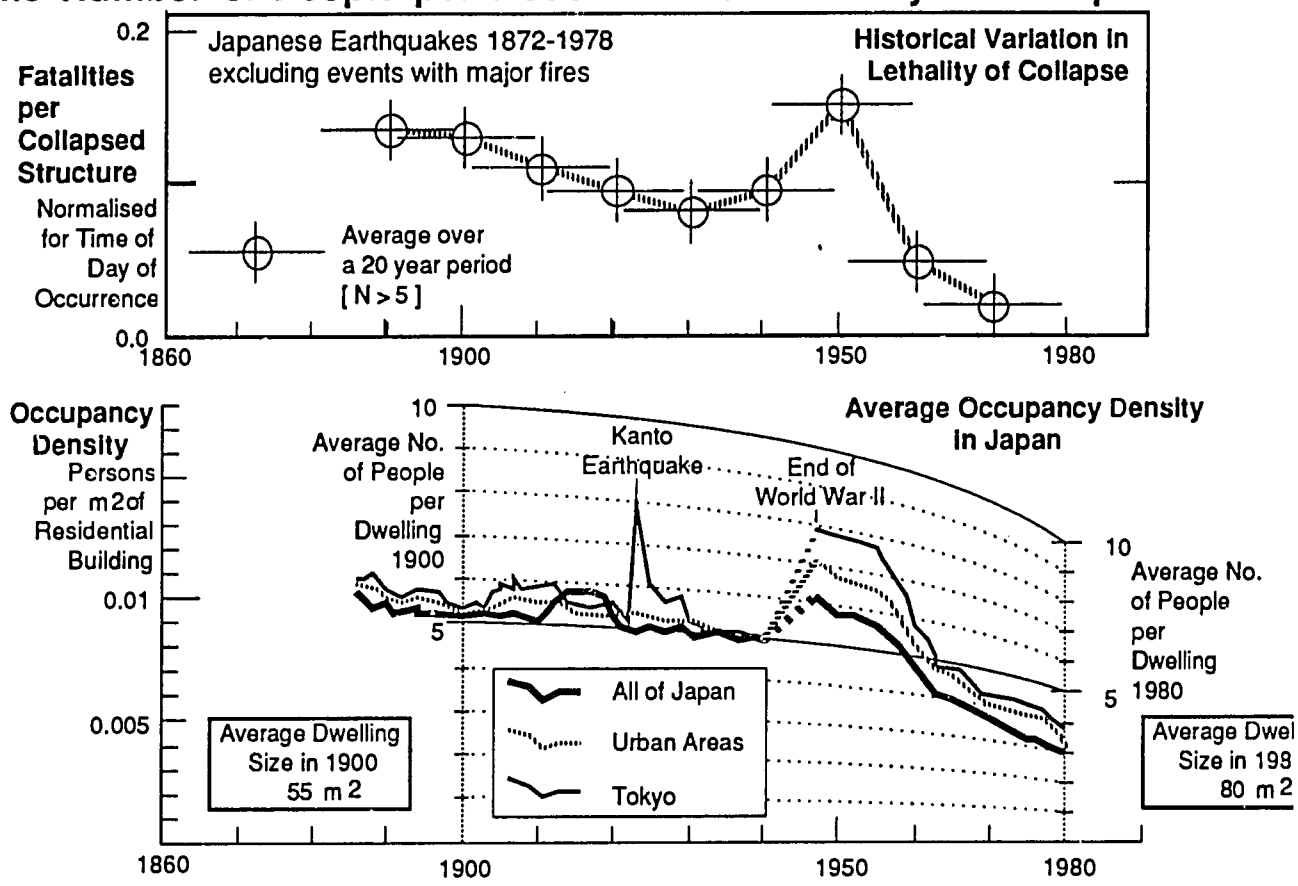

Figure 9
Relationship Between Lethality of Building Collapse and Occupant Density in Japan

C. Reduce Occupancy Densities in Vulnerable Buildings

The number of people occupying a house when it collapses is very important in determining the number of people killed in earthquakes. In figure 9 the number of people killed per building collapse in Japan can be seen to be directly linked to the average number of people living in each house. The increasing safety in Japan is due not only to increasing building quality giving fewer buildings collapsing, it is also due to increasing space standards meaning that fewer people are killed in each collapse.

Occupancy levels are not directly under the control of earthquake protection planners but planners can influence general trends towards higher space standards by:

- instigating safety licences for higher occupancy tenements
- making land available for new housing
- enforcing lower density developments
- encouraging the private sector building industry to participate in housing production through planning dispensations and other incentives
- prioritizing housing among other social services in the public sector

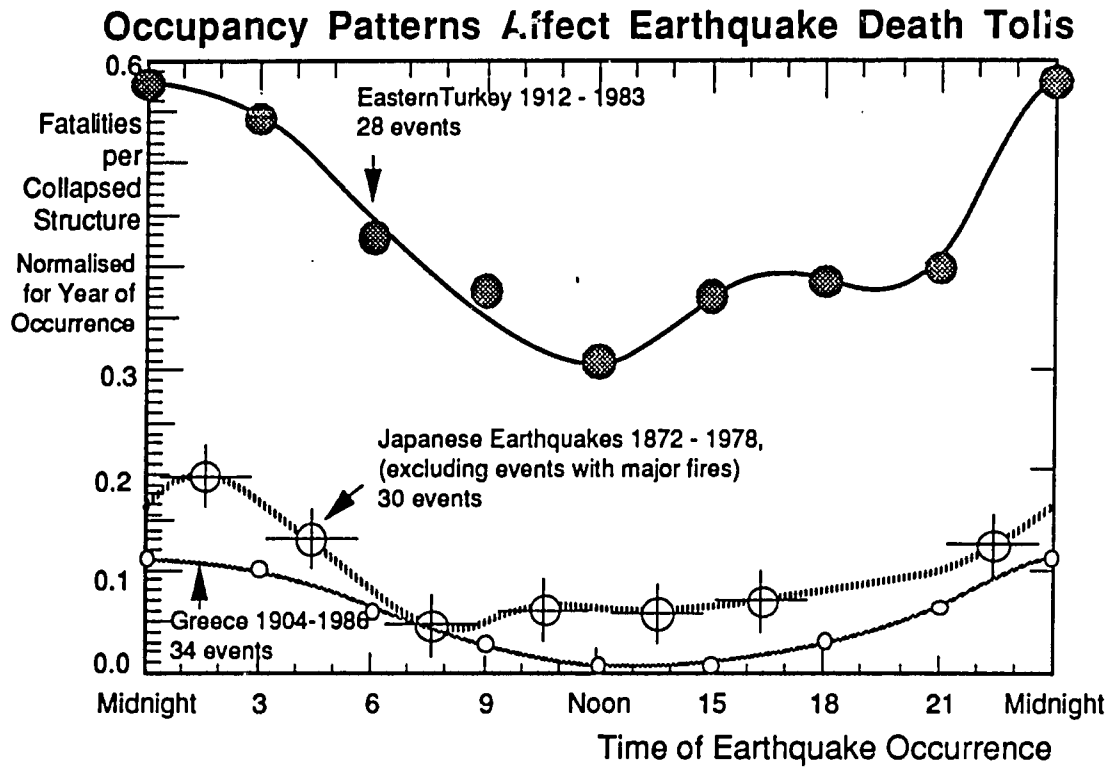

Figure 10
Variation in Lethality of Building Collapse by Time of Day for Three Different Countries

The occupant densities of the most vulnerable building stock should be the priority for reduction, even if it means allowing the numbers of vulnerable buildings to proliferate. From the point of view of minimizing earthquake casualties, 1,000 people are safer living in 500 weak masonry buildings than they are living in 100 weak masonry buildings: At any level of damage less than 100% collapse, fewer people are killed.

The background processes governing residential densities should be understood and in areas of high risk, occupancy levels should be closely monitored. The average number of people who normally share the same roof varies considerably between urban, single-person or nuclear-family-type households and rural, extended families with a large household. At one extreme, the risk of casualties is extremely low in the economically-depressed hill-towns of Greece, where the younger population has moved to the cities, leaving older buildings with very low occupancy, in the order of 0.3 people per house (usually the older citizens). By contrast, the casualty risk is extremely high in regions of Eastern Turkey where families as large as 18 people are found in the same house, running the agricultural domestic economy.

The average number of people inside a building changes through historical trends, demographic change, urbanization, land price increases, sudden disasters, and other influences on the supply and demand of housing accommodation. Some of Japan's most lethal earthquakes have occurred when other events, war bombing or a previous disaster, had forced people to shelter in other peoples houses, greatly increasing the number of occupants per house[8].

If planners are aware of the principle of spreading the casualty risk then density control, influencing space standards and, in extreme cases, rehousing or enforcing changes of use may be extremely

8 Coburn, Ohashi Murakami, Ohta , ibid.

effective methods of reducing potential casualty levels relatively rapidly. Average numbers of people per house varies considerably from one building type or sector to the next. Halving the average occupant density in a region of high seismic risk or in a building type of high vulnerability could half the death toll in the next earthquake. Human occupancy changes much more quickly than the physical building stock, so the timescale over which casualty risk reduction can be carried out is much shorter than building stock upgrading.

There are inevitable cost implications in increasing space standards or reducing densities and the whole process can be seen as part of the increasing standard of living of a developing society. It is easiest to achieve when populations are static and economies are growing.

Temporal Occupancy

The spreading of risk concept also applies to cyclic occupancy patterns during the day, week or year. Occupancy patterns change during the day and seasons of the year according to the people's cycle of activities. Typically, an earthquake occurring during the night is likely to catch more people indoors than an earthquake during the day. Studies of variation in lethality ratio in earthquakes in Japan, Italy, Turkey and other countries according to the time of day of earthquake occurrence have shown a good correlation with surveyed population activities and building occupancy, shown in figure 10.[9]

This has implications not so much for residential buildings, where occupancy patterns may be unchangeable, but for the types of high occupancy public buildings, the collapse of which would put large numbers of people at risk. Such building types may have sporadic occupancy, e.g. cinemas, religious congregational buildings, shopping malls, offices, public buildings, or permanently high occupancy, like hospitals, prisons, etc. It is worth noting that in the El Asnam earthquake, 1980, in Algeria, nearly 1000 people out of the 1300 killed in the earthquake were killed in the collapse of a single structure; a shopping mall.[10] Large concentrations of people at certain times in some buildings is a potential source of high casualties. As cities grow, traffic flows and other restraints promote the diversification of travel routines and there are already social trends towards spreading office hours and flexible working time. Some effort could be made to encourage these trends of diversifying time routines for work hours, commuting, shopping, leisure time etc., to try to reduce the peaks of high occupancy and flatten out the casualty risk over time.

Occupancy levels could also be very rapidly reduced, and reduced to very low levels just before an earthquake if it was possible to predict when an earthquake is about to strike.

D. Evacuate Buildings Before it Strikes

There is considerable enthusiasm in disaster planning for prediction of earthquakes and in a number of countries, large scientific research budgets have been devoted to instrumentation and developing seismological prediction techniques. However, prediction of earthquakes has so far proved elusive. Some earthquakes which announce their coming by a series of precursory shocks have been successfully foretold, but the large majority of earthquakes have so far been unheralded.

The theoretical possibility of routine earthquake prediction remains and if everybody was warned in time and evacuated their buildings then nobody should be killed by building collapse: Prediction holds out the possibility of casualty elimination.

9 Coburn, Ohashi Murakami, Ohta , ibid.

10 El Asnam earthquake 1980, fatality report.

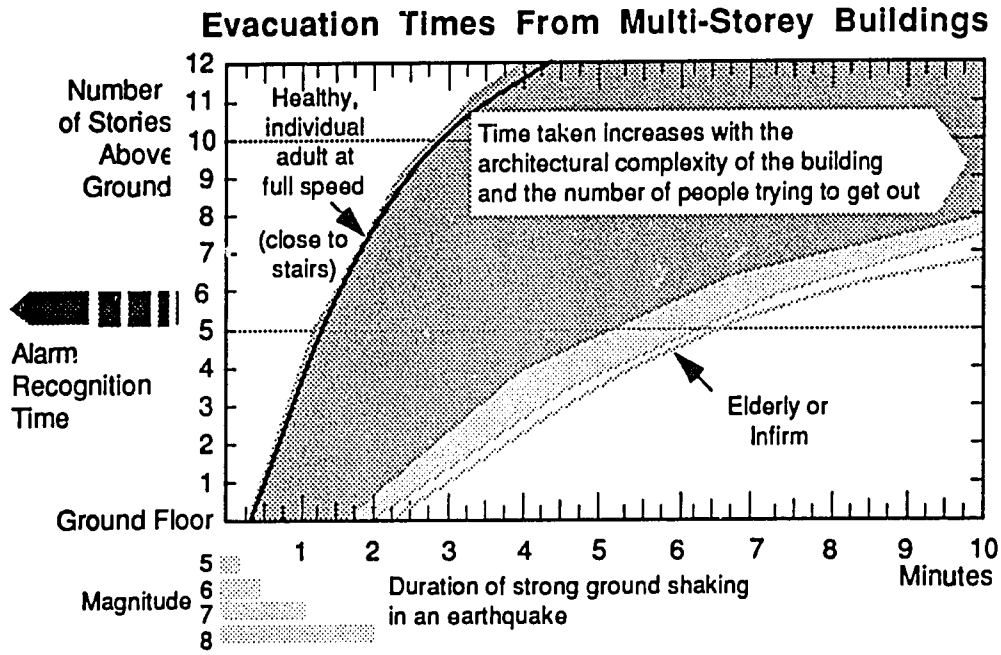

Figure 11
Time Taken to Evacuate Buildings Before an Earthquake [after Georgescu (1988)]

However, the practical problems of prediction, warning and evacuation are considerable and the complete elimination of casualties may be difficult to achieve. The time available before a predicted event cannot be guaranteed. Current procedures established for declaring an emergency evacuation, for example in Japan,[11] envisage a number of hours or days prior warning, time enough to assemble groups of experts for verification of precursory events, make a recommendation to the responsible official and to declare an emergency.

The subsequent time taken to implement the emergency evacuation could be critical. Evacuation times from buildings (figure 11) show the need for considerable periods of notice, even after the prediction has been scientifically scrutinized, a warning issued and that warning successfully disseminated to all building occupants in the affected area.

There have been a few occasions on which a major damaging earthquake has been successfully predicted and an evacuation effected before it struck. The most celebrated of these is the prediction of the Haicheng-Yingkou earthquake of February 4th 1975 in China[12] in which the evacuation of 3 large cities was officially ordered two days beforehand and a quake warning issued in the morning of 4th February. The 7.3 Magnitude earthquake occurred in the afternoon damaging 22 million square metres of property. It killed 1,328 and injured 16,980 people, claimed as the lowest mortality rate (0.02% of population within intensity >VII) in recent decades. After eight months preparation and a full-scale official evacuation, the Haicheng earthquake still killed 1,300 people. The problems of successfully isolating the 6.5 million people in the region away from the possibility of earthquake-induced hazards were obviously immense. The difficulties of practically implementing evacuation plans have been documented.[13]

Even in very successful evacuations, some people remain uninformed, perhaps in isolated communities or out of communication, and some are unable or unwilling to be moved. Often the most

11 NLA (1987).
12 Zhang (1987).
13 Mileti, Hutton and Sorensen (1981).

vulnerable members of the community, the old or the critically ill may be the most difficult to move and there are others for whom rapid evacuation may pose particular problems, like miners, workers in vital services, prisoners, etc.

The organization and pre-planning needs for a successful evacuation should not be underestimated[14]. The scientific investment necessary to make earthquake prediction a practicality will be pointless unless there is complementary investment in warning systems and organization to make a prediction usable.

If an earthquake is correctly predicted and a warning issued then it is likely to save the lives of many of the people who would otherwise have been inside buildings when they collapsed. A warning also gives time to shut down vital industries, prevent fire outbreak, stabilize furniture and building contents, stop trains, assemble and prepare emergency services and many other useful preparations to help alleviate the impact of the earthquake. But physical damage to buildings cannot be prevented, infrastructure cannot be protected, the main cause of economic loss in earthquakes is not removed, and not all people reach safety.

The difficulties of prediction means that many damaging earthquakes will continue to occur unannounced for the foreseeable future. Earthquakes will continue to occur outside those areas where earthquakes are expected to be imminent, so actions to reduce the possible impact of earthquakes must also be carried out outside those targetted for short-term prediction. The fact that short-term prediction cannot reduce the heavy economic impact of destruction to property means that even within the areas targetted for prediction, proper protection for the community must extend further than a few days warning, towards full damage mitigation policies.

E. Rescue More People Alive

Most of the factors examined so far have been conditions prevailing before an earthquake, with a view to examining how mitigation strategies and pre-earthquake planning could reduce casualties. However, most of the earthquakes over the next few decades will occur without prior mitigation work, perhaps even unexpected, and as soon as the shaking stops there will be an urgent need to minimize the life loss among the existing destruction. Effective emergency measures after the impact of a destructive earthquake can save considerable numbers of lives and reduce casualties.

The factors determining the number of people killed after a building collapses are the proportion of people who are unable to escape from the collapse (those trapped by collapse) their injuries and the length of time they are able to survive with those injuries, and how quickly they are able to be rescued and receive medical attention.

Injuries Inflicted in Building Collapse

Different types of buildings inflict injuries in different ways and to different degrees of severity when they collapse[15]. In earthquakes affecting weak masonry buildings, the primary cause of death is often suffocation from the earth used as walling or roof material which buries the victim when collapse occurs.[16] There is also evidence that suffocation is a real danger to those trapped inside reinforced concrete buildings from the dust generated by collapse[17] or from extreme pressures on the chest preventing breathing. Many victims trapped inside a collapsed structure also suffer traumatic injuries from the impact of building materials or other hard objects, and of these the most common appear to be skull or thorax injuries.[18]

14 Spence and Coburn (in preparation)

15 Beinin (1985).

16 Data from Dhamar Dutch Hospital, after the 1982 Yemen Arab Republic earthquake, and interviews with Army Medical Corps in Erzurum earthquake, Eastern Turkey, 1983.

17 See reports of dust adhering to lungs in autopsies from Mexico earthquake 1985, TMG (1986), and causes of death in Veterans Medical administration Building, 1971 San Fernando earthquake, USA, in Krimgold (1987).

18 Data from Ashkhabad earthquake, USSR, 1948, reported in Beinin (1985) and data from Italian earthquake 1980, in Alexander (1985).

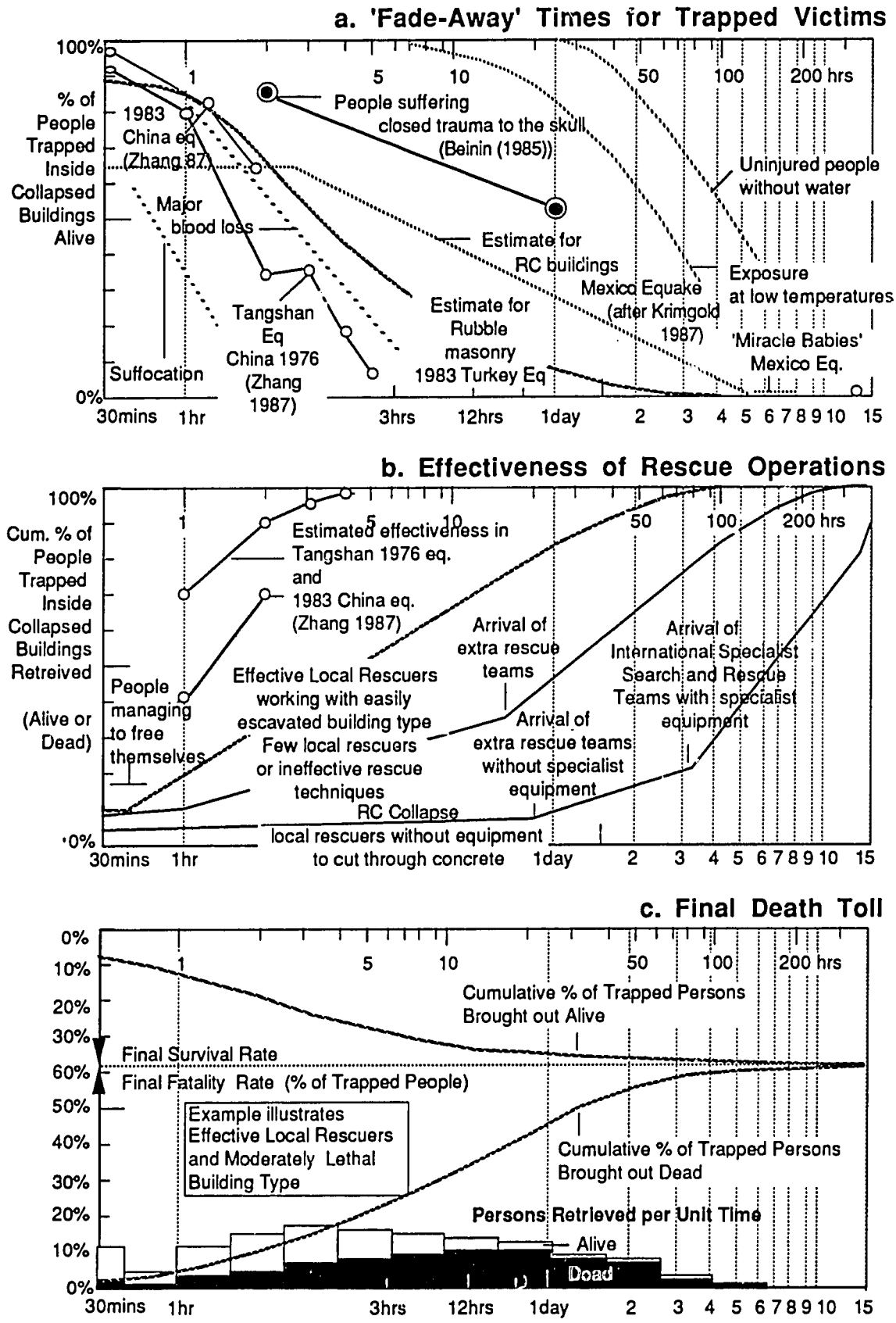

Figure 13

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In some earthquakes, head injuries are by far the most common cause of death.[19] Multiple fractures of the spinal column are commonly reported in many victims of some types of collapsed structures, who were either standing or lying down when the collapse occurred.[20] Extensive spinal injuries of this sort appear to be less common in earthen buildings and associated more with 'harder' building types with more rigid floors and roof slabs.

Another condition reported mainly in the collapse of large, concrete frame buildings is severe crushing of the thorax and abdomen or the amputation of limbs by extreme pressure.[21] Extreme pressures such as these come from large masses bearing down or structural members still connected to the large masses.

'Fade-Away' Time of Trapped Victims

Survival time depends on the type and degree of injuries inflicted by building collapse, compiled in figure 12(a). People occupying the building when it collapses may survive if they are not crushed or suffocated. This depends on the voids that are created within the collapsed structure. How long they survive (their 'fade-away' time) when trapped will depend on their air supply and level of injury. Different construction types, for example masonry and reinforced concrete, have different collapse mechanisms and cavitation characteristics. The void to volume ratio of the collapsed structure and the most likely location of those voids is of importance in locating and rescuing trapped people quickly.

Volume to void ratios are most favourable for reinforced concrete buildings.[22] The total collapse of masonry buildings provides fewer and much smaller cavities within the rubble than in frame structures. In the worst case, a victim may be completely buried by building material. Anyone trapped under a heavy layer of earth or dust is likely to suffocate within hours, if not minutes. Estimates of numbers of people being rescued alive after being buried under collapsed earthen building types in Italy, Turkey and China,[23] indicate that in 2 to 6 hours less than 50% of those buried are still alive.

Injuries received during the collapse of a structure may also be fatal if not treated quickly. Open wounds and internal haemorraging can be fatal within hours without treatment. The recovery of people suffering head injuries is very dependent of rapid medical treatment; data on people suffering closed trauma to the skull shows that about half die within 24 hours.[24] Other serious injuries similarly need medical aid within a matter of hours if the victim is to survive.

Longer term threats to people trapped without injury are exposure if the temperatures are low, infection in wounds, dehydration (particularly if temperatures are high), or eventual starvation. There is also the possibility that less serious injuries may become infected or lead to serious complications, such as 'Prolonged Crush Syndrome'.[25] The length of time that an individual can survive without treatment also depends on their strength and physiology. Older and weaker people are less likely to survive for the same length of time as a healthy, strong person.

The main conclusion from examining survival time is that extremely rapid and widespread rescue of trapped victims is needed to make a major reduction in the number of people killed after the occurrence of any particular event.

19 Analysis of casualties in Papayan earthquake 1983, Colombia, in Gueri and Alzate (1984).
20 Beinin ibid.
21 Mexico City News 21 September 1986
22 Krimgold (1987).
23 Zhang (1987).
24 Beinin (1985).
25 Noted by Kuzin in the Ashkhabad Earthquake, USSR, 1948, reported by Beinin, ibid.

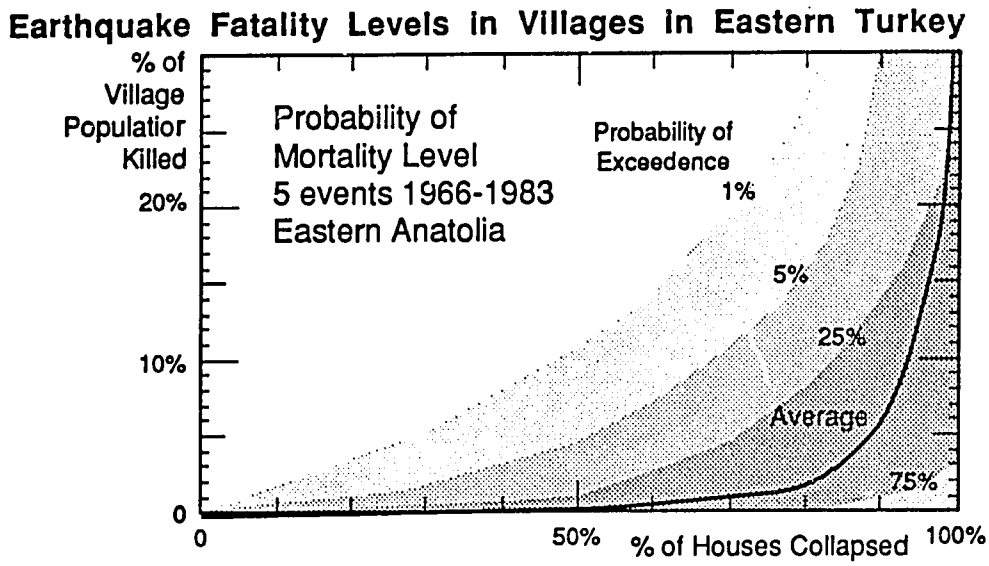

Figure 13
Mortality Levels Increase with the Level of Destruction of the Village, 5 earthquakes in Eastern Turkey.

Speed of Rescue

The speed at which people can be rescued from collapsed buildings is largely a question of resources and their distribution. After an emergency situation is recognized it takes time to assemble and organize rescuers, time to locate a trapped person and time to dig or cut them free from the collapsed building.

The most rapid help usually comes from people already at the scene of the collapse; people occupying buildings that have not collapsed or who have escaped being trapped themselves. It is estimated that 90% of people rescued alive are pulled quickly from the ruins by people on the scene.[26] The more people are immediately available to help rescue trapped occupants, the more lives can be saved. Building collapses kill more of their occupants in communities suffering a high proportion of their population trapped than in communities with only a small proportion trapped; the number of rescuers per trapped person is far greater. This can be seen in figure 13, which shows the mortality levels in villages in Eastern Turkey compiled from 5 earthquake inventories. The percentage of people killed, and the number of people killed per building collapse increases with the level of destruction of the village.

Manpower alone is not the only criterion. Rescuers need to be able to locate trapped people quickly and to free them and possibly to provide medical aid. This requires some basic skills and tools which those immediately on the scene may not always have. The efficacy of rescuers is an important factor; some rescue attempts by inexperienced people may well kill the people they are attempting to rescue. The location of people under rubble and their excavation can be achieved with relatively simple techniques and commonly available tools[27] if the expertise is available.

The equipment needed for rescue is also different for individual building types. The simple tools needed to dig through masonry rubble and to lift timber or steel beams are far more readily available than the specialized equipment needed to cut through concrete and to lift concrete slabs. Reinforced concrete is a very tough material to cut through and recently developing rescue techniques emphasize

26 Krimgold ibid.

27 See techniques developed for rescue from bombed brick buildings by the London fire brigade, described in Coburn and Hughes (1987).

the accurate location of trapped people before embarking on the difficult cutting and excavation exercise.[28]

The specialist skills now employed in location and rescue of victims trapped in collapsed reinforced concrete structures has become the province of international search and rescue teams. The relatively slow speed of deployment of these international teams, often several days before they can get from their country of origin to the site of the collapse, has lead to calls for the establishment of national or local brigades with far faster deployment times, appropriate to the needs of saving life.[29]

The effectiveness of a rescue operation can be measured by the % of trapped people brought out of the buildings (alive or dead) against time. This is illustrated in figure 12(b). The longer the trapped victims survive and the more effective the rescue operation is, the fewer people will die. By combining figures 12(a) and 12(b), the total number of people rescued alive can be estimated, as shown in figure 12(c). This gives a survival rate in terms of the total % of people trapped who survive. The converse of the survival rate gives the mortality rate of those trapped.

The example shown in figure 12(c) illustrates the notional case, shown with heavy lines in figures (a) and (b), of a 100% collapsed rubble masonry village in Eastern Turkey, in which 50% of the village's population is trapped and the other 50% are attempting to rescue them. They manage to dig out half of the trapped people in 6 hours (concentrating on those thay can find alive), 80% after one day and everyone, alive or dead, within 4 days. For the estimated 'fade-away' time of the people trapped in the rubble given in figure 12(a), this results in rescuing alive about 40% of those trapped, so 60% of those trapped died - a mortality rate of 30% of the village. This is approximately the average village mortality level for 100% destruction as depicted in figure 13. If it is assumed that the rate of rescue was somehow doubled, either by making instantaneously available twice as many rescuers or some other improvement in efficiency, then all living victims would be extracted within 6 hours, cutting the village mortality rate to 20% - a reduction in fatalities of a third. In less lethal building types, perhaps high cavitation frame buildings where victims may survive for longer, increases in rescue effectiveness would give better reductions in life loss.

There may be severe practical limitations on improving rescue effectiveness within the first few hours after the disaster. The need to transport large numbers of rescuers very rapidly into the worst affected areas is probably the most severe limitation on improving rescue. If such a thing is logistically possible, it will be expensive to undertake: One characteristic of emergency mobilizations is their expense. The cost of saving life is no longer important immediately after a disaster, but transportation costs, mobilization costs, equipment requisitioning and the loss of economic production by the population suddenly engaged in rescue activities adds up to a considerable total cost. If the cost of international search and rescue teams, flown thousands of miles in specially chartered transport planes, is added in, the cost per saved life in a rescue operation is likely to be far higher than saving life through mitigation actions beforehand.

In a comparatively modest rescue exercise after the 1983 earthquake in the rural areas of Eastern Turkey, handled solely by Turkish civilian and army teams, the provision of emergency rescue and medical services cost the Turkish government US$6.5 million[30]. The mobilized teams are estimated to have rescued around 300 people alive - a cost per saved life of over US$20,000. In urban disasters involving concrete building types and possible assistance from wider afield, the cost per saved life is likely to be very much higher.

28 Krimgold ibid.
29 Krimgold and Coburn, in preparation.
30 Coburn (1987).

Conclusions

	Changing Building Stock	Land-Use Planning	Density Reduction	Prediction & Evacuation	Rescue Effectively
Total Capital Investment:	Very High Cost	Low Cost	High Cost	Moderate	Moderate
Possible Reduction of Life Loss:	Big Reduction	Moderate Reduction	Major Reduction	Potential Elimination	Moderate Reduction
Cost per Saved Life:	High	Low	Moderate	Low	High
Organizational Needs:	Individual Action	Needs effective Urban Controls	Influence Housing Market	Disaster Preparedness System	Emergency Response Organized
Timescale:	Long Term	Long Term	Medium Term	Short Term	Immediate
Reliability:	Certain	Probable	Certain	Possible (poor reliability at present)	Probable
Other Needs:	Buoyant Building Market	Expanding City	Static Population	Technology Skilled Diagnosis Luck	Logistical Wizardry

Table 1
Summary of Strategies to Reduce Fatalities in Earthquakes

Limiting the capability of an earthquake to escalate into a hyper-fatality event is the most important priority for reducing human life loss. It is argued here that even minor improvements to structural safety and emergency preparedness could be enough to tip the balance and prevent casualty levels from rapid escalation.

Targetting is the key to effective casualty minimization. Efforts should be made to target actions on vulnerable building stock, concentrations of population and high occupant densities, by the governments of a limited number of countries, helped by the international community.

The actions that are most appropriate to increase protection levels for communities varies considerably. The direct comparison between the different strategies to reduce life loss presented here, is made impossible by the different circumstances under which they are effective. The opportunities of improving the quality of buildings are greater with a rapidly expanding building stock and high building demand. Improving space standards and reducing occupancy densities may not be possible in such situations. Prediction of earthquakes remains a theoretical possibility. Rescue and medical aid is the only method of reducing fatalities after the event, by which time comparison with pre-disaster measures is academic. Nevertheless there are qualitative comparisons that can be made between the effectiveness, the constraints and other considerations, summarized in Table 1.

No serious mitigation project could be undertaken that did not address the issue of making the building stock safer. Any earthquake emergency will inevitably include attempts to rescue trapped victims to the best capability possible. The other options; land-use planning, density reduction and earthquake prediction are essentially opportunistic - taking advantage of certain conditions that may arise to improve earthquake safety.

In general terms, there is more scope for making large reductions in casualties by mitigation projects before the event than in emergency response afterwards. The costs of saving life may also be generally lower. Any rational plan for reducing the impact of earthquakes would put more effort and

resources into preventative measures than to emergency response. There are additional benefits in attempting to reduce building damage because in addition to reducing casualties, reduced damage levels also mean reduced economic losses, which may be of equal concern to the authorities. Investment in stronger building stock, or land-use planning would take preference over lowering occupancy densities or investing in an earthquake prediction capability for that reason.

A city or regional authority wanting to instigate a programme to minimize casualties in future earthquakes should attempt an integrated set of strategies combining elements from each in the most appropriate mix for their set of circumstances. Optimization of investment strategies for fatality reduction needs study on a case-by-case basis. Seismic risk and casualty risk models are beginning to be developed that should compare and optimize all the range of action available for a given situation. The accuracy and data aquisition needs of such models are the subject of continuing research.

Finally, this paper has taken the view that effectiveness is important in considering casualty reduction programmes. Given the scale of the problem, perhaps a more important priority is simply the need to instigate casualty reduction programmes en masse, whatever their cost-effectiveness and irrespective of their exact achievements. Qualitative findings of research and a number of case studies now exist to provide pointers to the available methods of fatality reduction in earthquakes. It may not be necessary to evaluate them and to have the capability of predicting their result before they are implemented. The international community has a duty to publicize, legitimize and cross-fertilize the mitigation and preparedness actions now being carried out by different communities largely independently of each other. In this way, workshops of this sort may make a genuine contribution to reducing earthquake deaths across the world.

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EPIDEMIOLOGIC CONCEPTS AND EARTHQUAKE INJURY RESEARCH

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On June 12, 1989, we suffered two moderate earthquakes already called the "twin" earthquakes as they were very close in magnitude. But, they were quite different in feeling. The first was a short slam of very short duration. The second, 25 minutes later, was of the more typical shaking variety: unsteadiness for what seemed like a long time. At the time these hit, I was giving a final exam. The students were moderately perturbed but settled down quickly. I was led to a great deal of thought -- we were on the third floor of a twelve story building at the east end of the UCLA Center for the Health Sciences on the lip of a rather nasty fault. The doomsayers foretelling the earthquake to come would have liquefaction of the land on the lip of this fault, purportedly an extension of the Inglewood or "racetrack" fault which bids fair to do us more harm, given an 8+ earthquake, than the San Andreas.

In addition to this unappealing possibility of having the ground turn to liquid under us, I considered that we were in a small auditorium in the center of the building -- no windows, two exits to the surrounding corridor. Presumably the walls were bearing walls (a similar configuration occurs on all the floors). But with Mexico city in mind, I looked about for shelter, in case these two moderate earthquakes were the precursors of a larger problem. I was horrified to find that there was none -- a lectern, a blackboard, and chairs with writing arms comprised the room's furnishing -- no place to hide. Despite the many earthquakes and aftershocks that I have lived through, this was the first in which I had some responsibility for a group,- and felt so ill prepared.

I realized again how important, if thankless, is our varied research into the occurrence of preparedness for, protection during, and rapid response to earthquakes.

Earthquakes are members of that family of what David Koshland, editor of Science calls "Low Probability -- High Consequence Accidents" (Science 28 April, 1989). He was speaking about the Valdez oil disaster, but generously included earthquakes, nuclear accidents and dam collapses. Such events have usually been the province of geologists and engineers, disaster specialists, emergency medical care personnel, search and rescue teams and others concerned with the prediction of such events and management of their consequences.

There is, however, as we have been learning, a definite and important place for the epidemiologist and epidemiologic methods in the study of earthquakes. There is impact on humans against which the individual or population can be protected, events which can be prevented, harms that can be mitigated, persons at high risk who can be identified, environments that can be modified to effect protection and prevention.

There are a number of epidemiologic concepts that are particularly relevant to earthquake injury research. Four of them will be discussed in this paper:

1. Development of an epidemiologic model for an earthquake event.

2. The necessity for definitions of "disease",in this case earthquake injuries.

3. Determination of epidemiologic study designs appropriate to earthquake research.

4. Selection and use of controls (uninjured or unexposed individual) to discover associations between earthquake events, environmental and host characteristics and injuries suffered.

Epidemiologic Model

A model determines how we will direct our attention in research efforts. The apparent chaos of the real world situation requires some organization if we are to be able to sort out the important from the unimportant aspects of the real event. Models may range from the conceptual, perhaps as simple as a verbal description, to the physical, with crude or detailed structures or working parts, to elegant mathematical or statistical descriptions of a system. Models have the advantage of simplification of real world events; the concomitant disadvantage is that we may mistake the simplified model for the real world. Any model we select must be tested against reality and discarded when a better model is found.

Earthquakes of noticeable magnitude are relatively unexpected events -- in fact, except for areas in which earthquake swarms appear (e.g. Howard, CA) or aftershocks following a major earthquake, even in places noted for earthquake activity (e.g. California), earthquakes are rare events. Epidemiologically, they may be regarded as "sources" of the agent of injury. While usually thought of as a model for infectious disease, the agent-host-environment model appears to be very useful in this context, though the exposure is more to an environmental hazard than to a biological one.

Let us cast the earthquake event into this model:

The Agent:

The earthquake itself may be considered the agent. This can be analogous to identifying the charity luncheon or the egg salad as the agent for a food borne outbreak. The problem with this approach is that it fails to identify the organism or carrier. A more useful approach is to identify as the agent the shaking or earth movement associate with the earthquake. This is of a given magnitude at the epicenter. The shaking at parts remote from the epicenter may differ in character and intensity, though they derive from the same earthquake.

Host:

The individual human who may be affected, physically or psychologically by the shaking and consequences of it, is the host.

The Environment:

The environment is the total surrounding in which the host exists. (Buckminster Fuller is reported to have defined it as "everything that isn't me.") It includes the ground that is shaken, the ambient temperature, the time of day, the construction of the

building, the host's very clothing, persons other than the host being considered (themselves potential hosts for study), pets, gas mains, and so on. Each host's environment is unique, and further, is unique for that time. In terms of the environment, damage by one shake that provides a more dangerous environment for the second (e.g. a weakened wall) should be considered a part of the environment for the second shock. This will become important when we later discuss the types of injuries resulting from earthquakes. The environment, then, is the sum of the surroundings capable of impacting the host at the moment the shaking occurs.

Definition of Disease

The second aspect of epidemiology to be discussed here is the necessity for the clear definition of disease. "Verify the diagnosis" is the term taught to epidemiology students as the very first step in investigating an outbreak. But even before verification must come agreement on the definition of the disease of interest. Without a clear definition of what is and what is not included in the "disease" group, individuals with and without disease may be "misclassified". That is, at least some persons with disease will be called free of the disease, some without the disease will be called diseased. This means, depending on the degree of misclassification, that real associations between agent or environment and disease may appear less strong or disappear all together, while possibly some erroneous associations may appear plausible.

The earthquake literature, both popular and professional, reflects a large number of different definitions of earthquake injury based on severity (the more deaths, the less likely we are to be interested in cuts and bruises, leading to a "tip of the iceberg" phenomenon); or based on temporal proximity (anything that happened at the time of the earthquake was "caused" by the earthquake, heart attacks and all) or based on "connectedness" to the earthquake, so as to include post-earthquake injuries to search and rescue workers. None of these definitions are intrinsically unsound, but the use of multiple definitions by researchers makes comparison exceedingly difficult. For example, in our investigations after the Coalinga earthquake, we were anxious to include all possible injuries and earthquake related events. There weren't any deaths. In our work and that of others in Mexico City, the thousands of deaths overshadowed lesser outcomes completely. Recommendations on ways to promote survival or prevent disease might be wholly different given data from the two events.

What shall we use as a definition of outcome in the host following an earthquake? In approaching this, we should ask a prior question: How can this occurrence of an earthquake cause physical or psychological damage to a human?

For physical damage, I suggest, below, several mechanisms (each of which could be divided into innumerable subcategories of action). These mechanisms may be divided into first order effects: injuries as an immediate consequence of the shaking; second-order effects: injuries resulting from the effects (environmental or host) of the initial shaking; and third order effects: injuries or disease resulting from other mechanisms that themselves resulted from the shaking. Both physical and psychological injuries can be subsumed

under this classification, but except to acknowledge the importance of psychological effects and the research needed, I will confine the discussion here to physical injury, ranging from a small cut or bruise to death.

First order effects would include any injury that occurs essentially during the shaking. This may be a new occurrence -- "killed in truck hit by falling freeway overpass"; "leg broken when hit by moving desks"; "buried by collapsing wall". Or it may be an exacerbation of an existing condition -- heart attacks for example.

This category will include the bulk of injuries, and deaths. Most researchers would include the new occurrences, though there might be a difference of definition based on the severity of the event. Some might question the inclusion of exacerbations, however.

Second order effects are still associated with the shaking and its consequences, but less immediately. These injuries might include search and rescue workers themselves injured by falling walls and settling buildings in the process of rescue of earthquake victims, or householders (or looters) injured while looking for household valuables, or persons exposed to open gas mains or downed live electric wires.

If the investigator wishes to assign secondary injuries as costs of the earthquake, that is reasonable. However, to combine them with the first order effects may affect the consistency of the data, the determination of agent-host relationships and the development of effective preventive measures. For example, individuals engaged in searching rubble or in areas where gas or power exposure may occur may be quite different from the general population, and may also have been among the least affected by the shaking. Their earthquake experience may be very different from that of those sustaining first order injuries.

Third order effects are even more remote from the shaking and are indeed separate events that are indirect consequences of the earthquake. Examples of these would include injuries from fire where water supplies and fire fighting equipment were unavailable because of the earthquake, or disease brought about by a collapse of sanitation, or effects of critical lack of food and other supplies. Again these injuries and diseases may be attributed to the earthquake, but should be separated from first and second order effects in analysis.

The criteria for earthquake injury should be carefully determined by the investigators and fully described in publications. The investigator's criteria may or may not concur with those of media or even with those of other investigators. The purpose of different investigators and the specific research questions may call for different criteria. If external criteria are developed, possibly as a consequence of workshops such as this, the researchers should be free to subdivide within categories, or add categories, while retaining compatibility among studies.

Epidemiologic Study Designs

Epidemiology offers a number of study designs to explore or determine

the relationship or association between independent (agent, environment, host characteristics) and outcome (disease, injury, condition) variables. These are:

Case study - a usually detailed study of the circumstances and characteristics of an individual who is diseased (see disease definition above). Each person found to be diseased may have a case- study done. Case studies tend to be done individually and may not adhere to a standard common protocol.

Descriptive study - A research design in which the population as a whole and the population affected (e.g. diseased) are studied. Rates of disease for the population are determined. Subdivisions of those rates for limited information known about both the population and those affected may be made. Examples of this would include geographic subdivisions or age subdivisions.

Ecologic study - This is an extension of the descriptive study in which comparisons are made between the populations that differ in some important respect. It is assumed that the differences observed in the populations are also present in the affected individuals in those populations. For example, in comparing lung cancer death rates according to per capita cigarette smoking in different populations, it is assumed that the lung cancer victims smoked at least their per capita share. This may lead to ecologic fallacy (i.e. the relationships observed at the population level may not be true at the individual level). We have other reasons to believe this is true, but cannot demonstrate it solely on the ecologic study.

Case-control study - In this research design, persons who have the disease (injury) are identified. A control group of persons who do not have the disease is also identified, using various selection methods. The cases and controls are compared for exposure and for host characteristics. Case-control studies tend to be inexpensive, and quick, to have a fairly small group of subjects, and to be especially good for diseases that occur infrequently.

Cohort study - This research design requires identification of exposed and unexposed individuals, or a population that includes a spectrum of exposure or that can be expected to experience a spectrum of exposure. Baseline exposure data is obtained, and occurrences of disease noted. Cohort studies are quite large in scope, continue for lengthy periods, are quite expensive and of very little use in the study of rare events.

Historical cohort study - Because this type of study deals with exposures and events in the past, it is less time consuming and costly than the concurrent cohort study, and, by selection of appropriate controls for exposed individuals (see below), can be used to study rare events.

Intervention study - This is the true experiment. It most often is planned, but there is occasionally an opportunity for what is called a

"naturally occurring" experiment. The experimental study of earthquake injuries should not be overlooked, but is not usually feasible.

There are, typically, two kinds of studies of earthquake injuries. The first is the case study described above with a detailed study of injured individuals and, to the extent possible, of those killed. In general, the more sensational a news story, the more attention the case receives, so severe injuries, deaths and "miraculous escapes" are well covered. The slight injuries, or the threats that were not fulfilled go unrecorded or even unnoticed. The second kind of study describes the seismic events and gives counts of the injured, the dead, damage and other measurable outcomes. This is the descriptive or the ecologic study.

Case studies are important for a number of reasons. Such studies typically describe the events fully, to the extent of recollection or record available. The case study allows initial assessment of possible specific environmental and host factors apparently associated with the injury. These reports provide clues to follow up in other types of studies. The perception of the environment by individuals experiencing a major or great earthquake offers one advantage to case studies: the incredible memory of the horrible slow motion helplessness during the shaking. Most of those to whom I have talked who endured the February 9, 1981 earthquake in Los Angeles (San Fernando), myself included, can still recite virtually every moment of the shaking, our own responses and those of others. This "slow motion" phenomenon may account for the common reports of individuals trying to run away, hampered by "rubber legs" or other impediments, either as viewed by themselves or by others.

The second common type of study is the descriptive or ecologic study. In these studies each earthquake is taken as a whole and the events associated with that earthquake -- temporally, geographically, environmentally, economically -- are compared with other earthquakes. This is the damage and injury report -- my earthquake was "worse" than yours. (I do recall, after the 1971 earthquake, feeling somewhat chagrined to hear Professor Richter describe our experience as "a major quake but not a great one".) The traditional problems with the ecologic study obtain here, of course, with the possibility of ecologic fallacy.

The ecologic study may be based on excess deaths, self referrals to emergency room and such. The assumption is that these events are all caused by the earthquake, or that some definable excess is. This assumption may have some merit, but we must guard against post hoc fallacy (i.e. that anything that happens after the earthquake is due to it). The situation is even more complicated when "excess events" are considered (e.g. 20% more heart attacks than usual). This may fit our definition of an epidemic (more cases than expected), but there are serious problems in defining the variability for a normal day and in identifying which events are the normal daily ration and which are the excess attributable to the earthquake.

The ecologic study has its place, especially in identifying the personal, social and economic costs of the earthquake, but does not serve to answer our research questions that might lead to protection, prevention and

appropriate response.

Controls

Controls are essential for most epidemiologic studies. We believe that disease is not randomly distributed in the population. Therefore, persons who have disease (cases) should differ in some exposure, environmental or host characteristics from persons who do not have disease (controls). Persons who have certain characteristics, or are exposed to particular environments or agents (exposed) should differ in disease from those who did not have such exposure (controls). Persons who are randomly assigned to some treatment, or exposure (treated) should differ from those not treated, treated with placebo or not exposed (controls). These persons, identified as controls can be compared to the cases (diseased, exposed or treated, depending on the research design) and associations between disease status and exposure determined.

If we are to make determinations that will alter or enhance education, structural design or building codes, or lead to planning and maintenance of emergency response, then we must be more cognizant of the environmental milieu and the characteristics of individuals as they may differ for those who are and are not injured. We want and need the exquisite details of these case reports, coupled with the population based over-view of the ecologic study. We can achieve this by finding controls for the injured and doing similar detailed studies of those controls.

The characteristics of the controls to be selected will depend on the research question to be asked and the type of analytic study to be done. One, of course, thinks immediately of the case-control study. Earthquakes are rare events, earthquake are even rarer. We have today had numbers of the order of 0.34 events per 100,00 persons given to us. Thus, the case-control study, based on the identification of ill versus not ill, afflicted versus not afflicted, may seem the only possible design. The questions we can answer with this design will relate to the level of shaking, the environment and the preexisting characteristics of the host (age, sex, handicaps, etc.). We should not, however, overlook the opportunity for an historical cohort study, where particular exposures are identified and unexposed controls rather than uninjured ones are selected. The opportunity for an experiment may be presented by programs of retrofitting, educational programs or other inter-earthquake activity that may affect injuries. Communities rather than individuals would be the subjects of study.

Controls - Selection

It appears that the inclusion of controls in our earthquake research allows us to take full advantage of the excellent case study data while comparing exposures and characteristics of the injured to those in the population of which the injured are a part. However, the selection of appropriate controls is one of the most difficult tasks in epidemiology. There are many approaches to this problem.

Occasionally, the whole population is small enough to allow follow-up and questioning of everyone. Thus, no specific controls need be selected;

they are, effectively, naturally occurring. We have had the opportunity to use this type of control in building studies, particular in connection with the Imperial County quake. Virtually everyone in the building at the time of the earthquake was known, was available, and was interviewed.

Sometimes group controls become available, again particularly in building studies, where one building and its occupants are damaged, while nearby, similar building and its comparable occupants are not. Again, though one may need to detail the similarities of buildings and occupants, the problem of specific control selection is avoided.

In an earthquake study, any opportunity to sample the total community is severely limited, especially if there is major damage and disruption. In a small community, such as Coalinga, some such sampling was possible and was done for an ancillary study, providing a special set of controls for the injured. This population sample provides an excellent control group; the availability should be investigated.

More often, controls must be selected on the basis of usefulness, feasibility and availability. They are usually selected with respect to a particular case (injured person), possibly by address, driver's license number or any identifying mechanisms, or by geographic location, age or other specific matching criteria. It is this matching that causes a great deal of trouble in the selection of controls.

Selecting particular controls, rather than limiting or sampling the population in some way, effectively removes the opportunity to represent the population through the control group. We must then turn to another model for the control, that of replicates who differ in their injury status, but are similar in other respects. We believe, for example, that the elderly are probably more prone to severe injury than the young. We might, therefore, wish to have controls of a similar age. We believe that different distances from the epicenter and different modes of construction might result in different chances of injury, so we might look for occupants of nearby, similar houses, or perhaps occupants of the same house. There is a better chance for finding a suitable control this way, but there is a problem. The matching variables cannot be used in any analysis -- if we match an 85 year old woman with osteoporosis who was injured with another 85 year old woman who was not with osteoporosis, neither the effect of age or of osteoporosis on injury can be assessed in the study. Attempts to match closely may result in overmatching, leading to loss of valuable information.

In our studies, we have attempted to match for severity of shaking and for age (within broad limits) and sex. We tried to obtain two controls for each case, one a member of the household and the other a person of similar age and the same sex who lived nearby in the same type of house. Ideal, of course, would be a person of same sex and similar age in the same household. However, it is characteristic of at least American family structure that similar-aged adults are most likely to be of opposite sex. Children may be the same or opposite sex, but the age differences, though small compared with differences among adults, may be of major importance in terms of behavior and survival.

Recommendations

We are presently analyzing data from our several earthquake studies. We are incorporating data from the controls as selected, with attention to the usefulness of these controls and the problems associated with recruitment of appropriate controls. While we are convinced that the controlled study will be extremely valuable in earthquake research, we do not have all of the answers, either.

In conclusion, I would propose a number of recommendations for consideration:

1. We should develop appropriate definitions of earthquake injuries, including physical, emotional and social outcomes, for use by earthquake investigators. Such definitions would permit investigators to classify outcomes so that different studies, and different earthquakes, can be compared. The research necessary to develop these definitions can itself lead to new understanding of earthquake injury.

2. We should explore the methodology of the case control (and exposure-control) study including assumptions and control selection for use in earthquake research. We should formalize the approach, specifying the necessary flexibility for such research.

3. We should develop plans for identification and recruitment of controls so that a control group suitable to the particular earthquake can be selected immediately.

4. We should develop a bank of earthquake-related research questions including an assessment of the type, magnitude and extent of the earthquake necessary to answer the question. These questions should be centrally computer accessible so that a quick run would produce a list of potential research questions. A priority for selection should be included, in case more than one research question is applicable to the particular earthquake.

5. We should prepare questions, questionnaires and data collection instruments linked to the various research questions of interest so that they can be accessed immediately and printed out for field use. Especially important is development of a standardized protocol for case-study data collection. Investigators in countries at high risk of earthquakes may wish to prepare translations that would be immediately available. It would be desirable to key the data collection instruments to previously specially developed lap-top or desk-top personal computers for field data entry and preliminary analysis.

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THE PHYSICAL SETTING'S ROLE IN EARTHQUAKE INJURIES

by

Michael E. Durkin, M.Arch, M.P.H.

Introduction.

During the past two decades, over half a million people were killed or injured in earthquakes. Although most casualities occur in buildings, we know little about how physical setting elements contribute to earthquake-induced trauma or how building occupants can reduce the risk of injury.

The study of earthquake injuries and loss is a new field in earthquake research. Although injuries and loss are of major concern to all planners, health providers, structural engineers, and disaster researchers, the field is just beginning to evolve, with new research showing significant findings. The work has moved from rudimentary methods to increasingly sophisticated epidemiological approaches, which need to be synthesized and applied.

During the past six years we have conducted studies of injuries in several U.S. earthquakes and in major earthquakes in Mexico City, El Salvador, and Chile. Our overall purpose is to learn how building performance and specific physical setting elements contributed to earthquake-induced trauma, and how hazard reduction can reduce the risk of injury.

Most earthquake casualties occur in and around buildings. Our past research has documented how elements of specific physical settings (e.g. residential) contribute to earthquake-induced trauma and how building occupants can act in ways to reduce the risk of injury. These studies investigated the risk factors responsible for earthquake injuries in a variety of different building types, different construction types, and different shaking intensities. Risk factors included the physical setting element responsible for the injury, the actions of building occupants, the type and level of building damage, the type and severity of the injury, the medical care sequence following the injury and the short and long term impact of the injury on a case by case basis. We performed retrospective analysis of data on victims collected immediately after past earthquakes. This analysis, involving perspectives and methods from architecture, structural engineering and epidemiology identified patterns of injury and possible associations between specific types of injury and specific physical setting and/or occupant characteristics. These interdisciplinary investigations have significantly increased our data base on human injury in earthquakes and serve as a unique basis for the formulation of building-specific planning, design and occupant response guidelines. Furthermore, we are using this data to provide the basis for establishing the relative contribution of various risk factors to specific types of injuries in specific physical settings.

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Our studies have the following aims:

1. To identify the contribution of physical setting aspects such as structure, layout, and building contents to injury.

2. To identify the contribution of occupant actions and personal characteristics to earthquake injury.

3. To develop conceptual frameworks for understanding the relationship between physical setting aspects, occupant characteristics, and injury.

4. To develop methods (e.g. casualty estimation techniques) to assist earthquake casualty reduction and improve treatment.

Research Approach.

Our studies have evolved to utilize three different approaches. These are described below:

Case Interviews.

Previous investigations of earthquake injuries and fatalities have focused mainly on selected characteristics of earthquake victims (cases) such as age, sex, and injury type - relying mainly on data available in hospital records.

A major problem with this type of research is that it doesn't document the cause of the injury, relating it to the performance of the physical setting. Therefore, the results are difficult to use in predicting future injury rates given hypothetical damage patterns.

To address this problem we interviewed earthquake victims and review hospital records. The interviews greatly enhance the medical record review by collecting data on an extensive set of physical setting and occupant behavior factors that we think are associated with earthquake injuries.

Previous injury investigations focused mainly on the injured. We, however, are interested in building occupant risks, which involves data on the uninjured as well as the injured. To this end we have employed both case/control and historical cohort studies.

Case/Control Studies.

(to be discussed by Coulson)

Historical Cohort Studies.

In this application, the historical cohort approach considers a population group that experienced an earthquake. It attempts to document injury occurrence as related to different types and levels of exposure.

A promising variation of this approach focuses on the performance of a specific building or building type and the fate of its occupants.

We are thus conducting case studies of specific buildings to identify these risks. For example, as complete collpase of and heavy damage to numerous reinforced concrete structures characterized the Mexico City earthquakes, we selected a cross-section of damage levels ranging from complete collapse to moderate nonstructural damage.

Our studies, typically, include a number of variables, such as personal characteristics, location at the beginning of the earthquake, occupant actions and movements, the cause, type, and severity of injury, the search and rescue process, the receipt of medical care, and the longer term impacts of the injury.

Our Mexico City and San Salvador research is investigating, for the first time, critical elements in search and rescue, from the victim's perspective. It is also documenting the relationship of collapse patterns to occupant capabilities.

General Findings.

The earthquakes, studied so far, differed markedly in their damage patterns and consequently in their injury patterns and their implications for earthquake hazard reduction. Following these earthquakes we conducted several studies of earthquake victims including the survivors of collapsed structures. These surveys focused on occupant actions, degree of exposure to, incidence of, and severity of injury, and, where appropriate, the circumstances surrounding entrappment.

Our research found numerous implications and applications to loss estimation, earthquake preparedness and response planning. We found distinct injury patterns related to building performance and occupant actions. We found different injury, fatality, and entrappment rates in building collapse. We found that building occupants, even in collapsing structures had the time to and were able to take protective action. In investigating the relative contribution of physical setting elements to injury, death and survival we found that other factors such as the performance of nonstructural elements and building contents played a role in survival and lessening injury. We found that foreign search and rescue teams were largely ineffective. And, we found very high rates of untreated psychological disorders among relocatees.

Findings Related To Building Performance

At least 90% of the injuries that we have, so far, investigated happened in and around buildings.

Construction elements rather than building contents contributed to the overwhelming majority of serious injuries investigated so far.

Numerous injuries were caused by a combination of construction elements and building contents.

Complete building collapse does not result in death for all building occupants. Even collapsed structures can have substantial numbers of survivors.

Three reinforced concrete buildings investigated so far had gross survival rates of 24%, 46%, and 73% respectively suggesting that collapse patterns affect survival rates.

Building elements and building contents clearly play a role in life safety by preventing complete collapse.

When reinforced concrete buildings collapse, structural elements, and building contents often interact to form space pockets within which occupants might survive.

In certain types of collapse, injuries or building obstacles make self-help nearly impossible.

Findings Related To Occupant Performance.

Occupant capability in collapsing structures has not previously been documented. We determined that numerous occupants had both the time and ability to take several actions before the building collapsed.

Similarly, many occupants of damaged buildings that did not collapse engaged in several activities before being injured.

Findings Related To Search And Rescue Management

Most survivors were rescued relatively quickly. The duration of entrapment, in one of our case study buildings, ranged from twenty minutes to seventy-two hours, with the majority trapped under five hours. More generally, 36% of trapped respondents were freed within two hours, and 72% were freed within eight hours.

Most trapped victims were freed by collagues, fellow residnts, or passersby. Only a small proportion were freed by organized search and rescue efforts.

Most of those trapped were freed before organized search and rescue efforts could be launched.

training. Building occupants can be taught to identify possible shelters as well as hazards in the buildings they occupy. The findings also support our contention that occupants can act, and have important implications for training. However, they do not clarify what specific phases or actions helped. We are conducting further investigation of these and other heavily damaged structures to achieve additional results from which such information can be derived.

These data on entrapment and rescue support that view that search and rescue teams play a limited role in saving lives. By the time the teams arrive, especially foreign teams, and have decided on methods, most survivors have been rescued. Both the relatively short duration of entrapment and the frequency of rescue by co-workers, neighbors, and passersby underscore the importance of local resources and training.

The length of time of entrapment is crucial to survivability, especially to those who are injured. It's commonly accepted that twenty-four hours is the cut-off time for the survival of large numbers of trapped victims. Because most residents were rescued quickly, our data do not help answer, at present, a key question: When did the people who perished begin to die? We therefore cannot confirm or refute the twenty-four hour cut-off time for survival.

Finally, these data on entrapment and rescue support the view that search and rescue teams, as presently constituted, trained, and managed, save relatively few lives. By the time the teams arrive, especially foreign teams, and have decided on methods, most survivors have been rescued. Both the relatively short duration of entrapment and the frequency of rescue by fellow residents or other hospital personnel underscore the importance of local resources and training.

Because co-workers, and neighbors perform most of the rescues, training should focus on co-workers for essential rescue activities. This training seems essential to survival. The ways that people are entrapped are important to the possible training needs of co-workers.

The rapid rescues also call into question the potential role of foreign rescue teams. We know that foreign search and rescue specialists do in fact rescue people. Since eighteen of our twenty respondents were trapped under five hours, and all but one under twenty-four hours, a rescue team that arrives twenty-four hours after a collapse is not going to be effective. Consequently, foreign teams (depending on the country) may be more important as purveyors of equipment and technology than of manpower.

These findings underscore the importance of the immediate availability of stabilizing care at the collapse site and the close proximity of definitive care. They also underscore the need to integrate medical assistance into the search and rescue process.

Needed Future Activities.

1. Additional studies of selected building types.

   The location and timing of the earthquakes studied so far limits the generalization of a number of findings to the full range of construction types. Therefore, we need additional studies that supplement the building types already investigated.

2. Loss estimation techniques for estimating earthquake casualties as a function of building damage.

   During the last 10 years, considerable attention has been devoted to developing methods for estimating earthquake losses; however, development has focused primarily on estimating damage to buildings and economic loss ensuing from such damage. Little attention has been devoted to the estimation of earthquake casualties. Significantly, we now have a sizeable data base and methods keyed to it, so that we can make injury estimations less speculative. We need to draw on this previous work to develop a comprehensive earthquake casualty loss estimation methodology that combines the most efficient and effective casualty estimation techniques and the most current theories and data.

3. Anticipated health service demands following a major earthquake.

   We expect that the number of casualties resulting from a major U.S. earthquake will overwhelm surviving local health care services. Anticipated shortages of medical personnel, supplies, and facilities underscores the need to utilize surviving resources as efficiently and effectively as possible.

4. Better earthquake injury surveillance systems.

   Retrospective studies of injuries in past U.S. and foreign earthquakes are denied much valuable information due to the inability to locate earthquake victims. Residential damage and forced relocation compound the case location problem. A system for collecting supplemental information at the victim's first point of contact with the health care system would greatly facilitate such investigations.

5. Cultural and socioeconomic determinants of earthquake injury.

   Many of ethnic minorities occupy seismically hazardous buildings. For example, southern California and other seismically active areas throughout the United States currently have tens of thousands of unreinforced masonry buildings - a building type that has performed poorly in past U.S. earthquakes, and which structural engineers consider a serious threat to lives and property.

Despite their potential hazard unreinforced masonry buildings offer the only affordable shelter for economically and socially disadvantaged residents and marginal minority businesses.

We need to develop earthquake hazard reduction measures that are economically feasible. For example, the complete structural retrofit of many of these buildings cannot be economically justified. Such measures should also be culturally sensitive. For example, there is some evidence that recent Hispanic immigrants, because of their preconditioning in Latin American earthquakes will respond differently than will their non-Hispanic counterparts thereby exposing themselves to different kinds of earthquake risks. Therefore, we should direct research at developing architectural, administrative, and managerial hazard reduction techniques that are tailored to the expected actions of different ethnic minorities.

6. Medical care options at collapse sites.

We need to develop and assess several options for providing needed medical capabilities. Each option should involve a combination of external and internal expertise and resources. The external component includes the deployment of medical personnel and technology for the most efficient and effective coverage of collapse sites. The internal component rests on improving the medical capabilities of laypersons.

7. Training needs for emergency medical responders.

Most earthquake injury victims are first encountered by persons with inadequate medical expertise. This is the case regardless of entrapment.

We need to focus increased attention on the areas of managing rescue operations, training rescuers, including lay persons, in emergency medical care, and integrating emergency medical response and local health care system capabilities in light of expected injury patterns. Specific implications include development of localized search and rescue procedures that are sensitive to the physical setting circumstances of victims, improved light and heavy search and rescue training for corporations and individuals, and improved contingency planning for local hospitals. We need to develop training programs to improve the capabilities of laypersons for providing detection, screening, diagnosis, stabilizing care and to a certain extent transportation.

8. Maintaining hospital operation in earthquakes.

Hospitals are essential facilities following an earthquake. Despite their importance, hospital operations are easily

disrupted by earthquake damage. We need two types of methods to reduce health service disruption following earthquakes. The first type reduces structural and nonstructural damage to facilities and equipment. The second type provides alternative settings for service delivery.

Injury Study Publications and Reports.

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Durkin, Michael E., "The Role of the Physical Setting in Earthquake Damage: The Mexico Experience - Final Progress Report," (El Cerrito, California: Earthquake Engineering Research Institute) (in Press).

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Arnold, Christopher, Michael Durkin, Richard Eisner and Diane Whitaker, IMPERIAL COUNTY SERVICES BUILDING: OCCUPANT BEHAVIOR AND OPERATIONAL CONSEQUENCES AS A RESULT OF THE 1979 IMPERIAL VALLEY EARTHQUAKE (San Mateo: Building Systems Development) August 1982.

PRESENTATIONS 3

A COURSE IN

STRUCTURAL ASPECTS OF URBAN HEAVY RESCUE

JULY 15 & 16, 1989

ROCKVILLE, MARYLAND - VOLUNTEER FIRE DEPARTMENT

PREPARED BY: DAVID J. HAMMOND, STRUCTURAL ENGINEER

ENGINEERING COMMITTEE, U.S.A.R. INC.

This course is intended for use of those dedicated to furthering the knowledge in this area. It may be copied and/or used in part, as long as it is not for the profit of any individual or group.

STRUCTURAL ASPECTS OF URBAN HEAVY RESCUE

COURSE CONTENT

I. Earthquakes & other effects that have caused collapse

Pages: 1 & 2 Visuals: EQ1 Thru EQ10

Reference: Earthquake Country, Sunset Books, Lane Publishing Co.

II. Materials & Basic Structural Members

Pages: 3 Thru 10 Visuals: MTL1 Thru MTL14

References: Building Construction For The Fire Service, 2nd Edition, F C Branigan

III. Building Types And How They Failed

Pages: 11 Thru 15 Visuals: BF1 Thru BF15

Color Slide Presentation

IV. Shores & Shoring

Pages: 16 Thru 20 Visuals: SH1 Thru SH5

Color Slide Presentation

V. U-SAR Strategies - Workshop

No Text Visuals: UHR1 Thru UHR7

Color Slide Presentation

1. URM Buildings
2. Conc. Frame Bldg. - Soft 1st Story
3. Conc. Frame - Pancake Collapse, P-Delta Collapse, and Torsion Failure
4. Precast Building

I EARTHQUAKES & OTHER EFFECTS THAT HAVE CAUSED COLLAPSE

A. Destructive Forces

1. Earthquakes - Shaking effects on heavy and coupled structures
2. Wind - Hurricane, Tornado - Upward and outward
3. Snow / Heavy rain - mostly part roof collapse
4. Problems during construction - inadequate shoring, bracing

B. Earthquake Effects

1. Faulting of ground
2. Landslides
3. Liquefaction
4. Tsunami (Ocean wave)
5. Shaking - the only one we can design for - must avoid others

C. Shaking Effects

1. Caused by body and surface waves - can be complex

   a) Body waves are P (Primary) waves like compression waves and S (Secondary) waves that are side to side and most destructive

2. Can be vertical and horizontal shaking - but vertical shaking usually not as critical
3. Caused by initial violent movement (energy release) of a fault - bigger faults in general more potential energy and damage (See EQ1)
4. Motion can change as it moves thru soil and be amplified thereby causing greater damage to some buildings. In Western US vibrations are damped out in shorter distance than East of Rocky Mts. (See EQ2)
5. Eastern US earthquakes are much less frequent and less energy is released, but could be damaging because of being felt over larger area, and building construction is less earthquake resistant.
6. Intensity = Measure of sharpness of local shaking (EQ3)
   Magnitude = Measure of energy release (See EQ4)
   Duration = How long strong shaking
   Frequency Content = Type of shaking

- 260'

7. Effects on buildings

   a) Magnitude, Duration, fault rupture length related to total energy released (EQ5)

   b) Local intensity may not be related to magnitude

   c) Broad frequency content normally expected in California - can effect many sized buildings - expressed as spectrum (EQ6)

   d) Special effects can occur when softer sites couple with slower frequency of E.Q. motion -
      Mexico City - 1985 - 8-12 story buildings
      Caracas - 1967 - 10 story & 20 story buildings

   e) Building damage is normally more severe in softer soils especially to larger buildings

   f) Structures are loaded vertically and laterally by Quake. Since vertical load systems are designed for more than gravity the additional quake vertical load is usually not critical. Lateral loads subject a building to shear and overturning forces (EQ8)

   g) Odd non-uniform structures perform more poorly than uniform structures. (EQ7,8)

   h) When shaken, buildings that are close together can pound each other causing damage, collapse. (EQ9)

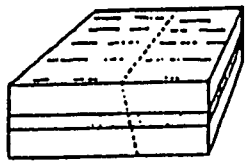
   i) Frame buildings with full basement surrounded by soil tend to suffer most damage above the ground floor and often basement is left as an intact story and possible access for SAR

   j) Failures can progress up or down from damage to primary support member especially in taller precast buildings. See (EQ10)

8. Damage to urban structures can occur from strong earthquakes (Richter Mag 6.5 +) if fault is located near or within urban center, or from Great Earthquakes (Richter Mag.8+) located on large fault.

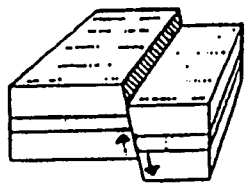
9. Aftershocks - occur after most earthquakes and present a special danger to rescue workers . (EQ7)

10. Most consistent observation is that earthquakes are different, contain complex motion and forces, and normally produce some surprises.



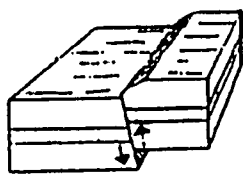
A

Fault, before movement



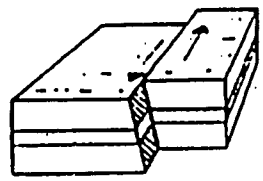
B

Normal Fault – fault surface dips towards downdropped block



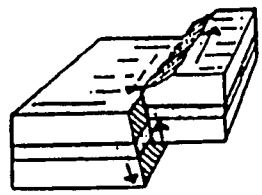
C

Thrust Fault – fault surface dips away from downdropped block



D

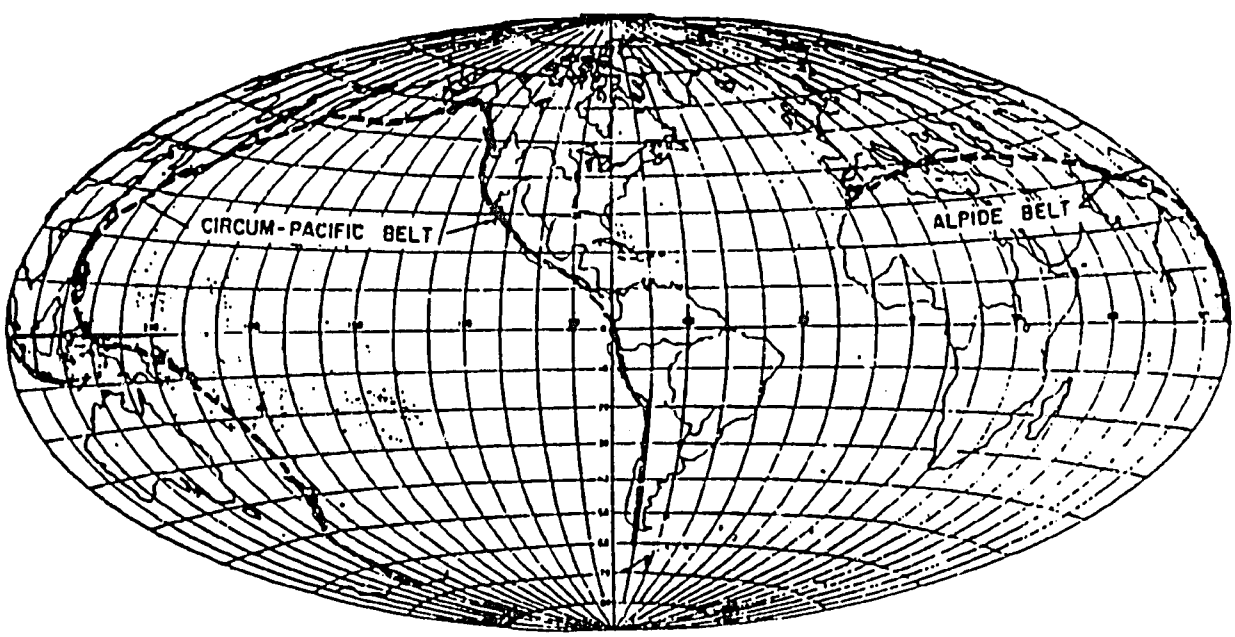
Strike-slip Fault – with left lateral movement (block opposite the observer moved to the left)



E

Left Lateral Thrust Fault combination of C & D This type of movement occured in San Fernando

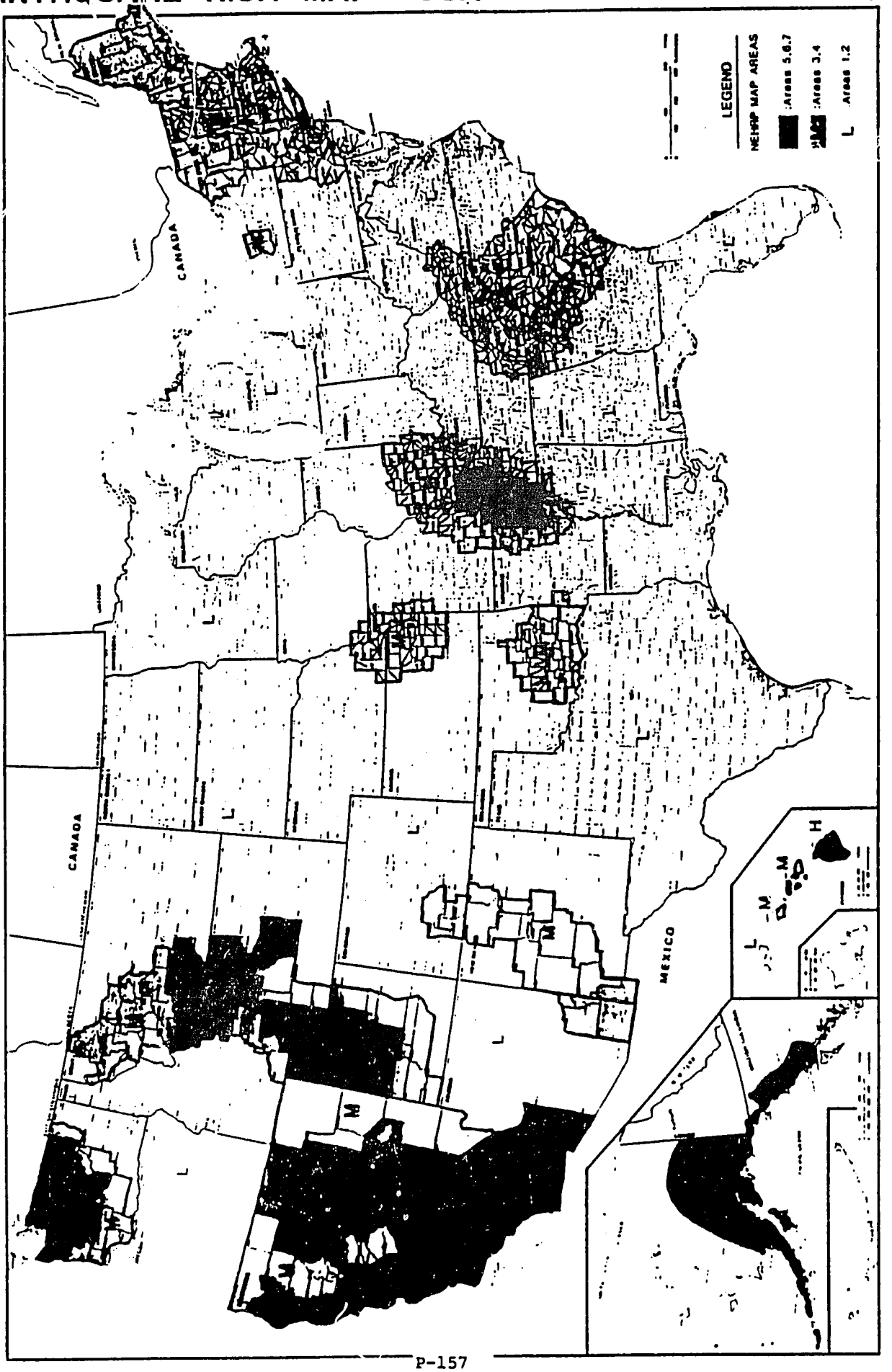
COMMON TYPES OF FAULTS



PRINCIPAL EARTHQUAKE BELTS OF THE WORLD

EARTHQUAKE RISK MAP • USA

EQ 2



-263'

MODIFIED MERCALLI EARTHQUAKE INTENSITY EQ 3

I. Not felt. Marginal and long-period effects of large earthquakes.

II. Felt by persons at rest, on upper floors, or favorably placed.

III. Felt indoors. Hanging objects swing. Vibration like passing of light trucks. Duration estimated. May not be recognized as an earthquake.

IV. Hanging objects swing. Vibration like passing of heavy trucks; or sensation of a jolt like a heavy ball striking the walls. Standing motor cars rock. Windows, dishes, doors rattle. Glasses clink. Crockery clashes. In the upper range of IV wooden walls and frame creak.

V. Felt outdoors; direction estimated. Sleepers wakened. Liquids disturbed, some spilled. Small unstable objects displaced or upset. Doors swing, close, open. Shutters, pictures move. Pendulum clocks stop, start, change rate.

VI. Felt by all. Many frightened and run outdoors. Persons walk unsteadily. Windows, dishes, glassware broken. Knickknacks, books, etc., off shelves. Pictures off walls. Furniture moved or overturned. Weak plaster and masonry D cracked. Small bells ring (church, school). Trees, bushes shaken visibly, or heard to rustle.

VII. Difficult to stand. Noticed by drivers of motor cars. Hanging objects quiver. Furniture broken. Damage to masonry D, including cracks. Weak chimney broken at roof line. Fall of plaster, loose bricks, stones, tiles, cornices also unbraced parapets and architectural ornaments. Some cracks in masonry C. Waves on ponds; water turbid with mud. Small slides and caving in along sand or gravel banks. Large bells ring. Concrete irrigation ditches damaged.

VIII. Steering of motor cars affected. Damage to masonry C; partial collapse. Some damage to masonry B; none to masonry A. Fall of stucco and some masonry walls. Twisting, fall of chimneys, factory stacks, monuments, towers, elevated tanks. Frame houses moved on foundations if not bolted down; loose panel walls thrown out. Decayed piling broken off. Branches broken from trees. Changes in flow or temperature of springs and wells. Cracks in wet ground and on steep slopes.

IX. General panic. Masonry D destroyed; masonry C heavily damaged, sometimes with complete collapse; masonry B seriously damaged. General damage to foundations. Frame structures, if not bolted, shifted off foundations. Frames racked. Serious damage to reservoirs. Underground pipes broken. Conspicuous cracks in ground. In alluviated areas sand and mud ejected, earthquake fountains, sand craters.

X. Most masonry and frame structures destroyed with their foundations. Some well-built wooden structures and bridges destroyed. Serious damage to dams, dikes, embankments. Large landslides. Water thrown on banks of canals, rivers, lakes, etc. Sand and mud shifted horizontally on beaches and flat land. Rails bent slightly.

XI. Rails bent greatly. Underground pipelines completely out of service.

XII. Damage nearly total. Large rock masses displaced. Lines of sight and level distorted. Objects thrown into the air.

Masonry A. Good workmanship, mortar, and design; reinforced, especially laterally, and bound together by using steel, concrete, etc.; designed to resist lateral forces.

Masonry B. Good workmanship and mortar; reinforced, but not designed in detail to resist lateral forces.

Masonry C. Ordinary workmanship and mortar; no extreme weaknesses like failing to tie in at corners, but neither reinforced nor designed against horizontal forces.

Masonry D. Weak materials, such as adobe; poor mortar; low standards of workmanship; weak horizontally.

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RICHTER MAGNITUDE

EQ 4

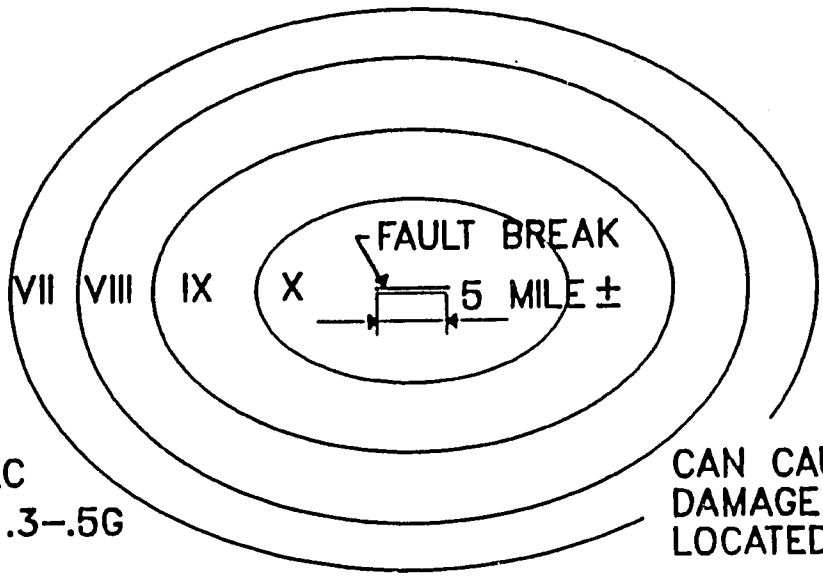
- QUANTITATIVE MEASURE OF MAXIMUM INTENSITY (EFF PEAK ACCELERATION) & TOTAL ENERGY RELEASE – APPROXIMATE
- MEASURES MAXIMUM AMPLITUDE RECORDED ON STANDARD WOOD–ANDERSON TORSION SEISMOMETER
- LOGARITHM OF THIS AMPLITUDE IS CORRECTED FOR THE STANDARD DISTANCE OF 100 KILOMETERS FROM EPICENTER TO SEISMOMETER
- A CHANGE IN RICHTER MAGNITUDE (R. MAG.) OF ONE IS A CHANGE OF 10 TIMES IN THIS MEASUREMENT
- R. MAG. CAN VARY FROM ZERO TO 9 OR MORE
- A CHANGE OF ONE, SAY FROM R. MAG 6 TO R. MAG 7 REPRESENTS A 32 FOLD CHANGE IN TOTAL E Q ENERGY

ENERGY RELEASED BY R. MAG 8 IS 1000 TIMES R. MAG 6

APPROXIMATE RELATIONSHIP BETWEEN MAGNITUDE AND INTENSITY

RICHTER MAGNITUDE	ENERGY RELEASED (ERGS)	FELT AREA (SQ MILES)	DIST. FELT	MAX MMI INTENSITY
3.0 - 3.9	$9.5 \times 10^{15} - 4.0 \times 10^{17}$	750	15	II - III
4.0 - 4.9	$6.0 \times 10^{17} - 8.8 \times 10^{18}$	3,000	30	IV - V
5.0 - 5.9	$9.5 \times 10^{18} - 4.0 \times 10^{20}$	15,000	70	VI - VII
6.0 - 6.9	$6.0 \times 10^{20} - 8.8 \times 10^{21}$	50,000	125	VII - VIII
7.0 - 7.9	$9.5 \times 10^{22} - 4.0 \times 10^{23}$	200,000	250	IX - X
8.0 - 8.9	$6.0 \times 10^{23} - 8.8 \times 10^{24}$	800,000	450	XI - XII

PLAN VIEW OF POTENTIAL CALIFORNIA EARTHQUAKE

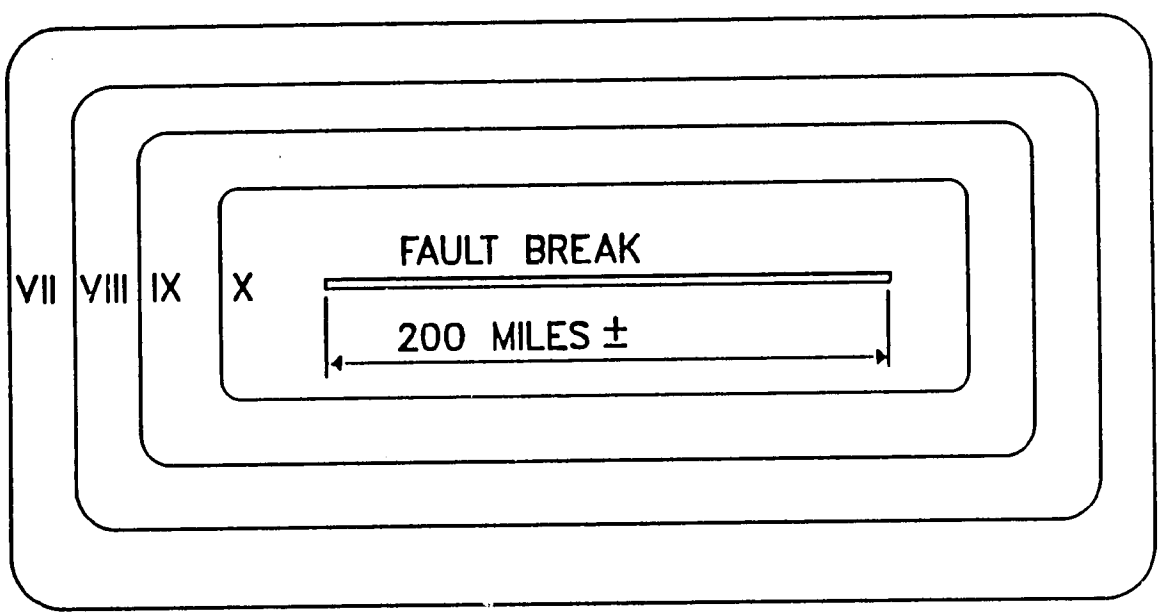


DURATION 5–15 SEC
EFF PEAK ACCEL .3–.5G

CAN CAUSE MAJOR DAMAGE IF FAULT IS LOCATED WITHIN CITY

RICHTER MAGNITUDE 6.5–7.0 E Q

PROBABLE EARTHQUAKE



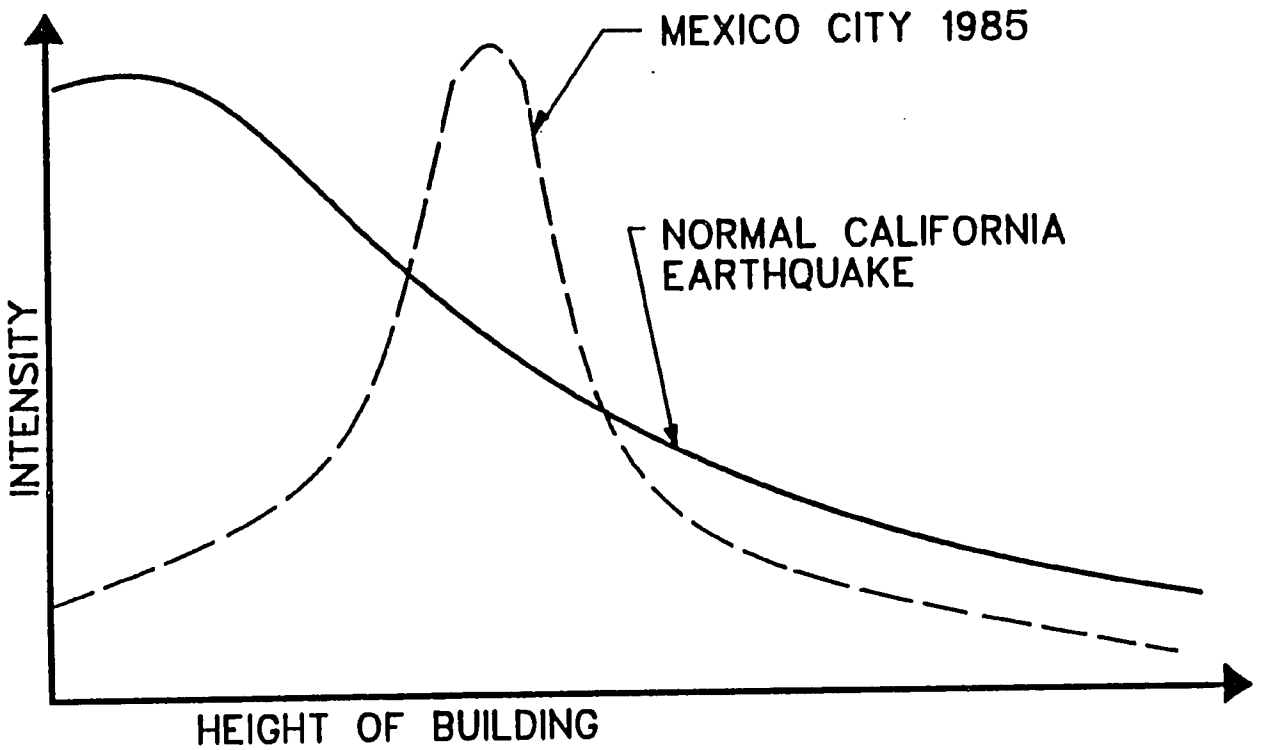
DURATION 30–60 SECONDS
EFF PEAK ACCEL .4–.6G

TOTAL ENERGY RELEASE IS 30 TO 100 TIMES PROBABLE E Q

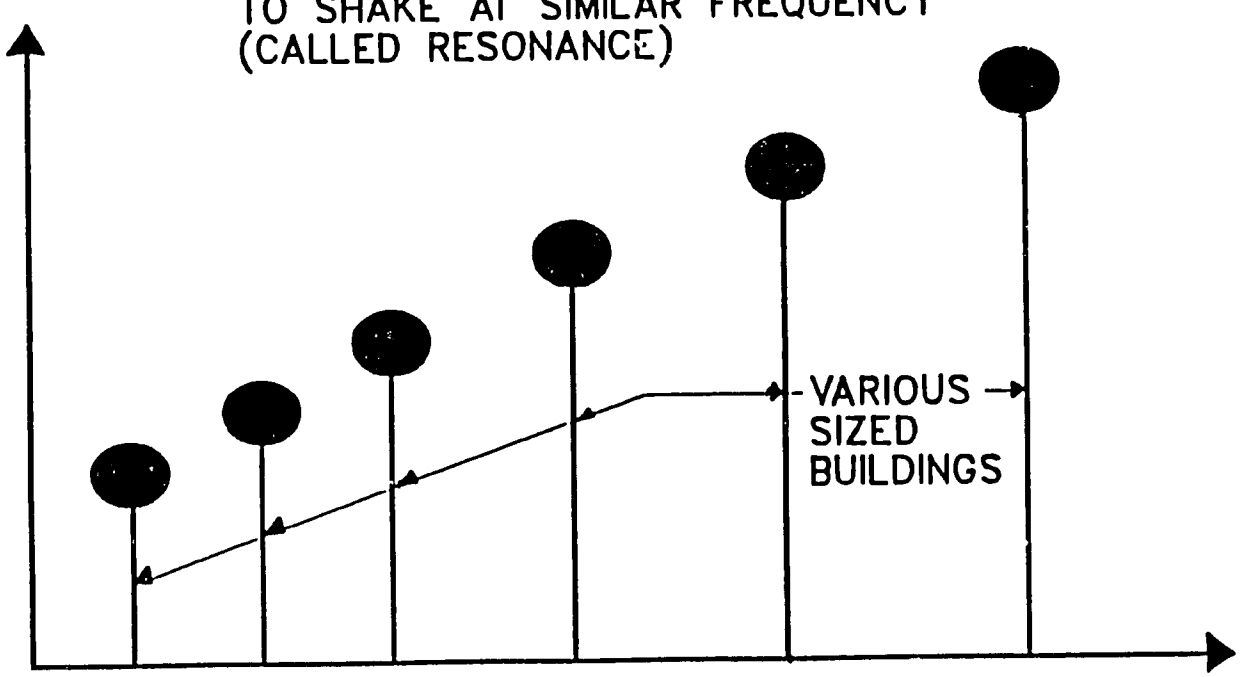
RICHTER MAGNITUDE 8.0+ E Q EQ 5

MAXIMUM CREDIBLE EARTHQUAKE

EARTHQUAKE EFFECTS ON DIFFERENT BUILDINGS EQ 6



CAN HAVE SPECIAL INDIVIDUAL SITE AMPLIFICATION EFFECTS IF THE BUILDING AND SITE TEND TO SHAKE AT SIMILAR FREQUENCY (CALLED RESONANCE)



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AFTERSHOCKS

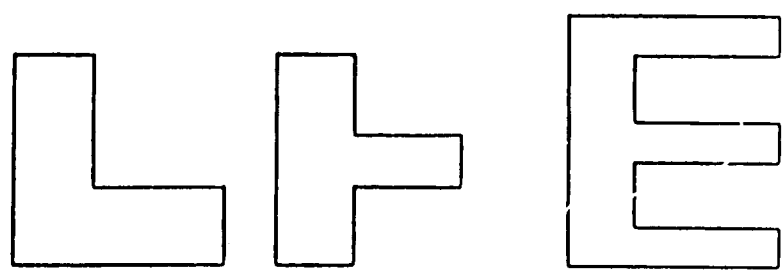
EQ 7

- SMALLER EARTHQUAKES THAT OCCUR ON THE SAME FAULT AFTER THE ORIGINAL QUAKE. THEY ARE MORE MINOR ADJUSTMENTS OF FAULT STRESSES
- WILL OCCUR AFTER GREAT, LARGE, & SMALL EARTH QUAKES UP TO MOUNTHS AFTER ORIGINAL ONE
- CAN BE OF GREAT DANGER TO USAR WORKERS, SINCE THEY HAVE CAUSED PREVIOUSLY DAMAGED BUILDINGS TO COLLAPSE AND RESCUE TUNNELS TO CAVE IN
- THEY HAVE BEEN AS LARGE AS ORIGINAL QUAKE FOR SEVERAL RICHTER MAG. 6 RANGE QUAKES (SAN SALVADOR, N. ITALY, WHITTIER)
- U S G S RULE OF MINUS 1 TIMES 10
  IF ORIGINAL QUAKE IS RICHTER MAG. 7
  THEN EXPECT 1 AFTERSHOCK IN RANGE 6
  10 " " " 5
  1000 " " " 4
  1000 " " " 3

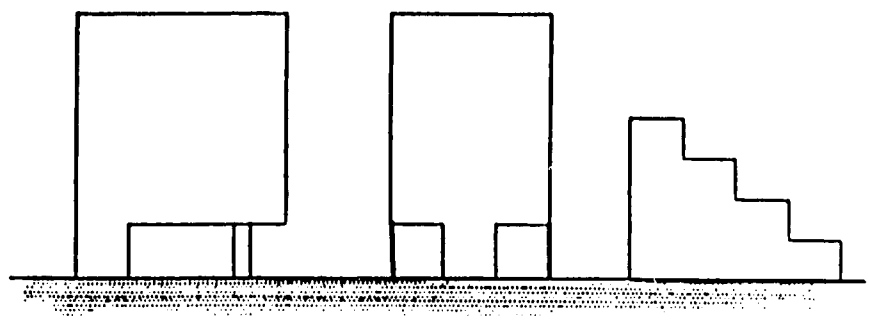
ODD SHAPES THAT INVITE POOR QUAKE PERFORMANCE

- ODD, ASYMMETRIC SHAPES IN PLAN

(ACTUALLY QUITE COMMON)



- ODD, IRREGULARITIES IN ELEVATION



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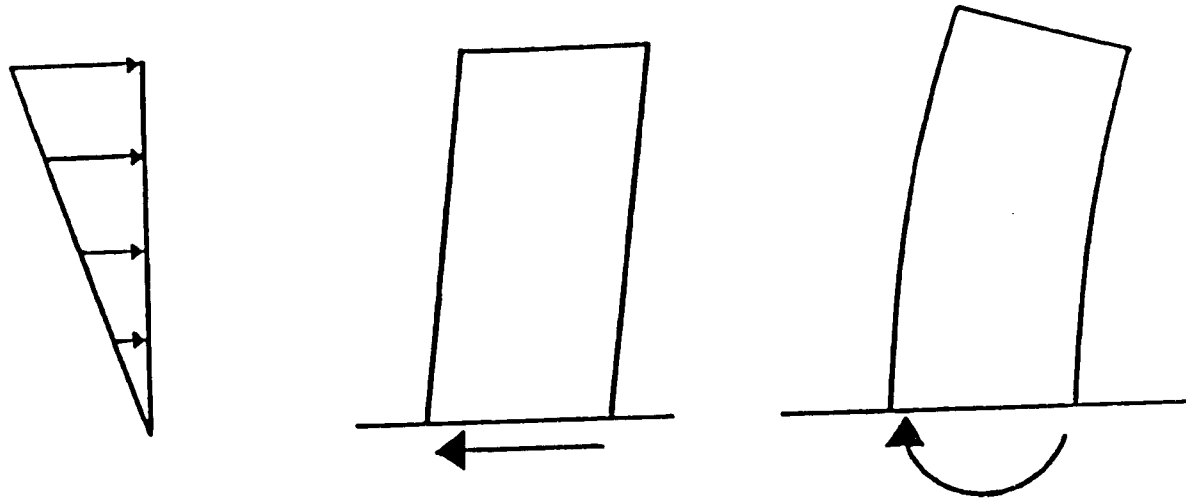
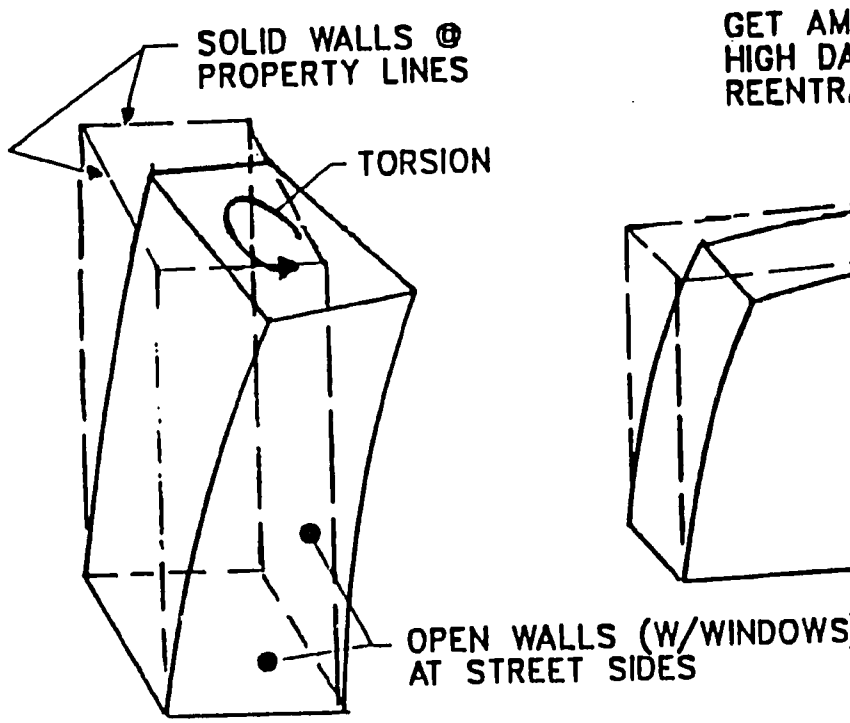
QUAKE FORCES ON BUILDINGS

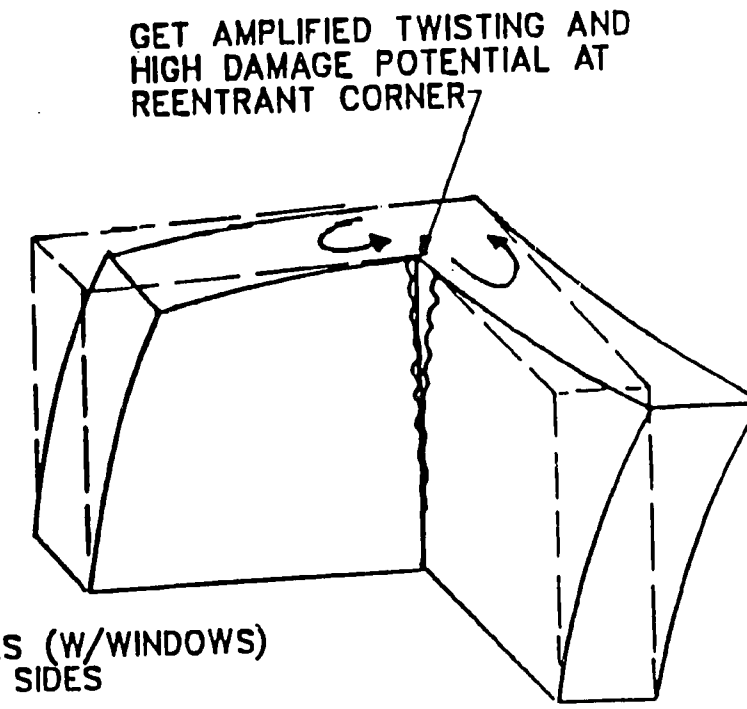


LOAD SHEAR MOMENT

- LOAD REVERSES BACK AND FORTH, AND GET MOST EFFECT FROM QUAKE MOTIONS THAT ARE SIMILAR TO BUILDINGS NATURAL FREQUENCY
- WHEN BLDGS NATURAL FREQUENCY, NATURAL FREQ. OF SOIL UNDER BLDG, AND PREDOMINATE FREQ. OF QUAKE ARE SIMILAR, A DISASTROUS RESULT CAN OCCUR • CALLED RESONANCE



TORSION • CORNER BLDG
(ALSO CAN OCCUR IF ONLY ONE SIDE IS OPEN)



TWISTING OF ODD SHAPE

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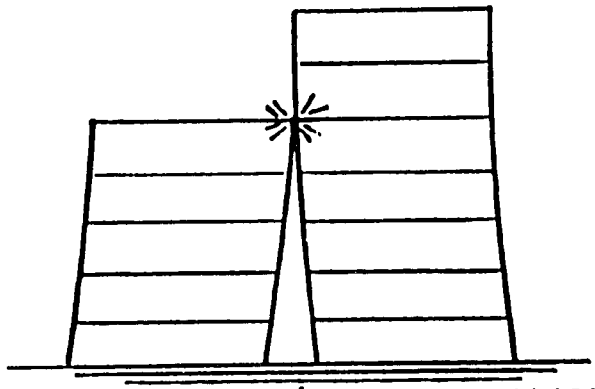
QUAKE EFFECTS ON BUILDINGS

EQ 9

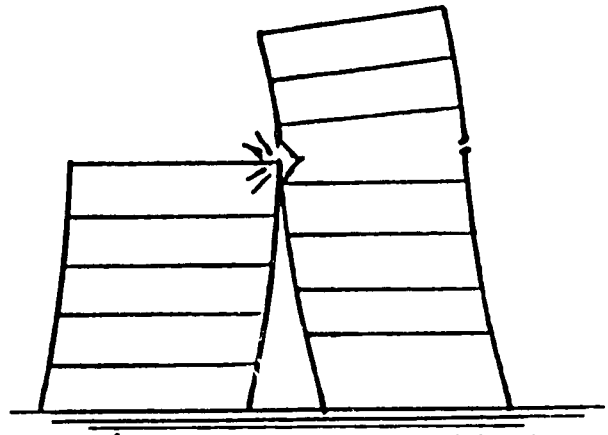
• POUNDING OF ADJACENT BUILDINGS



BUILDINGS W/ FLOORS ALIGNED

CAN HAVE SIGNIFICANT DAMAGE BUT MOSTLY LOCAL CRUSHING AT FLOOR LINE

CAN ACTUALLY BE BENEFICIAL IN DAMPING OUT LARGE OSCILLATIONS THAT COULD CAUSE GREATER DAMAGE

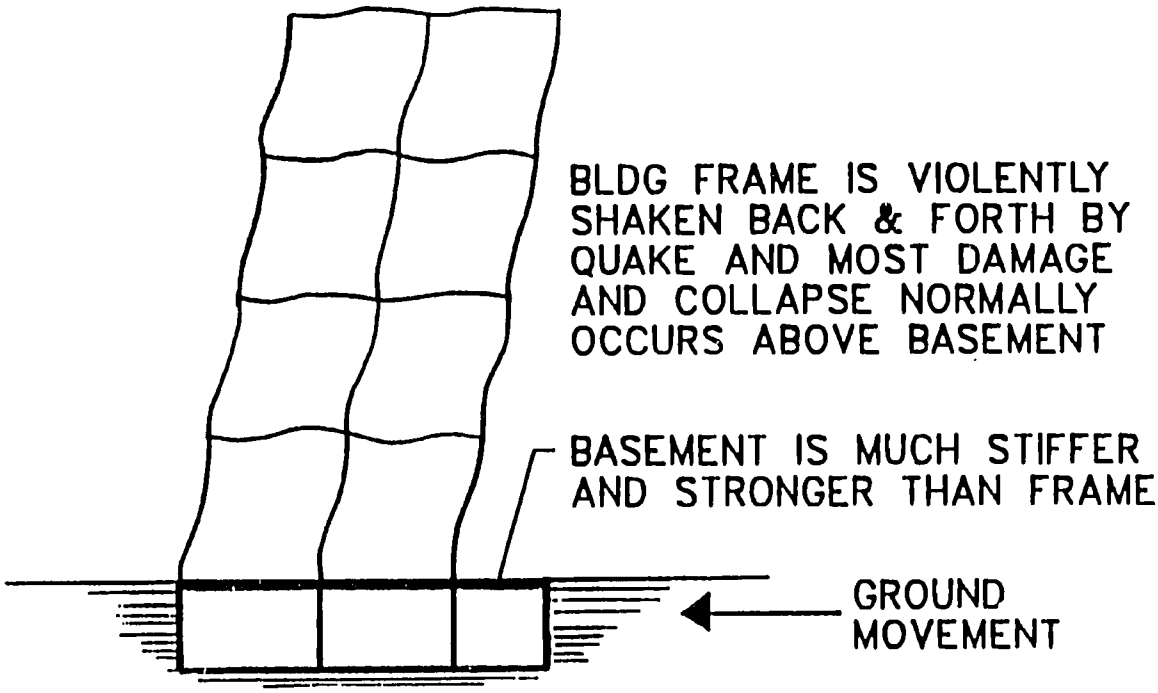


W/ FLOORS NOT ALIGNED

FLOOR OF ONE BUILDING CAN HIT AND SEVERLY DAMAGE COLUMN OF OTHER

UPPER PART OF DAMAGED BLDG CAN COLLAPSE AND EVEN FALL ON TOP OF BLDG THAT HIT IT

• FRAME BUILDINGS WITH BASEMENTS

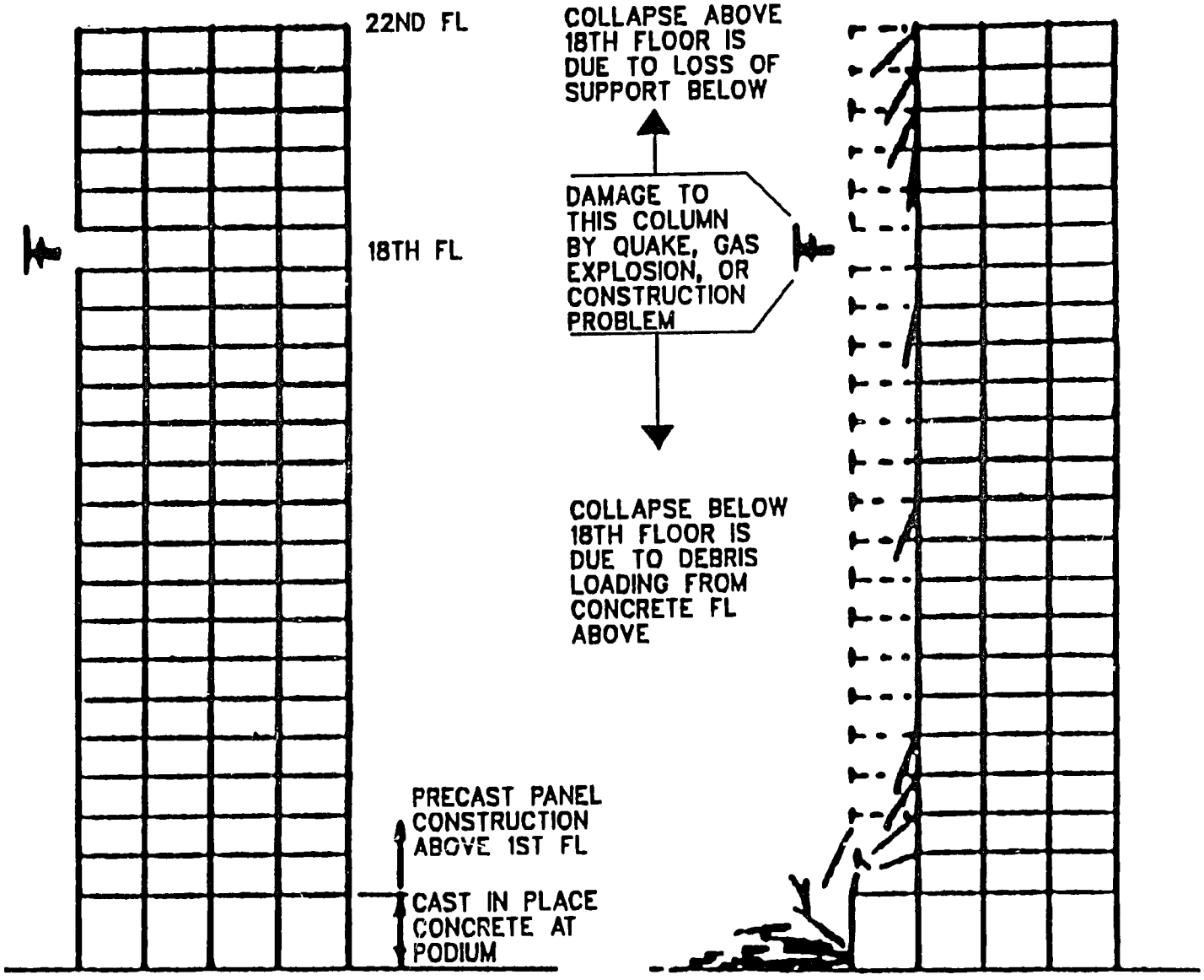


BUILDING WITH BASEMENT

270

PROGRESSIVE COLLAPSE

EQ 10



INITIAL FAILURE OF SINGLE PRIMARY SUPPORT MEMBER

CHAIN REACTION OF FAILURES

-271-

II MATERIALS & BASIC STRUCTURAL MEMBERS

A. Basic Stresses

1. Tension - Stretch member. Get special, desirable ductile action with steel. (See MTL1)

2. Compression - Can cause crushing for fat members or buckling for slender ones. Buckling is more dangerous, since it is normally sudden failure. (MTL1)

3. Bending -

   a) Simple Beams have tension stresses on bottom, since bottom of beam gets stretched. They have compression stresses at top as it gets shorter. (MTL2)

   b) Continuous Beams have alternate tension and compression each side as bending direction changes. (MTL2)

   c) Shear Stresses occur in all beams, and are greatest adjacent to supports. Shear stress can be described as tendency to spin little elements of the beam. In concrete beams these shear stresses develop diagonal tension cracks, since concrete is very weak in tension. (MTL2)

4. Punching Shear - Occurs where a two way flat slab is connected to a column and is the tendency of the slab to drop as a unit around the column as the column appears to punch thru the slab. (MTL3)

5. Bolt Shear - Tendency of pin like connector bolt, nail, screw to break across it's cross section (MTL 3a)

6. Building Wall Shear and Overturning - Lateral forces of wind and earthquake cause shear and overturning stresses. (MTL3a)

B. Materials (See MTL4)

1. Wood

   a) Tough, light fibrous, fire supporting, cut from living trees and graded by humans

   b) Defects like knots, splits and non-straight grain cause stress concentration

   c) Growth pattern - fast spring wood vs. slow summer wood leads to structural problems of weak beam cross grain tension, shear strength and shrinkage

d) Shrinkage, mostly in width/depth, not length causes special problems in connections.

e) Connections should feature bearing but can be bolted - better if nailed with multi-connections

f) Plywood sheathing of wood structures makes them very tough and earthquake resistant.

2. Steel

a) Tough, light, strong, ductile, formable into any shape - needs to be fireproofed - starts to loose strength above 700 degrees Fahrenheit

b) Has almost magical property of ductility. That is, it can be overstressed and severely bent, but still have enough strength to resist failure. This makes the ideal structure in that it gives warning of collapse (has forgiveness).

c) Formed into shapes to make it most efficient

d) Efficiently connected by welding or high strength bolting

3. Concrete

a) Essentially cast rock, strong in compression but weak in tension

b) Need to add steel for tension, often deformed round bars. Also reinforced by pretensioned small bonded bars or postensioned, unbonded 1/2" dia woven cables placed in plastic sheaths

c) Concrete shrinks and cracks and is easily connected together if cast in place

d) Can be precast on site or in factory into wall slabs, beams, tees, double tees, cored slabs etc. Problem then is to competently connect them together, since earthquake forces will be determined by strength of members and ductility of joints.

e) To produce seismicly resistant concrete the rocks and mortar binder must be kept inside the reinforcing bar cages. This can give the reinforced concrete some of the favorable properties of steel and therefore some forgiveness. Most difficult in frame type buildings.

4. Masonry

a) Clay brick or concrete block made into walls with mortar joints (and reinforcing steel in many newer buildings)

b) Highly dependent on workmanship and quality of materials. Older unreinforced masonry walls were built with mortar containing lime cement (degrades with weathering)

c) All masonry and concrete walls are best well tied into roof and floors of building. (Usually are not in older buildings)

C. Structural Members

1. Trusses (MTL5)

a) Usually made from wood and/or steel although concrete has been used in other countries.

b) Consist of relatively slender members that are connected together as a series of triangles.

c) Members are either stressed in tension or compression but sometimes stresses reverse as live load changes.(people, vehicles, rain)

d) Connections are critical and many old wood trusses have problems when splits in wood occur at bolts.

2. Concrete Floor Framing Systems (MTL6)

a) There are many types, but most common are shown.

b) Size and location of reinforcing is outlined in Appendix IIa.

c) All concrete cracks for various reasons. See Appendix IIb.

3. Shear Walls & Box Building (See MTL7 & 8)

a) Flat floor / roof planes, called diaphrams and mostly solid walls make up box buildings.

b) Floor / roof diaphrams are made of plywood, diagonal wood sheathing, corrugated metal deck with and without concrete topping, and concrete.

c) Shear walls are made of plywood, wood sheathing, concrete, and concrete block.

d) Box buildings should have walls on all four sides, but will have openings in them. When properly designed they resist earthquakes well.

e) Most box buildings are 3 stories or less but can be up to 13 stories

4 Moment Resistant Frames (See MTL9)

a) This type of frame is kept from moving sideways (laterally) by the beams and columns being large enough and well connected to form a rigid vertical gridwork

b) Steel and heavily reinforced concrete are used today in successful moment resistant frames.

c) Older concrete frames often don't have enough rebar ties and stirrups to hold the concrete together thru the prolonged load reversals of a large earthquake.

d) It's best to have moment resistant frames through out a building, but they can also be found only at exterior walls.

5. Diagonal Braced Frames (See MTL10)

a) Are most always made of steel and are similar in action to shearwall

b) May be X bracing using slender rods (mostly in older and all metal buildings), but it's better to use larger members like tubes or double angles that resist both tension and compression.

c) It's not umcommon to use moment resistant and braced frames in the same building, as well as other combinations (MTL11)

d) See MTL 12 for comparison of action of Moment Resistant Frames vs. Shear Walls

6. Suspension / Tension Structures

a) More uncommon structures that use height (drape of cable) to produce greater efficiency

b) Earthquake damaged slabs often form tension like structures after failure that prevent total collapse (MTL 13 & 14) This will cause unplanned tension forces in remainder of structure, lean over, but may prevent catastrophic collapse

APPENDIX IIa - REINFORCING STEEL IN CONCRETE STRUCTURES

A. General

1. Reinforcing steel (rebar) is found in some amount in even the oldest concrete structures. Even steel angles were placed in the oldest ones and square bars were used until the 1940's. Deformed, round bars are the most common types to be found and in sizes from 3/8" Dia. to 1 1/8" Dia. In old concrete frames, bars up to 1 1/4" SQ. can be found.

2. The following are generalizations of the most common patterns of rebar used. (One can find exceptions to every given condition)

B. Walls

1. For thicknesses up to 8 inches will have one layer of bars - will occur at center of wall:

   Spacing: from 8 to 16 in. ea. way (vert. & horiz.)
   Size: from 3/[illegible] to 5/8" Dia.

   Bigger bars are normally added adjacent to openings and will extend beyond edges of openings. There may even be diagonal bars at corners of openings.

2. Walls over 8 inches thick should have two layers of rebar, each about 1 inch clear of surface.

   Spacing: each layer 8" to 16" ea way
   Size: each bar each way 3/8 to 3/4" Dia.

   Horizontal and vertical bars in each layer <u>should</u> line up if one is cutting thru the wall. Bigger bars are again added adjacent to openings in <u>ea</u> layer.

C. One Way Slabs - normally span from 8 to 16 feet between parallel beams and are from 6 to 10 inches thick.

1. Normally bars near top and bottom of slabs about 1" clear in each case - bars vary 1/2" to 3/4" Dia.

2. Bottom bars - thru out slabs each way:

   in short direction 4" to 12" o.c.
   in long direction 10" to 18" o.c.

   Bottom bars normally splice at each beam. See (BF8) for how bottom bars bend up to become top bars

3. Top Bars - found centered over and perpendicular to beams and girders. These bars normally don't extend thru out entire slab.

   Bar Size: 1/2" to 3/4" Dia.
   Bar Spacing: 4" to 12" o.c.

   These bars may be supported on spacer bars placed at 3 to 4 Ft. o.c. perpendicular to them. It is not normal for top and bottom bars to vertically align.

D. Pan Joist - deep concrete ribs that are usually about 6" wide and spaced from 24" to 36" o.c.

   1. Bottom Bars - two 1/2" to 1" Dia. bars each rib placed within 1" of bottom. One of the two may be bent up to the top at 45 degree angle within about 5 feet of the supporting girder. (See BF8)

   2. Top Bars - Two to four 1/2" to 3/4" Dia. bars are placed in slab above rib and parallel to it, 4 inches or so apart, and 1 1/2" clear from top Most of this rebar will be within 5 feet each side of supporting girder. Smaller (3/8 to 1/2" Dia.) top bars are placed thru out the 3 1/2 to 4 inch slab at about 12" o.c. each way at mid depth.

E. Two Way Slabs - flat slabs
   (Two way slabs supported by beams, similar)

   1. Normally have bars similar to one way slabs except some top bars may extend thru out slab and will vary. Bars are 1" clear from top and bottom of slab

   2. Bottom Bars -

      Size: 1/2" to 3/4" Dia. each way
      Spacing: 4" to 12" o.c. each way

   3. Top Bars - most closely spaced over columns and placed each way

      Size: 1/2" to 3/4" Dia. each way
      Spacing: 4" to 18" each way

F. Two Way Slabs - waffle slab - same as two way flat slab except bottom bars are found only within ribs and about 1" from bottom. Ribs are about 6" wide, 24" to 36" o.c. and may have one or two bottom bars each. Top bars are similar to normal two way slab.

G. Beams, Girders - usually 12 to 18" wide and 18 to 24 inches deep

1. Bottom Bars - two to six - 3/4" to 1 1/4" Dia. within 2" of bottom. More bars in mid 2/3 of length. Some bars may bend up at 45 degree angle at about 5 Ft. from each supporting column, wall or girder. Bottom bars splice at supports. (BF8)

2. Top Bars - two to six 3/4" to 1 1/4" Dia. bars placed in slab above beam and parallel to it, 4" or so apart. Most rebar will be within 5 Ft. of support but usually two bars will extend full length, with splice midway between supports.

3. Vertical Bars - called stirrups extend from top to bottom of beam at each face about 1" clear. (See BF8)

   Bar Size: 3/8" to 1/2" Dia.
   Bar Spacing: from 4 to 8 inches near supports
   from 12 to 16 inches near midspan

H. Columns - round, square, or rectangular supporting members

1. Horizontal Ties: are usually about 1" from column surface and are <u>usually</u> shaped the same as the column (Spirals for round columns and individual square ties for square columns, but can find spiral ties in square columns)

   Tie size: 3/8 to 5/8" Dia.
   Tie spacing: 3 to 6 inches for spiral
   6 to 18 inches for ties

2. Vertical Bars - Are usually placed more or less evenly around periphery of column. Square columns will have at least one bar in each corner

   Bar size: 5/8" to 1 1/4" Dia. / Sq.
   Bar number: 4 to 8 bars
   (even up to 16 in very large columns)

3. Vertical bars splice just above each floor. Ties have hooks at one corner of column.

APPENDIX IIb - CRACKS IN CONCRETE

A. If it's not cracked it's not concrete. Cracks must form for the reinforcing steel in the concrete to be working.

1. Shrinkage Cracks

   a) Occur within 60 days of pour
   b) Diagonal cracks spread from interior corners, doors, windows, and floor openings
   c) Straight cracks (more or less) occur every so often 5 Ft. o.c., 10 Ft. o.c., 20 Ft. o.c. depending on how often joints occur and condition of concrete and curing.

2. Tension Cracks

   a) Occur when concrete is stressed, beams, walls, sometimes columns, and reinforcing steel is stretched (may be above yield limit) and therefore cracks open. As long as cracks are thin and don't get bigger (wider) structure is probably not degrading.

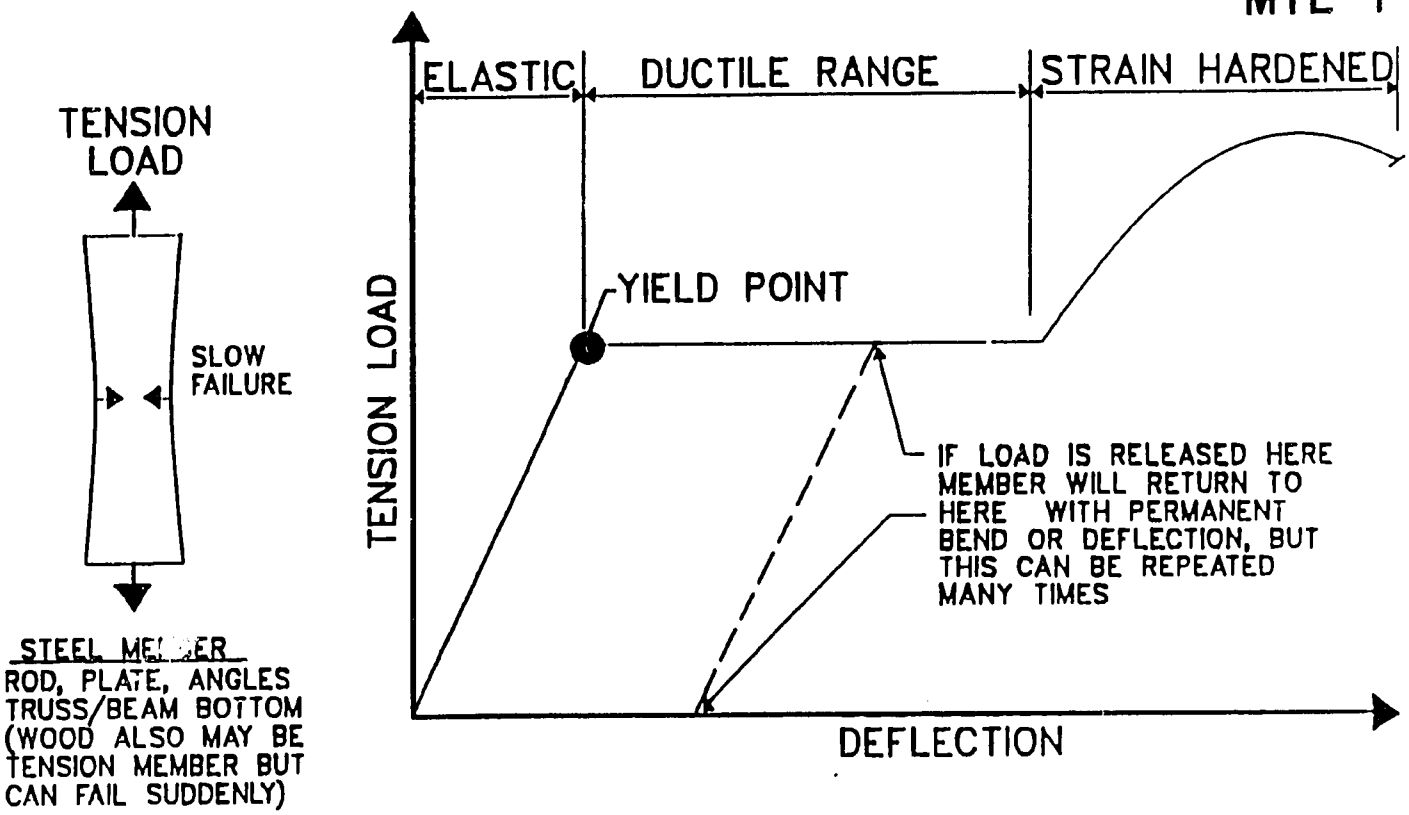
3. Diagonal Tension Cracks

   a) Occur when high shear stresses occur in columns, beams, and/or shear walls
   b) Get cross pattern of cracks due to earthquake forces because load reverses several times. Again as long as these cracks are thin, and remain so the structure is probably not degrading. (See MTL2&7 for typical location of cracks)

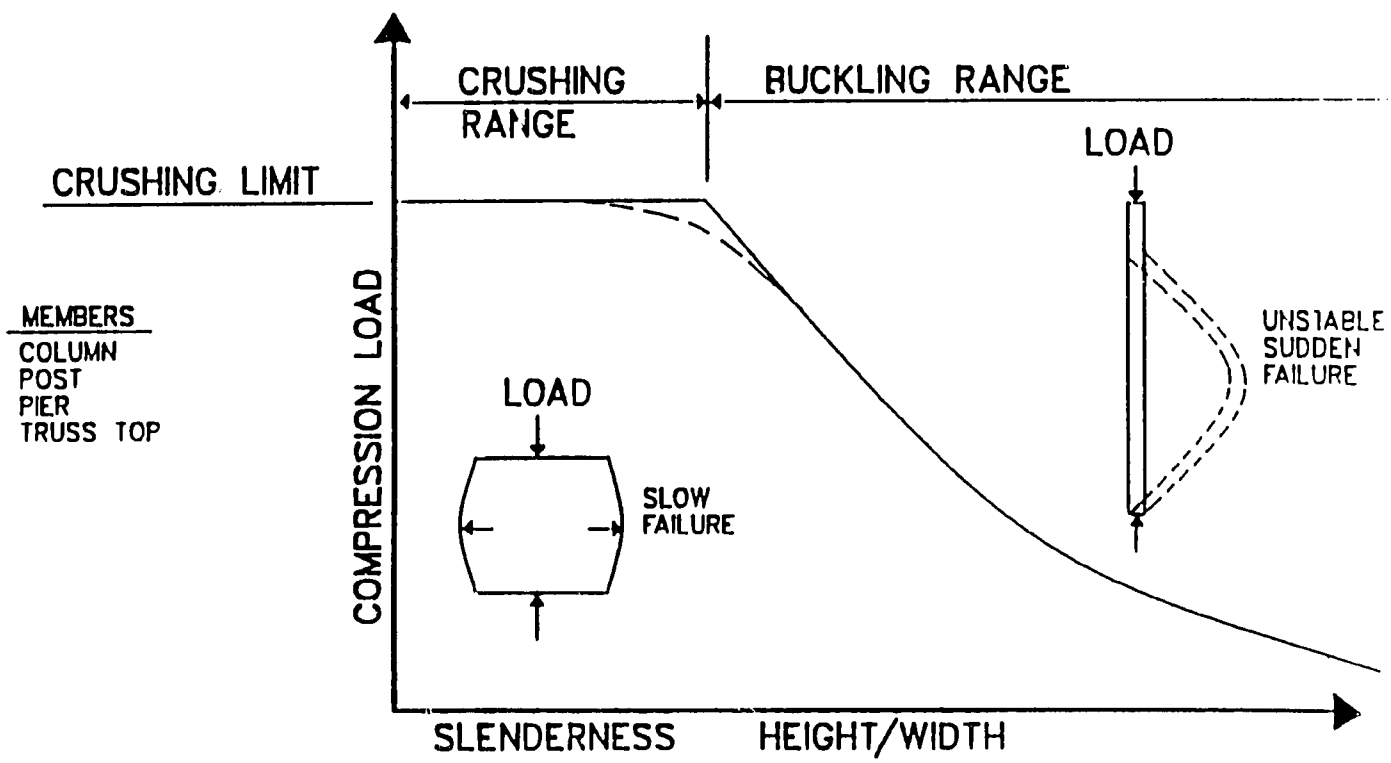
4. As a simple test for changes in a critical structure part one may place a card or piece of paper in the critical cracks and observe if they are getting wider.

   One can also place masking or other tape across joint to check for change, but sometimes it's difficult to get tape to stick in dusty conditions. Moderate cost (about $10) strain gages can also be placed across cracks as indicators of change.

   Note: Temperature cracks will change daily getting larger with lower temperature



DUCTILITY ● ALMOST MAGICAL PROPERTY OF STEEL



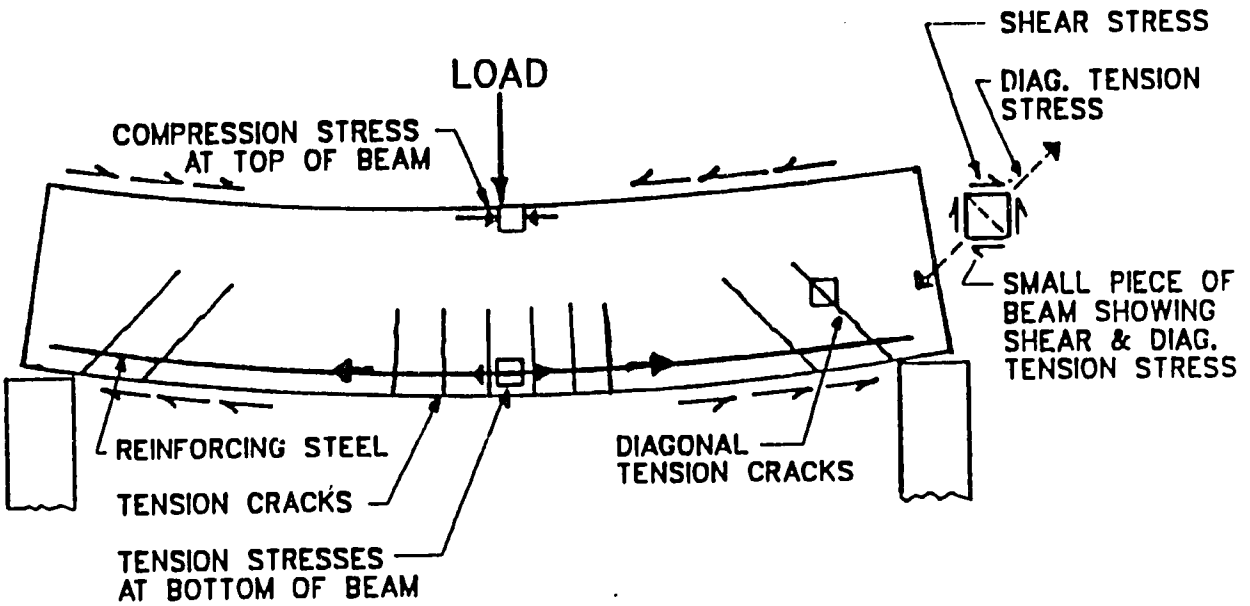
ACTION OF COMPRESSION MEMBERS

WOOD, STEEL, OR CONCRETE

P-174

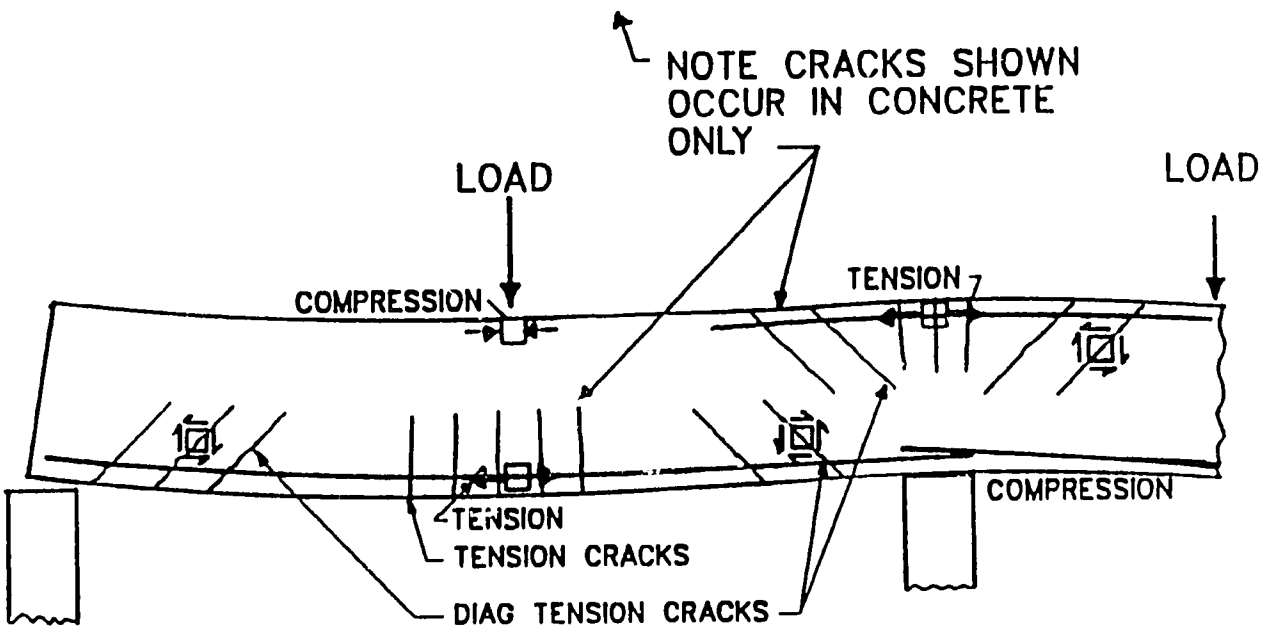
BENDING AND SHEAR

MTL 2



SIMPLE BEAM WOOD, CONCRETE, & STEEL

(JOIST, RAFTER, PURLIN, GIRDER, MOST PRECAST CONC.)



CONTINUOUS BEAM CONCRETE & STEEL

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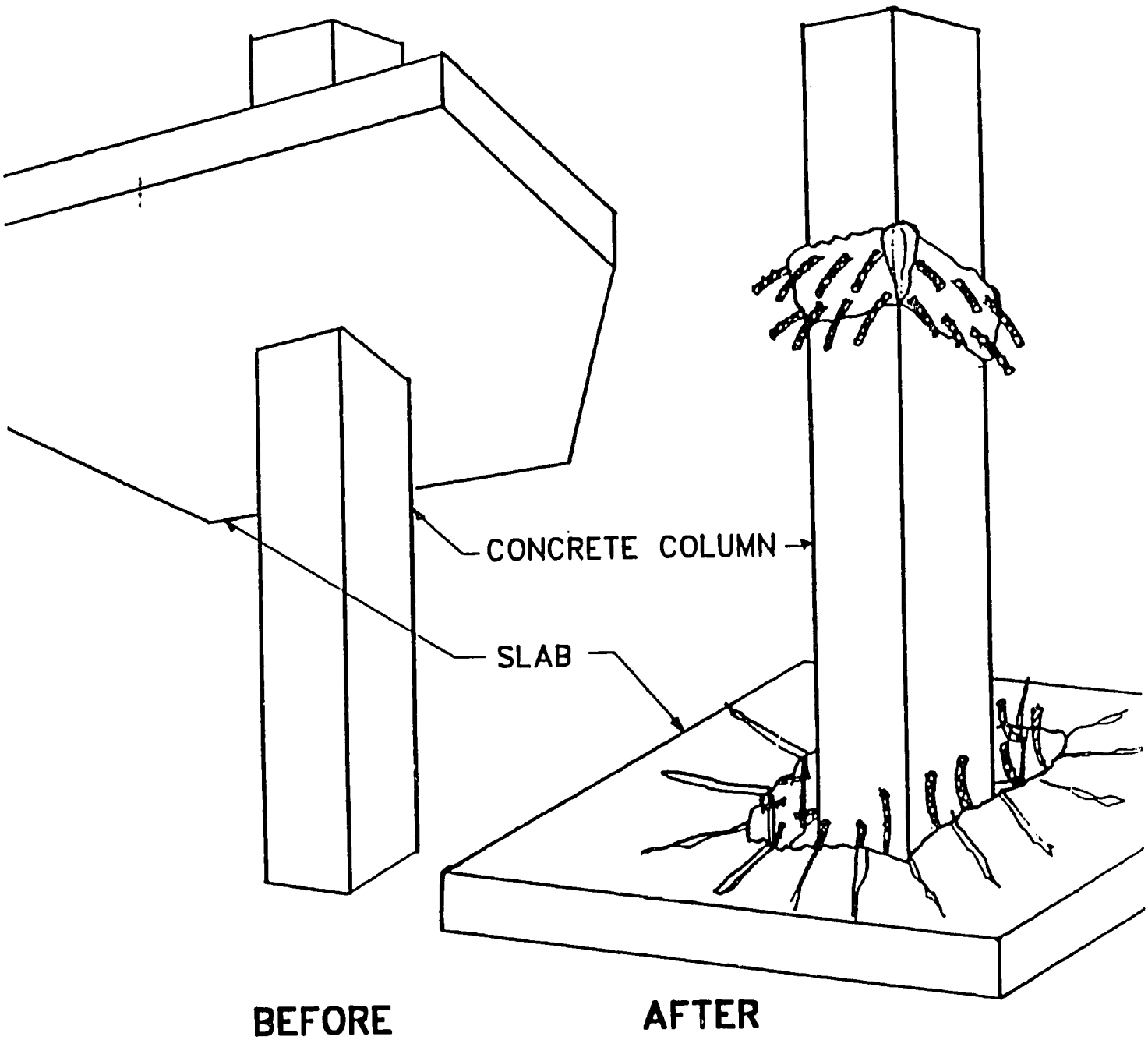
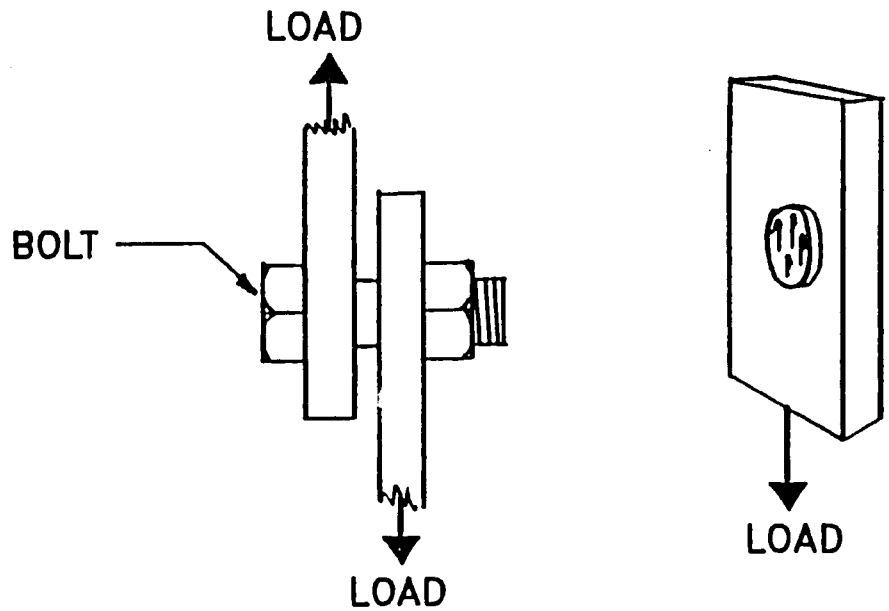
PUNCHING SHEAR • CONCRETE FLAT SLABS

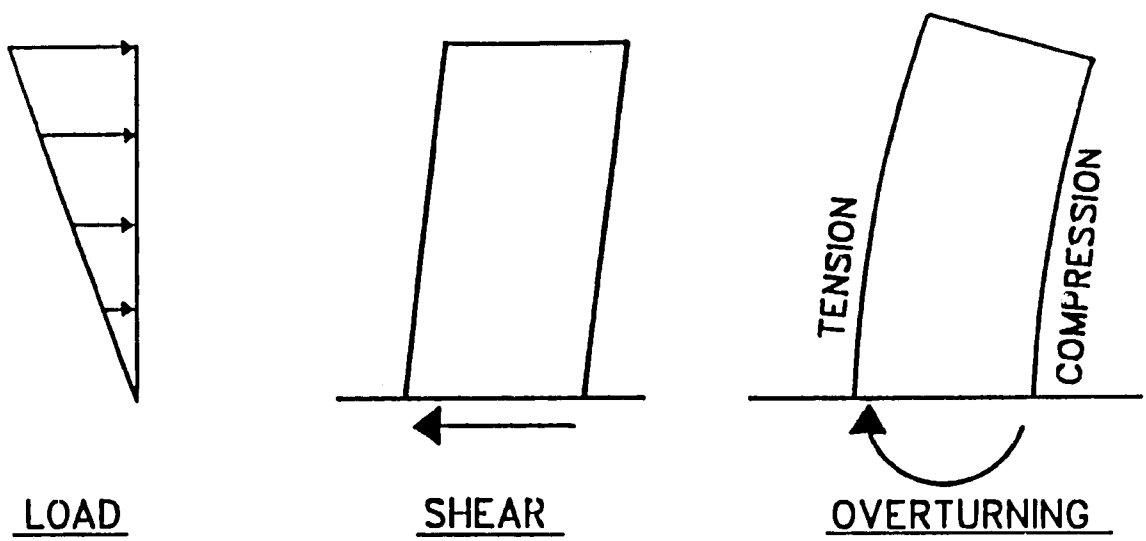
MTL 3



- POTENTIAL FOR SUDDEN FAILURE
- HIGH POTENTIAL IN AFTERSHOCK WHEN FLOOR IS LOADED WITH HEAVY RUBBLE FROM FLOORS ABOVE
- LIFTSLAB FAILURES HAVE OCCURED PROGRESSIVELY AT THEIR NATURAL JOINT AT THIS LOCATION



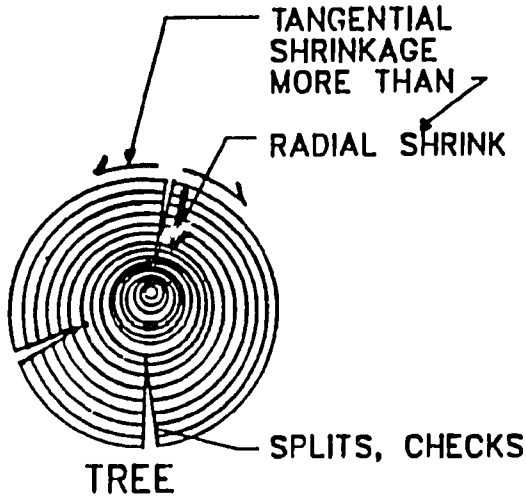
BOLT SHEAR

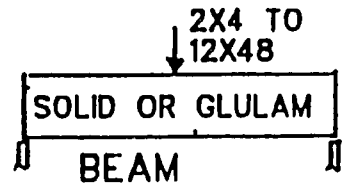


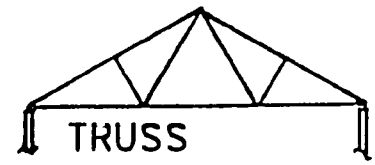
BUILDING SHEAR AND OVERTURNING

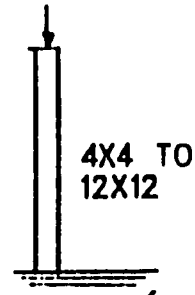
MATERIALS

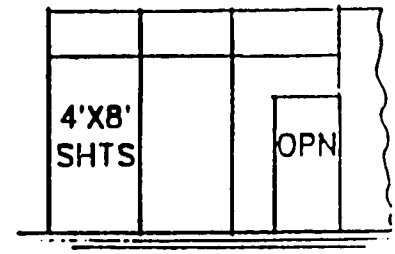
MTL 4



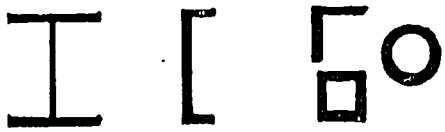




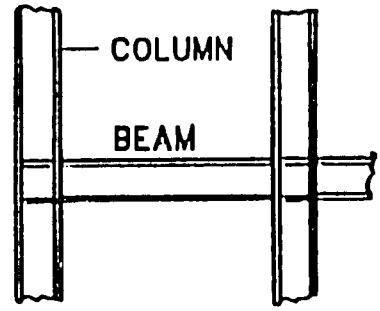




WOOD

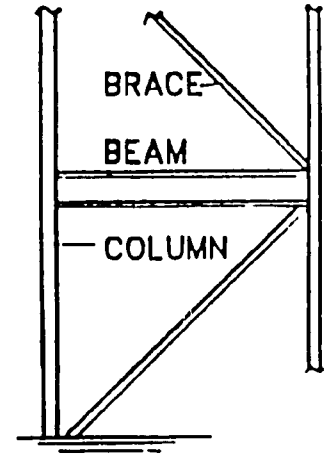


ROLL INTO ANY SHAPE
(USE EFFICIENT SHAPES)



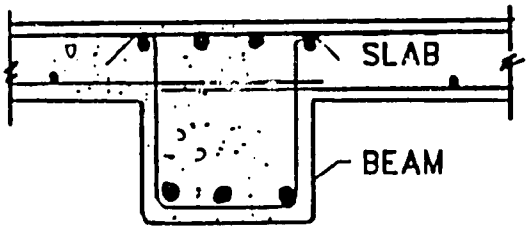
MOMENT FRAMES

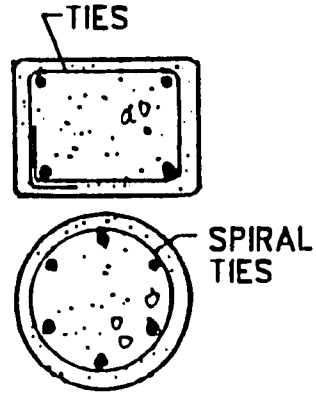
BEAMS
TRUSSES
COLUMNS (POST)



DIAGONAL
BRACED FRAME

STEEL





BEAM, SLAB, JOIST

COLUMNS (POST)

MOMENT FRAMES

SHEARWALLS

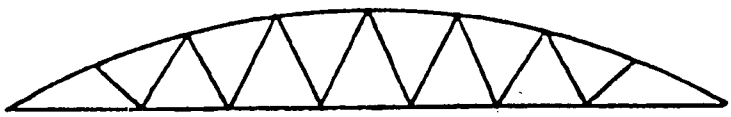
DIAG BRACED FRAME

TRUSSES

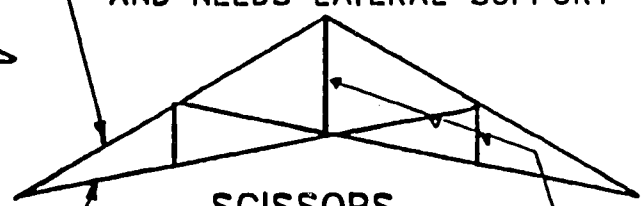
REINFORCED CONCRETE

284'

TRUSSES



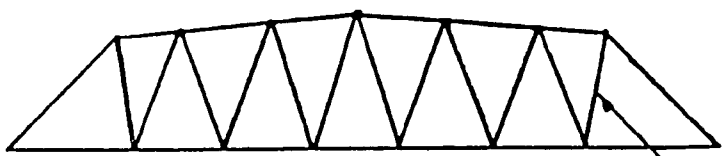
BOWSTRING



SCISSORS

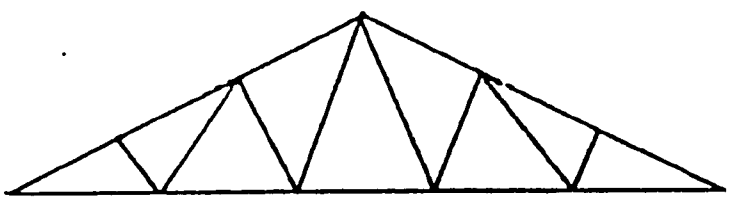
TOP CHORD IN COMPRESSION AND NEEDS LATERAL SUPPORT

BOTTOM CHORD IN TENSION CAN BE A PROBLEM IN WOOD IF SPLITS OCCUR AT BOLTS



CAMELBACK

WEBS (INSIDE MEMBERS) ARE IN TENSION OR COMPRESSION AND MAY REVERSE

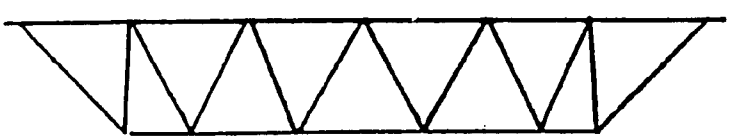


A OR W

NOTE

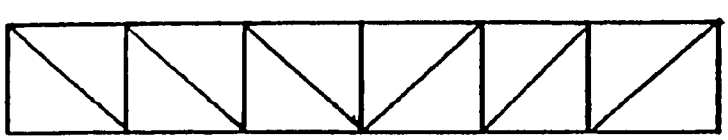
MOST TRUSSES ARE DESIGNED ASSUMING THAT LOADS ARE APPLIED AT INTERSECTIONS OF CHORDS AND WEBS

SHORING SHOULD ONLY BE DONE AT THESE POINTS WHEN SOME PERPENDICULAR BRACING IS ALSO LOCATED THERE



PARALLEL CHORD

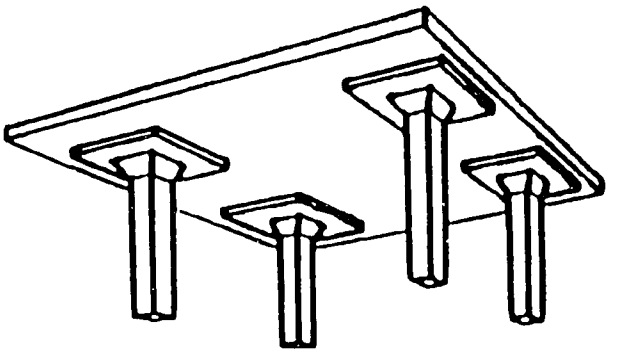
STEEL BAR JOIST
WOOD/STEEL TRUSJOIST



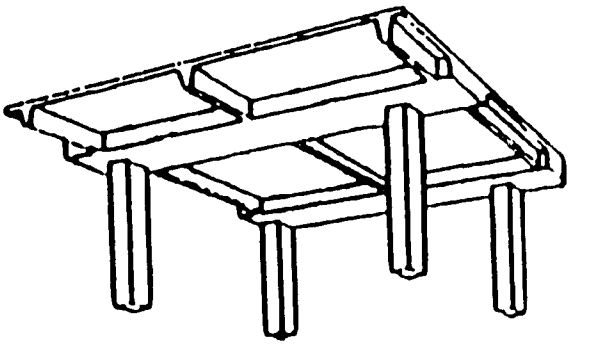
HOWE W/TENSION DIAG

CONCRETE FLOOR FRAMING SYSTEMS

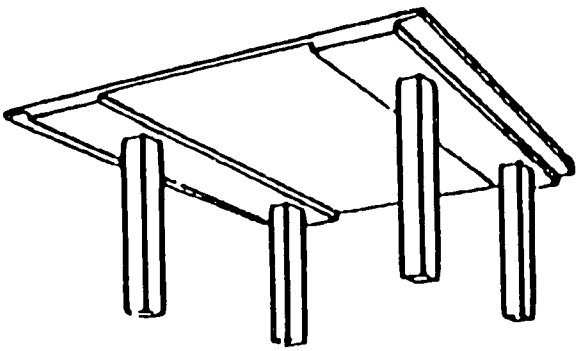
MTL 6



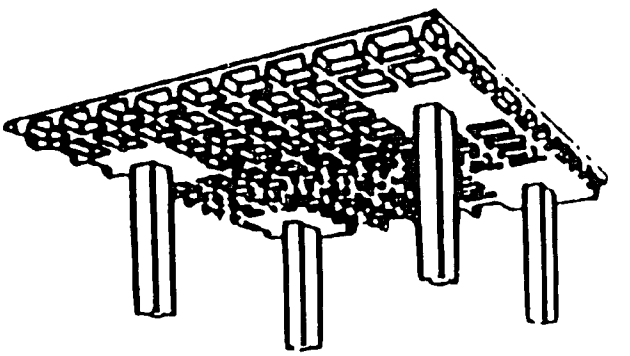
FLAT SLAB



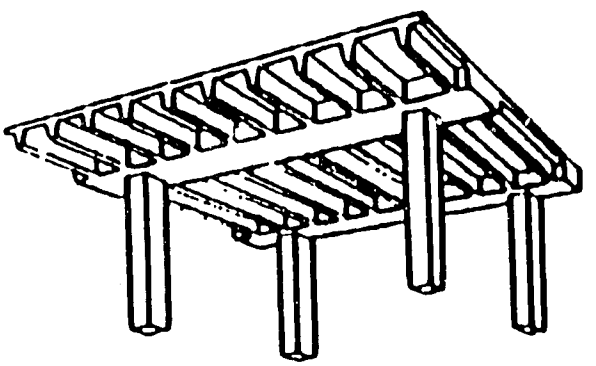
SLAB, BEAM, & GIRDER



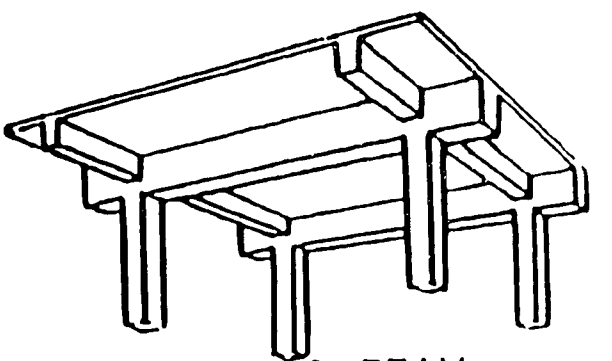
SLAB & BAND BEAM



WAFFLE SLAB



PAN JOIST & GIRDER

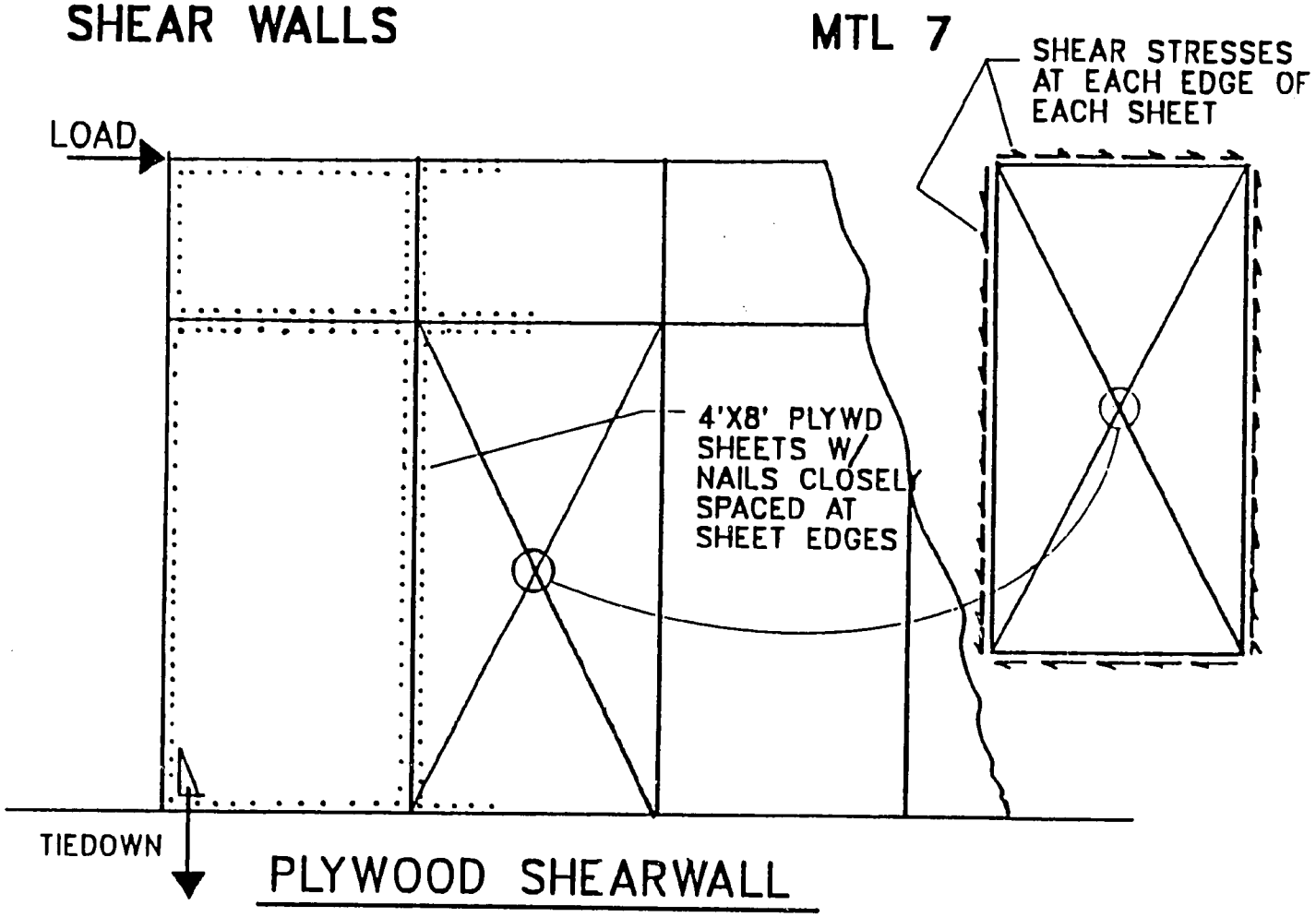


2 WAY SLAB & BEAM

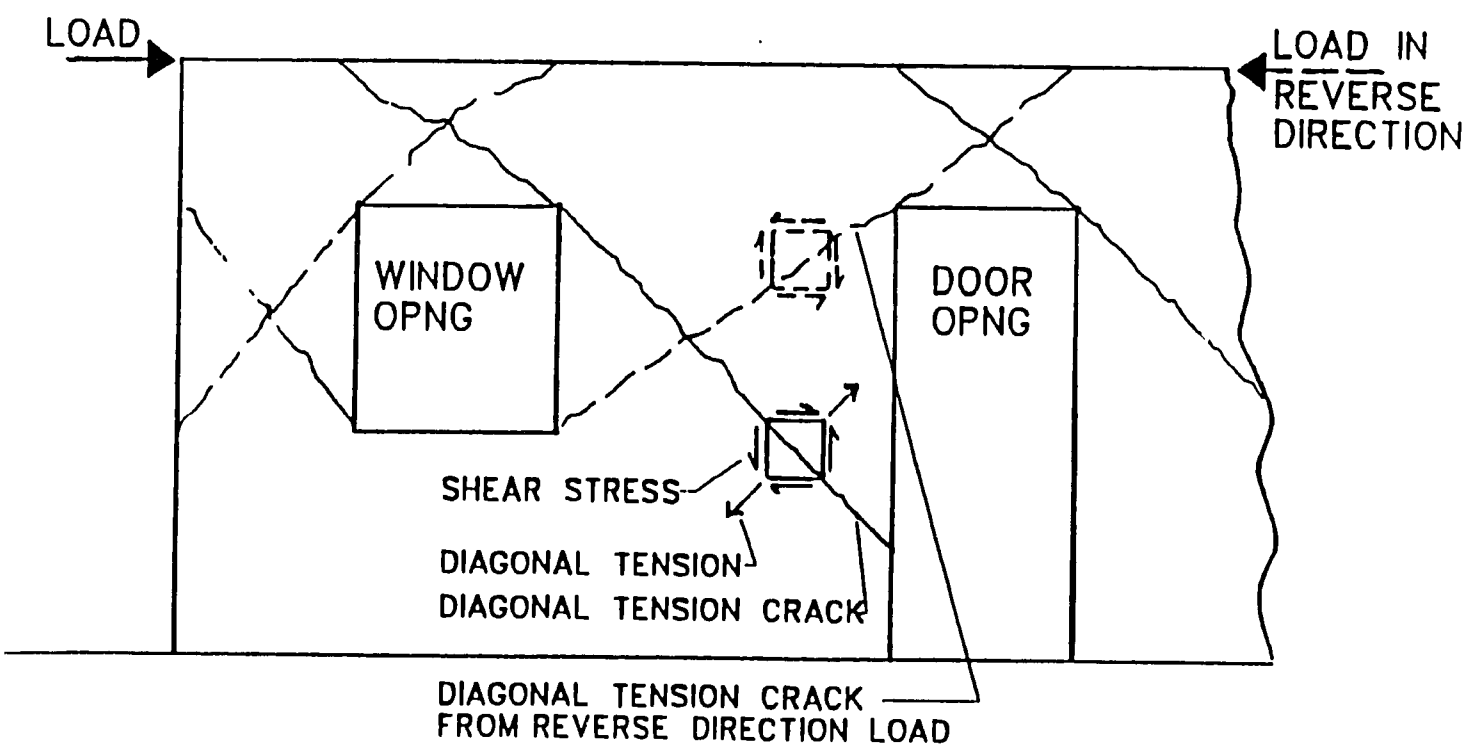
286

SHEAR WALLS

MTL 7



PLYWOOD SHEARWALL

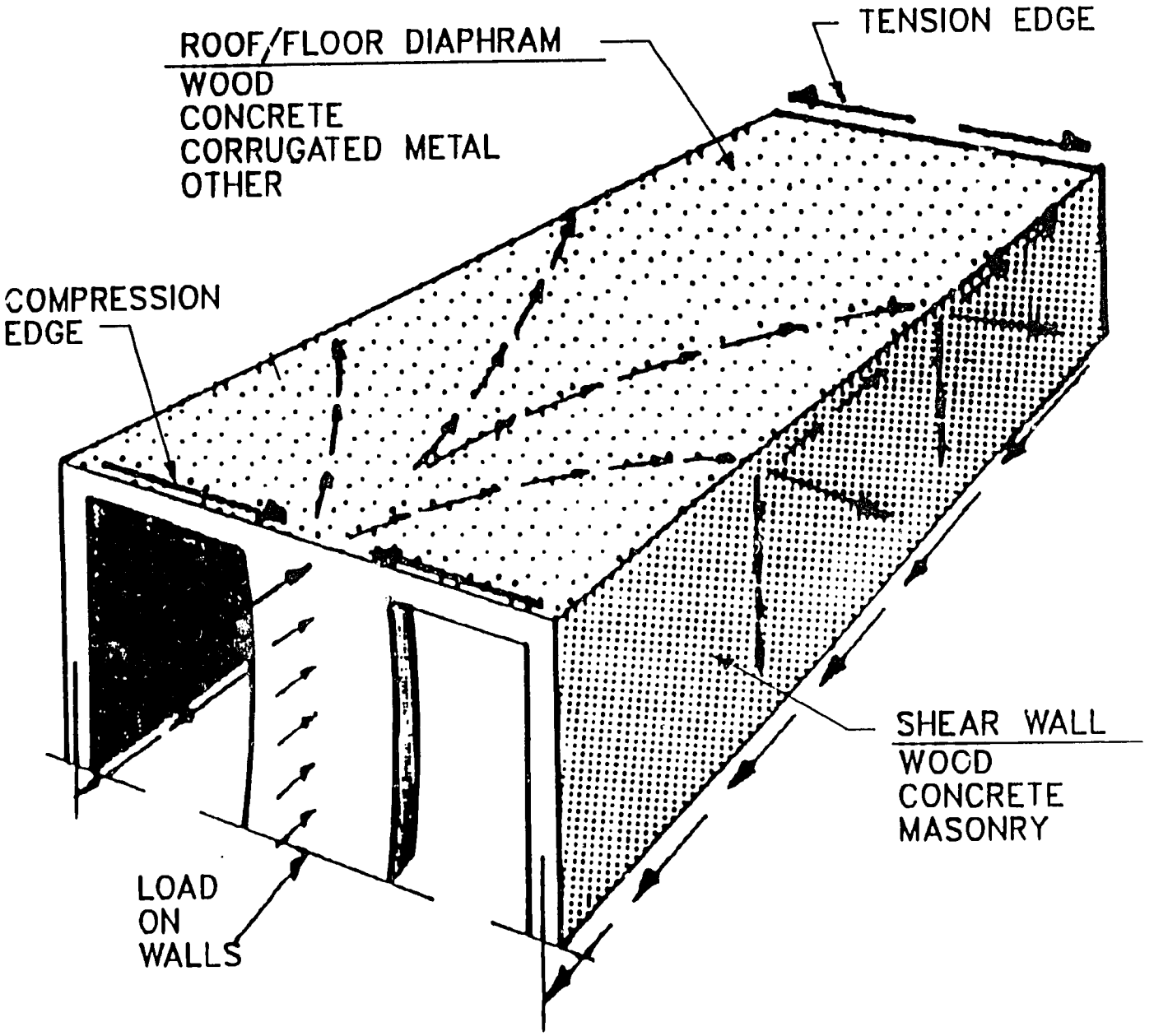


CONCRETE SHEARWALL

P-181

BOX TYPE BUILDING ONE STORY

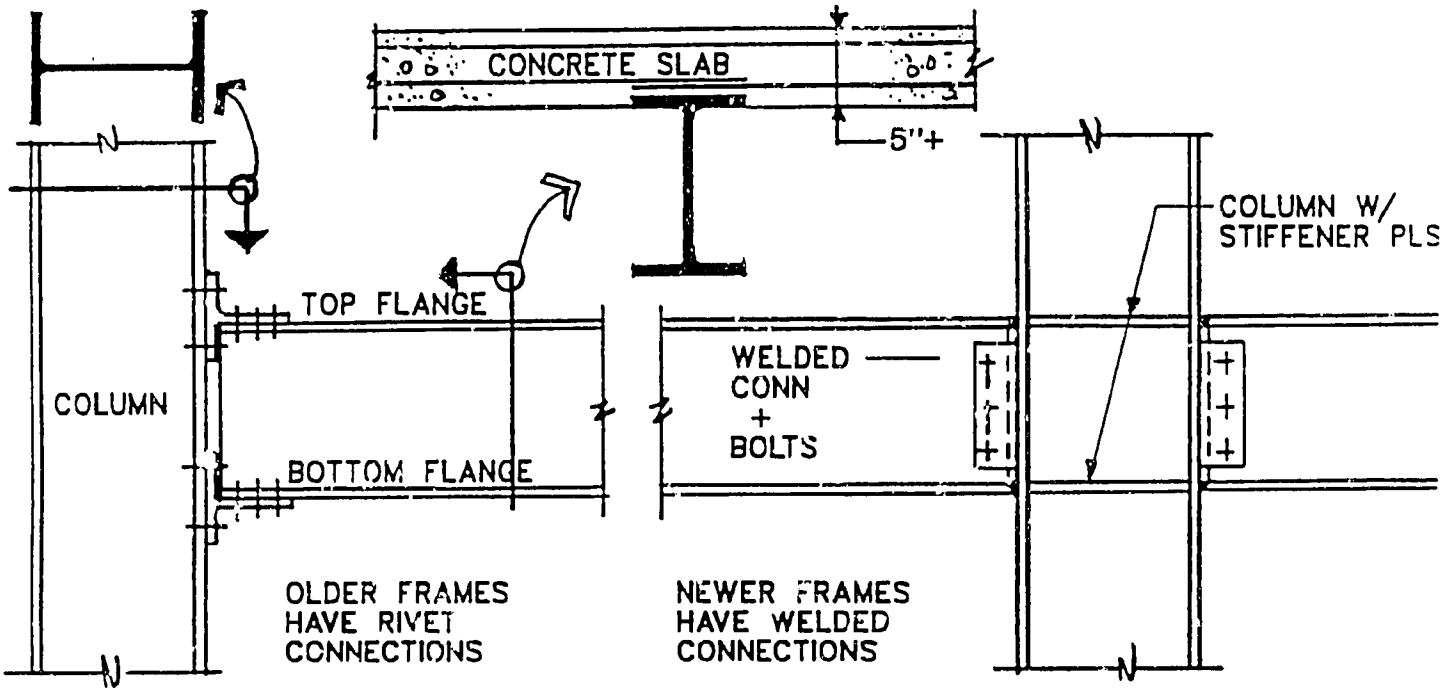
MTL 8



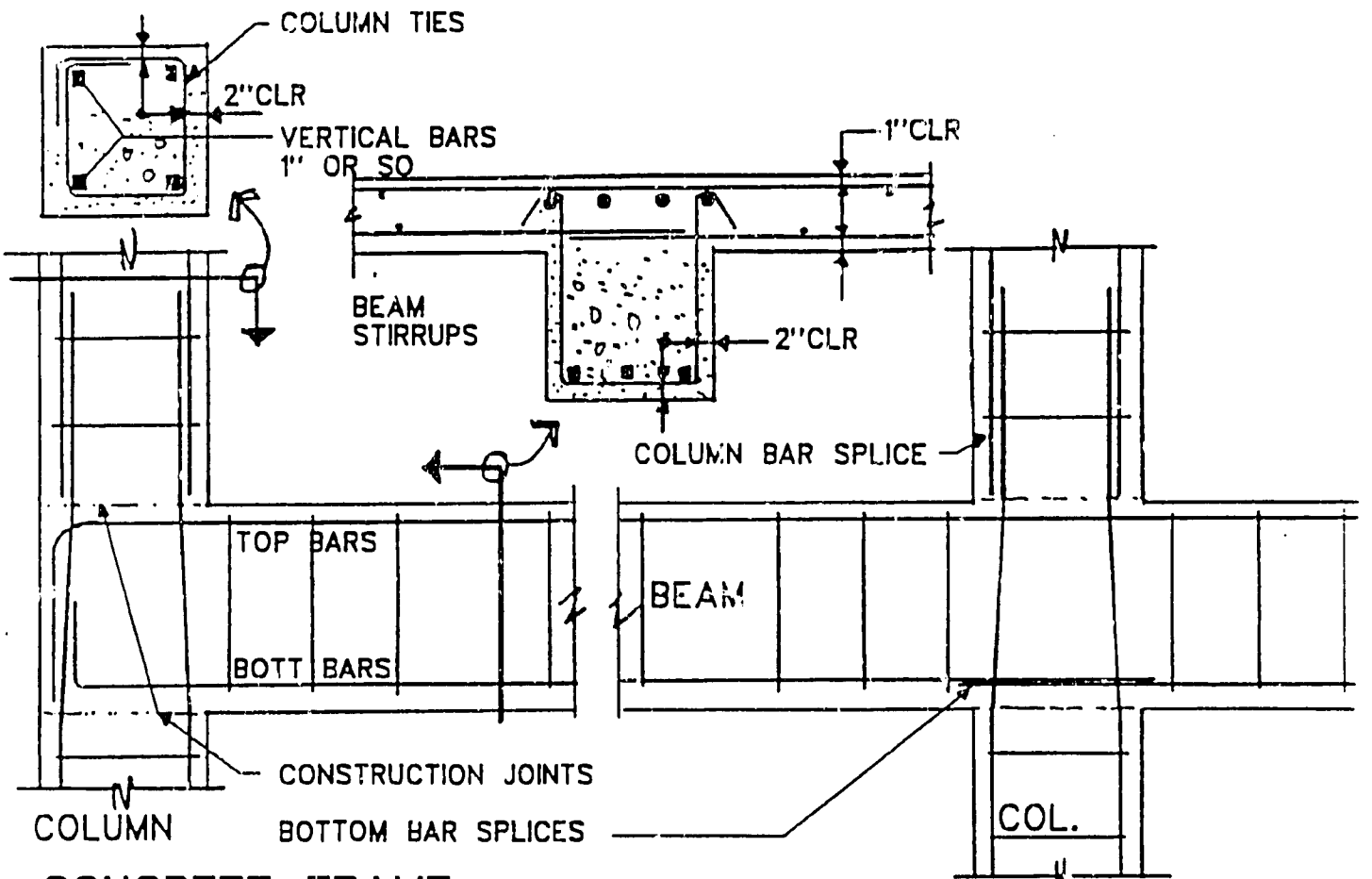
288

MOMENT RESISTING FRAMES

MTL 9



STEEL FRAME

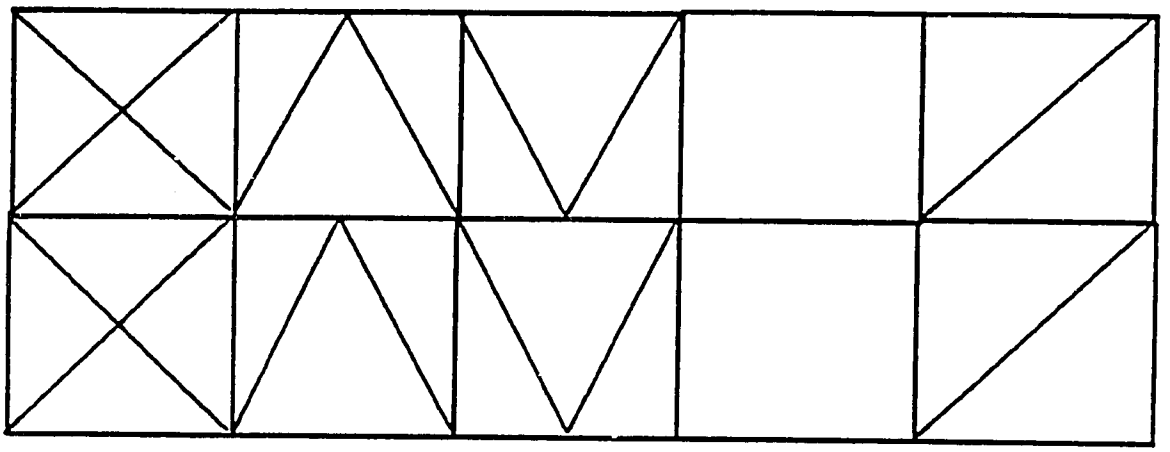


CONCRETE FRAME

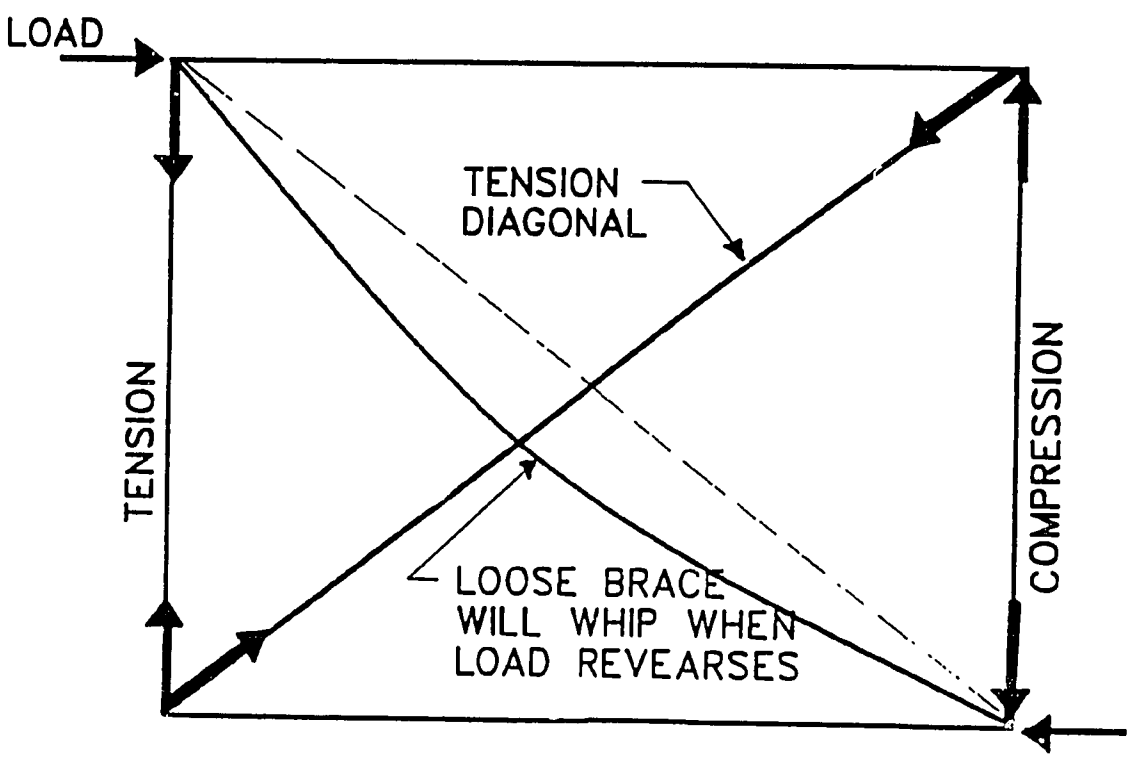
-289

STEEL WALL DIAGONAL BRACING SYSTEMS

MTL 10

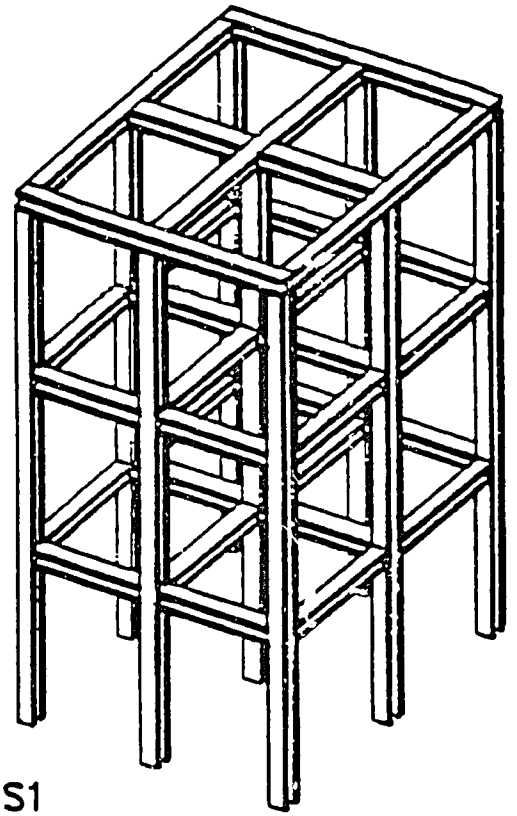


X BRACE | INVERTED V BRACE | V BRACE | DIAGONAL BRACE



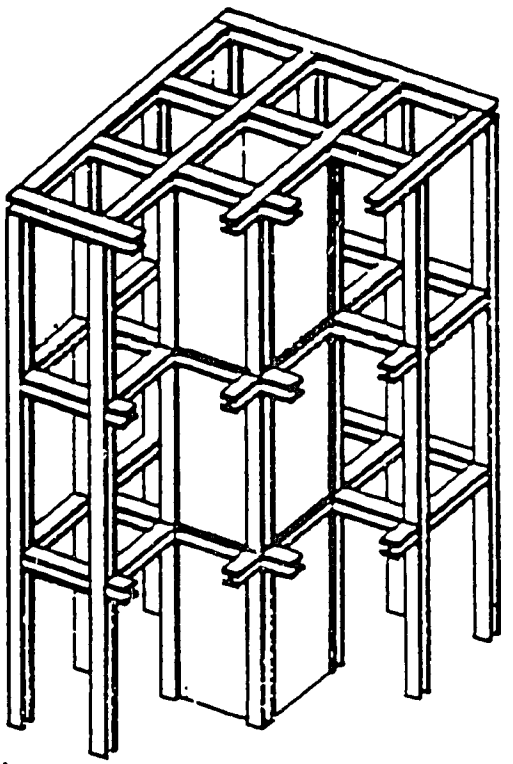
FRAME TYPE BUILDINGS

MTL 11



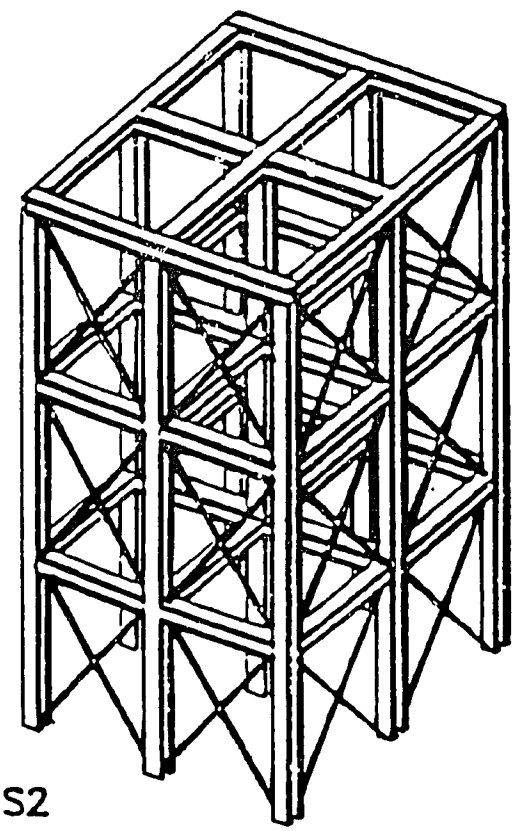
S1

STEEL MOMENT RESISTING



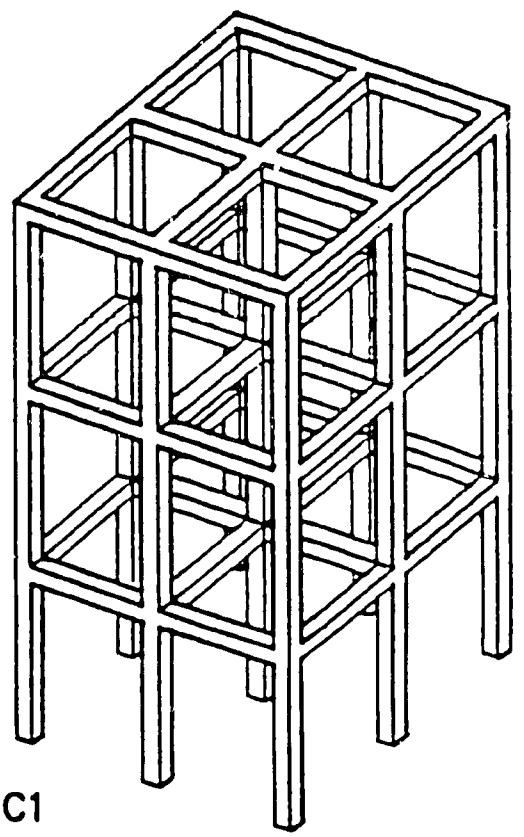
S4

STEEL FR. W/CONC SHEAR WALL



S2

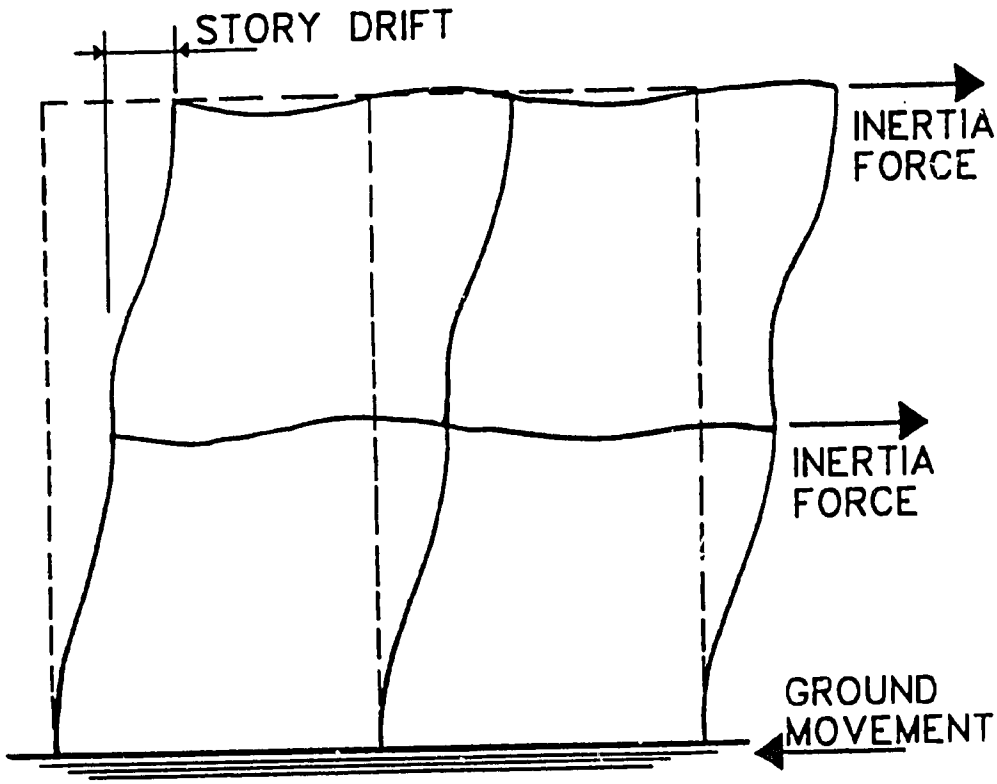
BRACED STEEL FRAME



C1

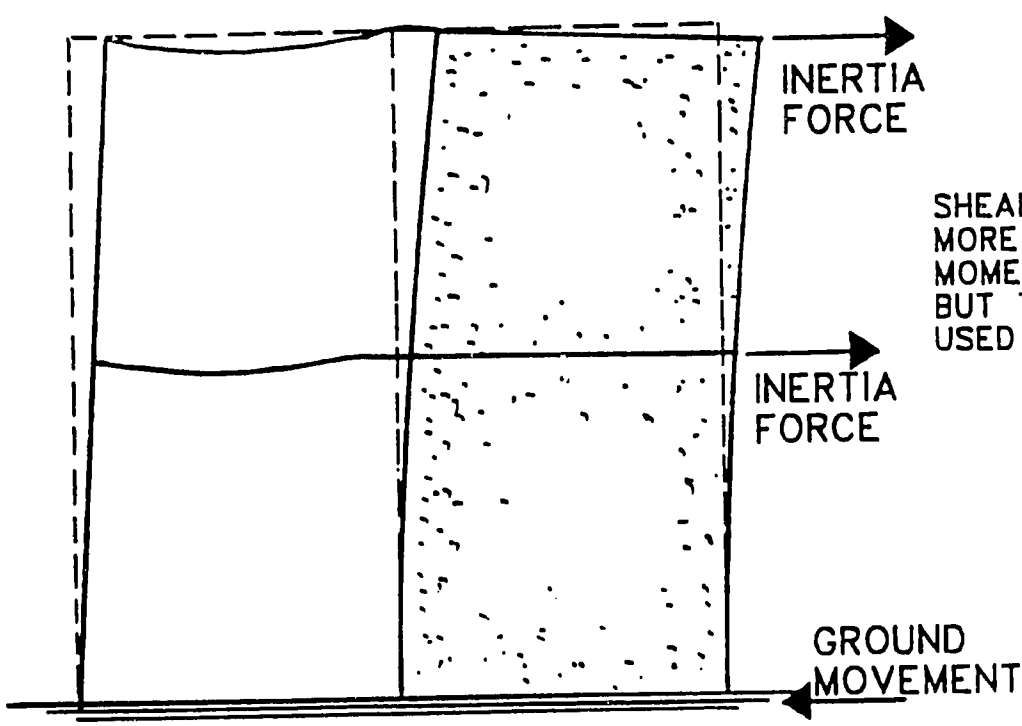
CONCRETE MOMENT RESISTING

LATERAL BRACING METHODS



MOMENT RESISTANT FRAME

RESISTANCE IS PROVIDED BY BENDING OF STEEL OR REINFORCED CONCRETE MEMBERS THAT ARE RIGIDLY CONNECTED



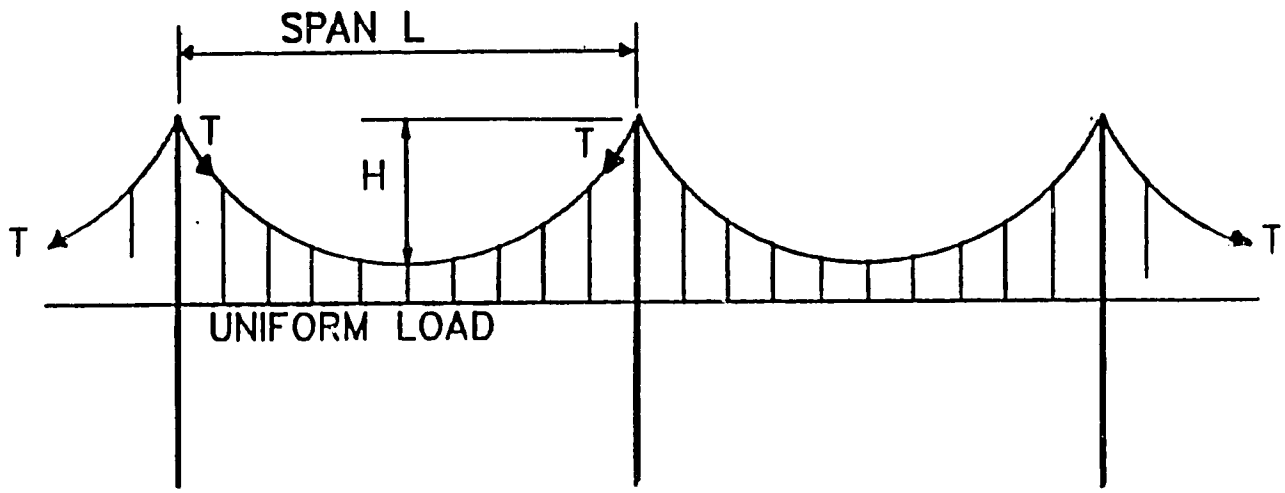
SHEAR WALLS ARE MORE RIGID THAN MOMENT RES FRAMES BUT THE ARE OFTEN USED IN COMBINATION

SHEAR WALL (DIAGONAL BRACING SIM)

WALLS ARE MADE FROM REINFORCED CONCRETE OR WOOD STUDS WITH PLYWOOD OR DIAGONAL BOARD SHEATHING

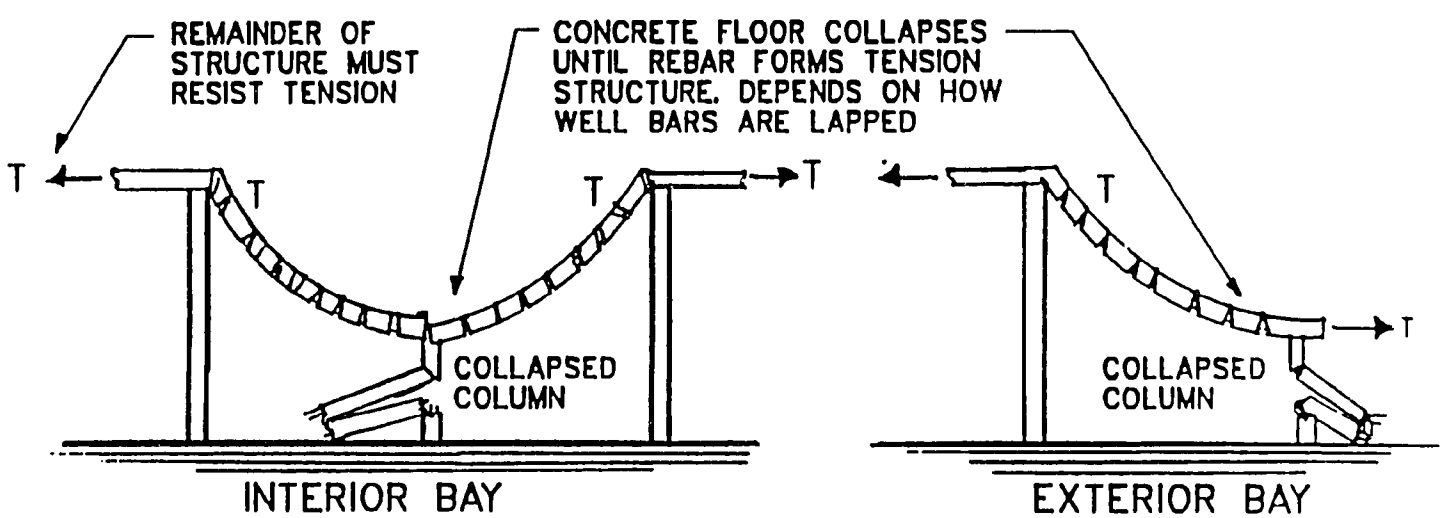
TENSION/SUSPENSION STRUCTURES

MTL 13



SUSPENSION BRIDGE

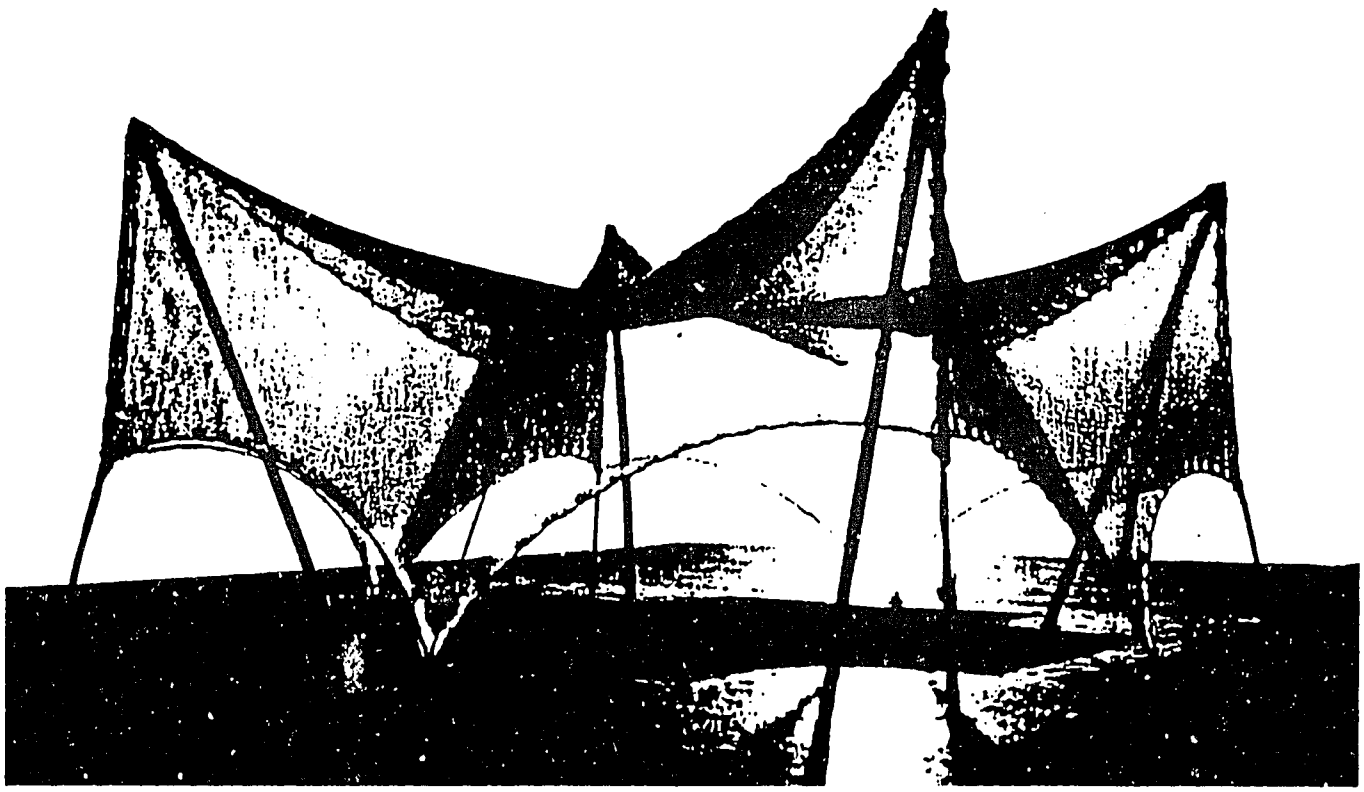
TENSION T IS DETERMINED BY LOAD, H, AND L



PARTLY COLLAPSED BUILDING

TENSION MEMBRANE STRUCTURES

MTL 14



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III BUILDING TYPES AND HOW THEY HAVE FAILED

A. New Useful Method to Classify Buildings (See BF1)

1. Rapid Visual Screening of Buildings For Potential Seismic Hazards funded by FEMA and written by Applied Technology Council

2. Method is intended to be used in sidewalk survey of existing buildings to preliminarily determine location of hazardous buildings.

3. Normally would take less than 30 minutes per building to obtain data and fill out form.

4. Rates building from 6.5 good to zero. Less than about 2 would be potentially hazardous, requiring further study. (BF1a)

5. URM, C1, C3, TU, PC2, and non-uniform buildings are expected to be the most hazardous in California.

6. Most building collapses occur when vertical stability elements (walls and columns) either separate from building, and break at joints with floors, or break between floors. One can generalize the failure types to: (BF12)

   a) Heavy wall buildings (URM, TU, Conc. or Masonry wall low rise with wood floors)

   b) Heavy floor buildings (Concrete Frames, C1, C3)

   c) Precast concrete buildings (PC2)

   d) There are buildings that are combinations of types or don't fit these categories.

B Unreinforced Masonry Buildings URM (See BF2,3)

1. Usually from 1 to 6 story buildings with URM walls and wood floors.

2. Estimated to be 8000 in L.A., 6000 in S.F., and as many as 50,000 in California. 1986 SB549 requires that cities identify these buildings, including steel and concrete frames with URM infill. (BF4)

3. Common Failures:

   a) Parapets and full walls fall off buildings. due to inadequate anchors (See BF 5)

b) Multi thickness walls split and collapse or break at openings. Mortar is often weak and made with only lime cement.

c) Walls that are not loaded by roof/floors more often fall off since load tends to compress wall and hold it together.

d) Roof/floors may collapse if no interior wall supports and if earthquake has long enough duration.

e) Cavities usually formed by wood floors in familiar patterns of Vee, Lean To, and complicated pancake. (BF13)

f) Older steel frame buildings with unreinforced or lightly reinforced masonry infill, often shed this weak, brittle covering as they flex to resist the quake. (BF6)

g) Broken bricks often line the streets where these buildings are located and people can be trapped in sidewalk, auto, etc.

C Older Concrete Frame Buildings (See BF7,8,9)

1. Usually from one to thirteen stories, and could have URM infill. May have 6 inch thick shearwalls in some.

2. Most hazardous include:

a) Soft (high, open) first story buildings

b) Open front buildings (solid side walls, small openings at rear)

c) Corner buildings with torsion action (two open wall and two solid walls)

3. Common Failures (BF14,15)

a) Columns break at intersections with floor beam. Inadequate rebar and ties don't confine the concrete when subjected to high shear and tension stresses. Failure may be driven by strong P-Delta effect.

b) Short columns in exterior walls get high shear and tension stresses focused into them by surrounding massive concrete.

c) Bending and punching shear failure at intersections of flat slabs (waffle etc.) and columns.

d) URM infill can fall off, often pop out of surrounding frames. Also, URM infill can cause columns to shear off at floor line or top of URM.

4. Weak concrete and poor construction can make all above conditions worse and more likely to lead to larger collapse.

5. Collapse Types: (Illustrated by slide presentation)

   a) Pancake with voids dependent on projections in structure (beams vs. flat slabs) and contents.

   b) Upper or middle floors only - very difficult to predict action in aftershock.

   c) Overturned structure - usually shear wall building tension/shear failure at base. Tall thin frame building can get tension stresses in exterior column due to overturning effects and when load reverses to compression the columns, deteriorated by tension failure cannot withstand load (rocks come out of the rebar basket)

   e) Corner building with street sides hanging off remainder - have part frame and part tension structure.

   f) Odd shaped building with some wings collapsed. Again can get part tension structure.

   g) Progressive failure - often corner column at upper level fails and progressively loads structure below (EQ10)

   h) Pounding of one building on neighbor - cause column collapse if rigid floor of one hits at mid height of neighbor column. Stability problem heavy load vs. unstraight column support (EQ9)

D. Precast Concrete Frame (See BF10)

1. One to six stories tall, although precast wall panels may be used in taller buildings. Floors/roof may be Tee, double Tee, or cored slab sections supported by precast girders and columns. Lateral resistance is often provided by reinforced masonry or concrete walls.

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2. Common Failures

a) Joint failures - joints between roof/floor and walls, between roof panels, between wall panels. This can lead to complete collapse as the building breaks into very large parts.

b) Wall panels separate from building and fall off. If panels are non bearing only local failure may be the result.

c) Progressive failure caused by joint failure between column and beam or slab and wall panel that then results in failure of structure just above due to lack of support and then to structure below collapse due to heavy debris loading. (See EQ10)

E. Tilt Up Concrete Wall Buildings (See BF11)

1. Usually one story with wood roof but may be up to 3 stories with wood floors, concrete floors, steel framing with concrete filled metal deck floors, or concrete fill 1 1/2" to 4" thick on wood floor.

2. Common Failures:

a) Walls separate from wood floors/roof causing at least local collapse of floor/roof, possible general collapse of walls and floor/roof.

<u>Note:</u> This problem should not occur if buildings are properly interconnected (post 1976) and or if floors/roof are not wood.

b) Suspended wall panels fall off building

<u>Note:</u> Suspended panels could be problem on S1, S2, C1, C2, PC2, and RM buildings.

c) Walls may have short, weak columns between window openings that fail like concrete frame buildings.

d) Large buildings that are Tee or L shaped in plan can have failures at the intersecting corners.

3. Major weight of these buildings is normally the walls themselves so most failures should be limited to exterior bays of the buildings.

F. Post-tensioned Lift Slabs

1. From 3 to 13 stories high buildings made with thin (6 to 8") flat slabs poured as pancake stack then lifted into place on concrete or steel columns.

2. These buildings are laterally braced with cast in place concrete shear walls that form stair/elevator cores and/or reinforced masonry shear walls.

3. A six story apartment building of this type collapsed in the 1964 Alaska EQ due to overturning of the stair cores. A twelve story building of this type collapsed during construction in 1987.

4. The resulting collapsed structures had very closely spaced broken slabs that were essentially unreinforced concrete. The unbonded reinforcing cables became loose when slabs break, leaving the concrete unreinforced. The lack of projecting beams plus longer spacing of columns leads to the close spacing of collapsed slabs.

STRUCTURAL BUILDING TYPES • ATC-21-1 BF 1

IDENTIFIER	GENERAL DESCRIPTION
W	WOOD BUILDINGS OF ALL TYPES
S1	STEEL MOMENT RESISTING FRAMES
S2	BRACED STEEL FRAMES
S3	LIGHT METAL BUILDINGS
S4	STEEL FRAMES W/ CAST IN PLACE CONC WALLS
C1	CONCRETE MOMENT RESISTING FRAMES
C2	CONCRETE SHEAR WALL BUILDINGS
C3/S5	CONCRETE/STEEL FRAME W/ URM INFILL WALLS
TU	TILT-UP CONCRETE WALL BUILDINGS
PC2	PRECAST CONCRETE FRAME BUILDINGS
RM	REINFORCED MASONRY BUILDINGS
URM	UNREINFORCED MASONRY BLDGS

BUILDING TYPES MOST LIKELY TO BE DAMAGED

URM	1 TO 6 STORIES (MOST 3 STORY & LESS) 8000 IN L A 6000 IN S F 50000 IN CAL. INCLUDES STEEL & CONC FRAMES W/ URM INFILL 1986 SB 547 CH 250 REQUIRES IDENTIFICATION.
C1/C2/C3	PRE 1947 CONCRETE BUILDINGS
PC2/TU	PRECAST CONCRETE BUILDINGS (OLDER - POORLY CONNECTED BUILDINGS) • MULTI STORY RESIDENCE BUILDINGS • LOW RAISE COMMERCIAL & PARKING STRUCTURES • TILT UP CONC WALL BLDGS, 1 TO 3 STORY • SIMILAR BLDGS W/ CONC BLOCK WALLS • POST TENSIONED LIFT SLAB BUILDINGS
OTHERS	NON UNIFORM BUILDINGS • MULTI STORY W/ SOFT FIRST STORY • OPEN FRONT COMMERCIAL BUILDINGS • ODD SHAPED BUILDINGS T, L, ETC • CORNER BLDGS - TORSION

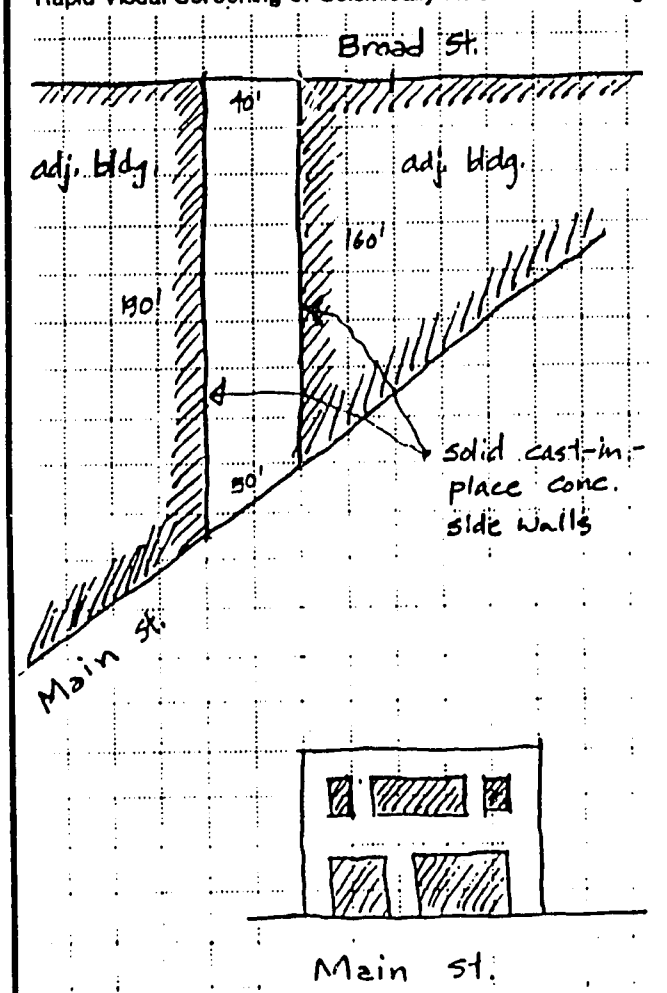
-300'

ATC-21 SAMPLE FORM

BF 1a

ATC-21/ (NEHRP Map Areas 5,6,7 High)

Rapid Visual Screening of Seismically Hazardous Buildings



Scale: (plan) 1/4" = 20' Broad St. facade →

Address 570 - 574 Main
Anytown Zip 12345
Other Identifiers
No. Stories 2 Year Built 1922
Inspector KW Date 3/11/88
Total Floor Area (sq. ft) 16,190
Building Name
Use bank, office
(Peel-off label)

OCCUPANCY	
Residential	No. Persons
(Commercial)	0-10
Office	(11-100)
Industrial	100+
Pub. Assem.	
School	
Govt. Bldg.	
Emer. Serv.	
Historic Bldg.	

Non Structural Falling Hazard ☐

DATA CONFIDENCE

☆ = Estimated, Subjective, or Unreliable Data

DNK = Do Not Know

STRUCTURAL SCORES AND MODIFIERS

BUILDING TYPE	W	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	(C1) (MRF)	C2 (SW)	C3/S5 (URM INF)	PC1 (TU)	PC2	RM	URM
Basic Score	4.5	4.5	3.0	5.5	3.5	(2.0)	3.0	1.5	2.0	1.5	3.0	1.0
High Rise	N/A	-2.0	-1.0	N/A	-1.0	-1.0	-1.0	-0.5	N/A	-0.5	-1.0	-0.5
Poor Condition	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Vert. Irregularity	-0.5	-0.5	-0.5	-0.5	-0.5	-1.0	-0.5	-0.5	-1.0	-1.0	-0.5	-0.5
Soft Story	-1.0	-2.5	-2.0	-1.0	-2.0	-2.0	-2.0	-1.0	-1.0	-2.0	-2.0	-1.0
Torsion	-1.0	-2.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
Plan Irregularity	-1.0	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-1.0	-1.0	-1.0	-1.0
Pounding	N/A	-0.5	-0.5	N/A	-0.5	-0.5	N/A	N/A	N/A	-0.5	N/A	N/A
Large Heavy Cladding	N/A	-2.0	N/A	N/A	N/A	-1.0	N/A	N/A	N/A	-1.0	N/A	N/A
Short Columns	N/A	N/A	N/A	N/A	N/A	-1.0	-1.0	-1.0	N/A	-1.0	N/A	N/A
Post Benchmark Year	+2.0	+2.0	+2.0	+2.0	+2.0	+2.0	+2.0	N/A	+2.0	+2.0	+2.0	N/A
SL2	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3
SL3	-0.6	-0.6	-0.6	-0.6	-0.6	(-0.6)	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6
SL3 & 6 to 20 stories	N/A	-0.8	-0.8	N/A	-0.8	-0.8	-0.8	-0.8	N/A	-0.8	-0.8	-0.8
FINAL SCORE						1.4						

COMMENTS
- renovated facade and interior, side walls still show original cast-in-place concrete
- assume frame action in transverse direction

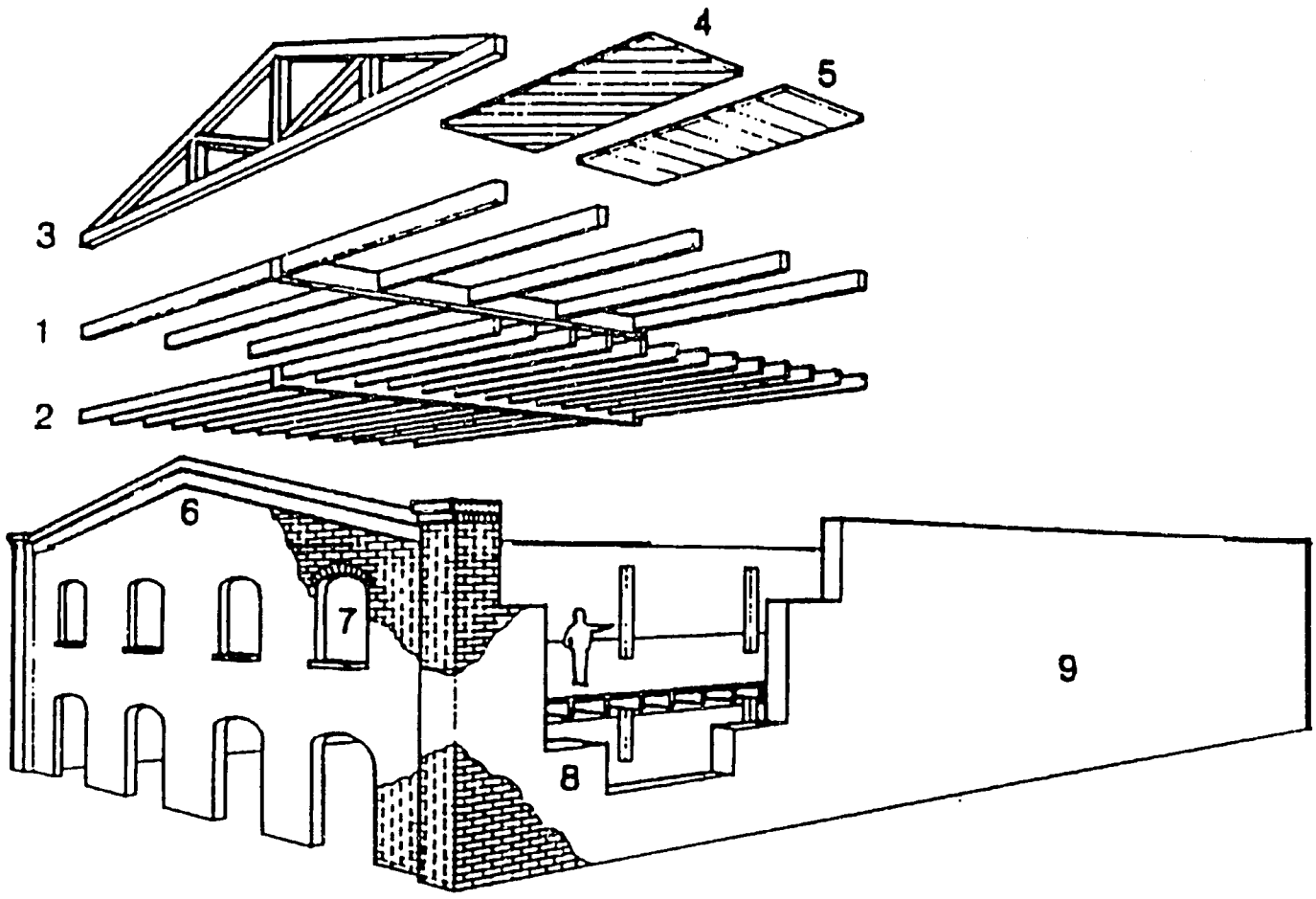
Detailed Evaluation Required? (YES) NO

UNREINFOFCED MASONRY • URM

BF 2

Roof/floor span systems:
1. wood post and beam (heavy timber)
2. wood post, beam, and joist (mill construction)
3. wood truss– pitch and curve

Roof/floor diaphragms:
4. diagonal sheathing
5. straight sheathing



Details:
6. typical unbraced parapet and cornice
7. flat arch window openings

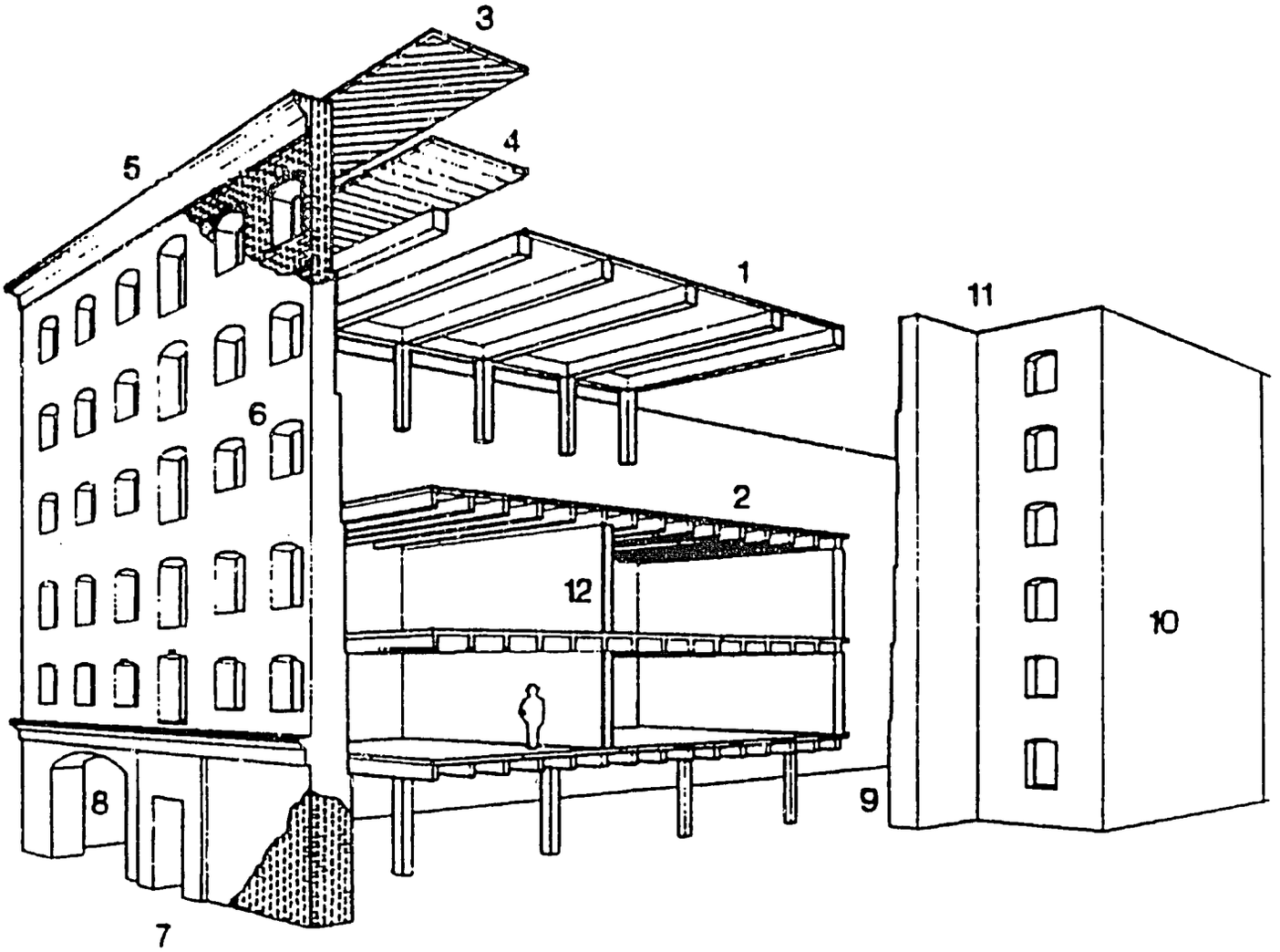
Wall systems:
8. bearing wall– four or more wythes of brick
9. typical long solid party wall

UNREINFORCED MASONRY • URM

BF 3

Roof/floor span systems:
1. wood post and beam (heavy timber)
2. wood post, beam, and joist (mill construction)

Roof/floor diaphragms:
3. diagonal sheathing
4. straight sheathing



Details:
5. typical unbraced parapet and cornice
6. flat arch window openings
7. typical penetrated facade of residential buildings
8. large openings of ground floor shops

Wall systems:
9. bearing wall— four to eight wythes of brick
10. typical long solid party wall
11. light/ventilation wells in residential bldg
12. non-structural wood stud partition walls

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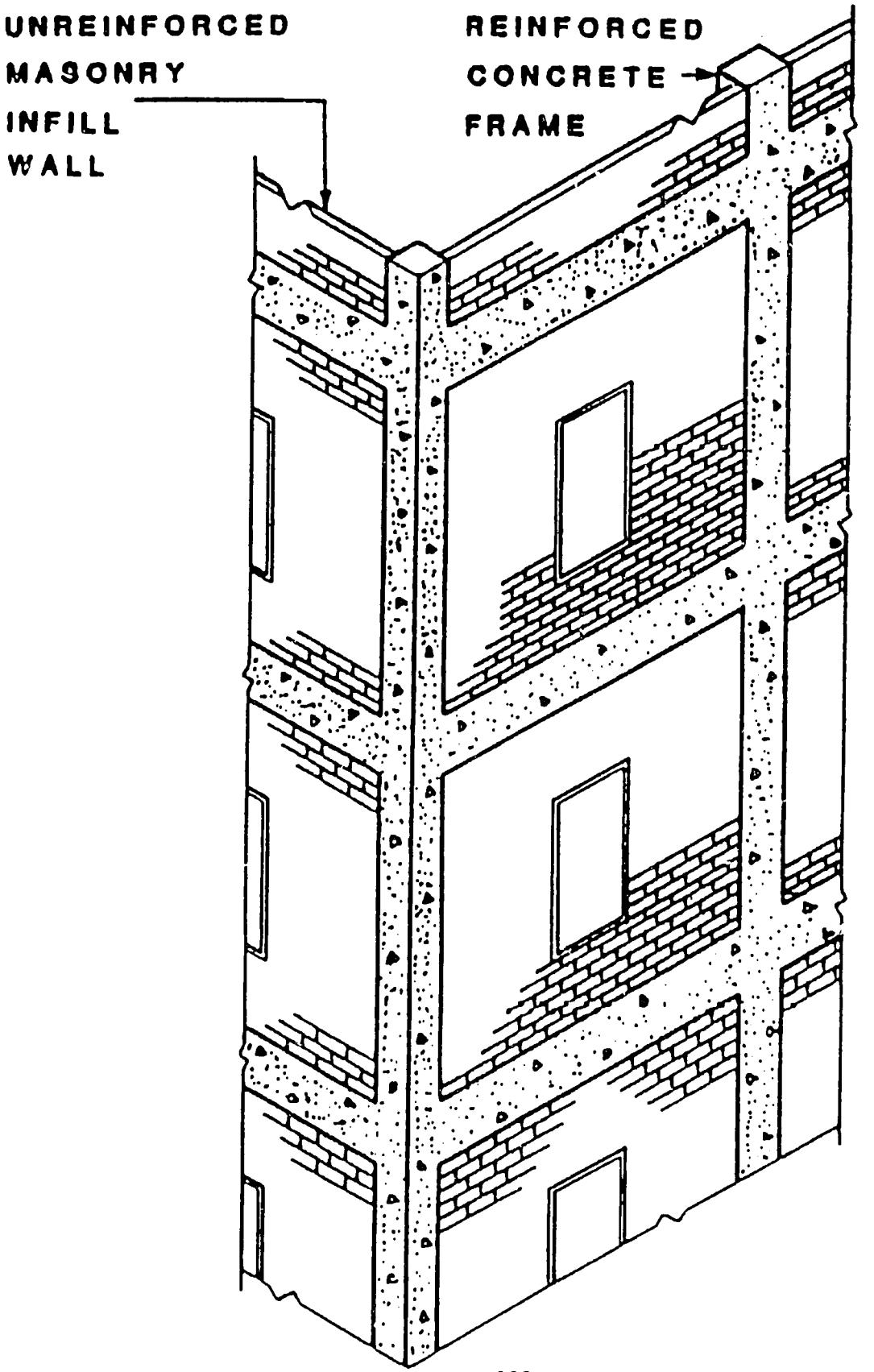
UNREINFORCED MASONRY • URM

BF 4



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CONCRETE FRAME WITH URM INFILL

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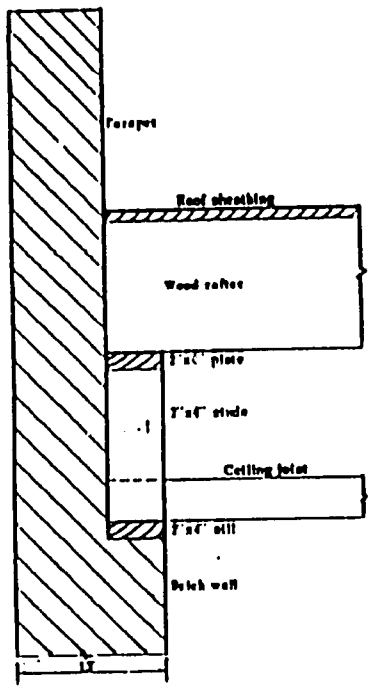
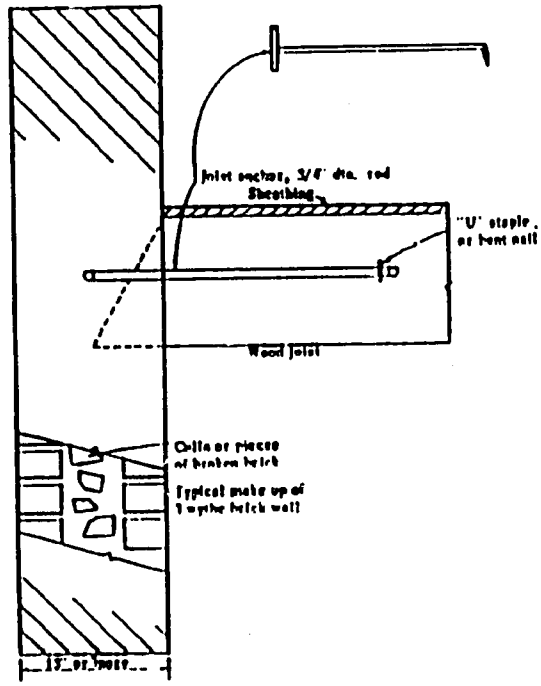
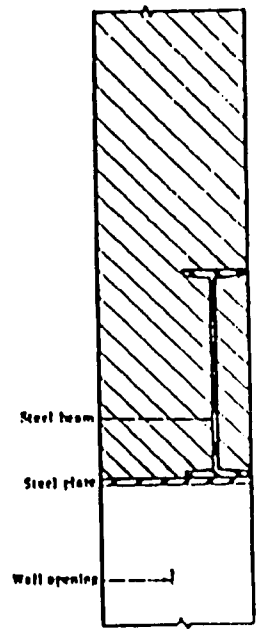
DETAILS TO ANCHOR UNREINFORCED MASONRY WALLS



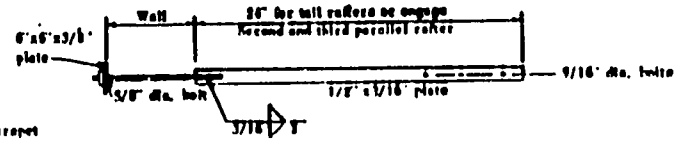
DETAIL A
Roof Rafter at Wall



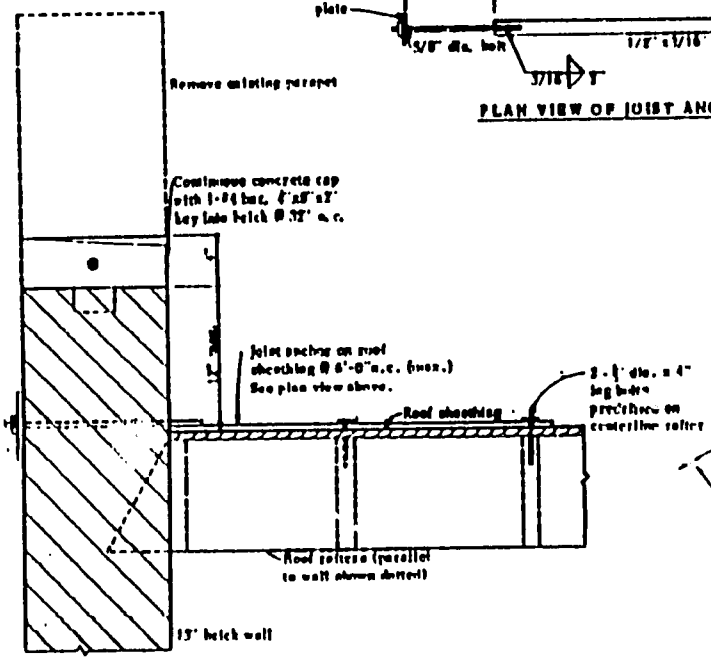
DETAIL B
Floor or Roof Joist at Wall



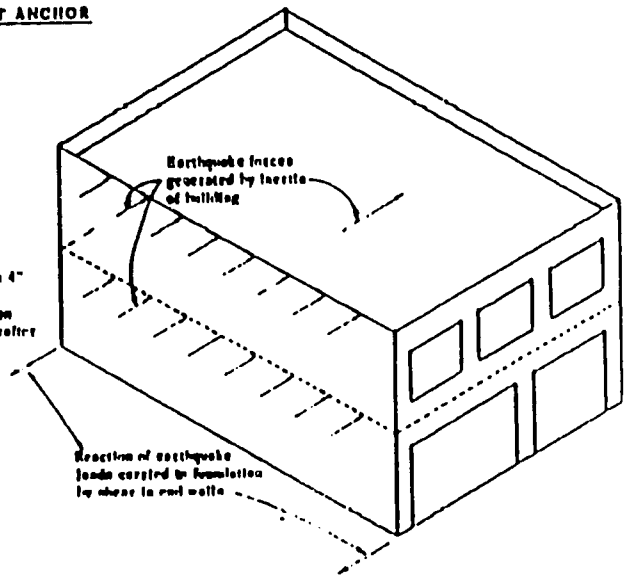
DETAIL C
Steel Lintel at Opening



PLAN VIEW OF JOIST ANCHOR



DETAIL D



DETAIL E

BF 5

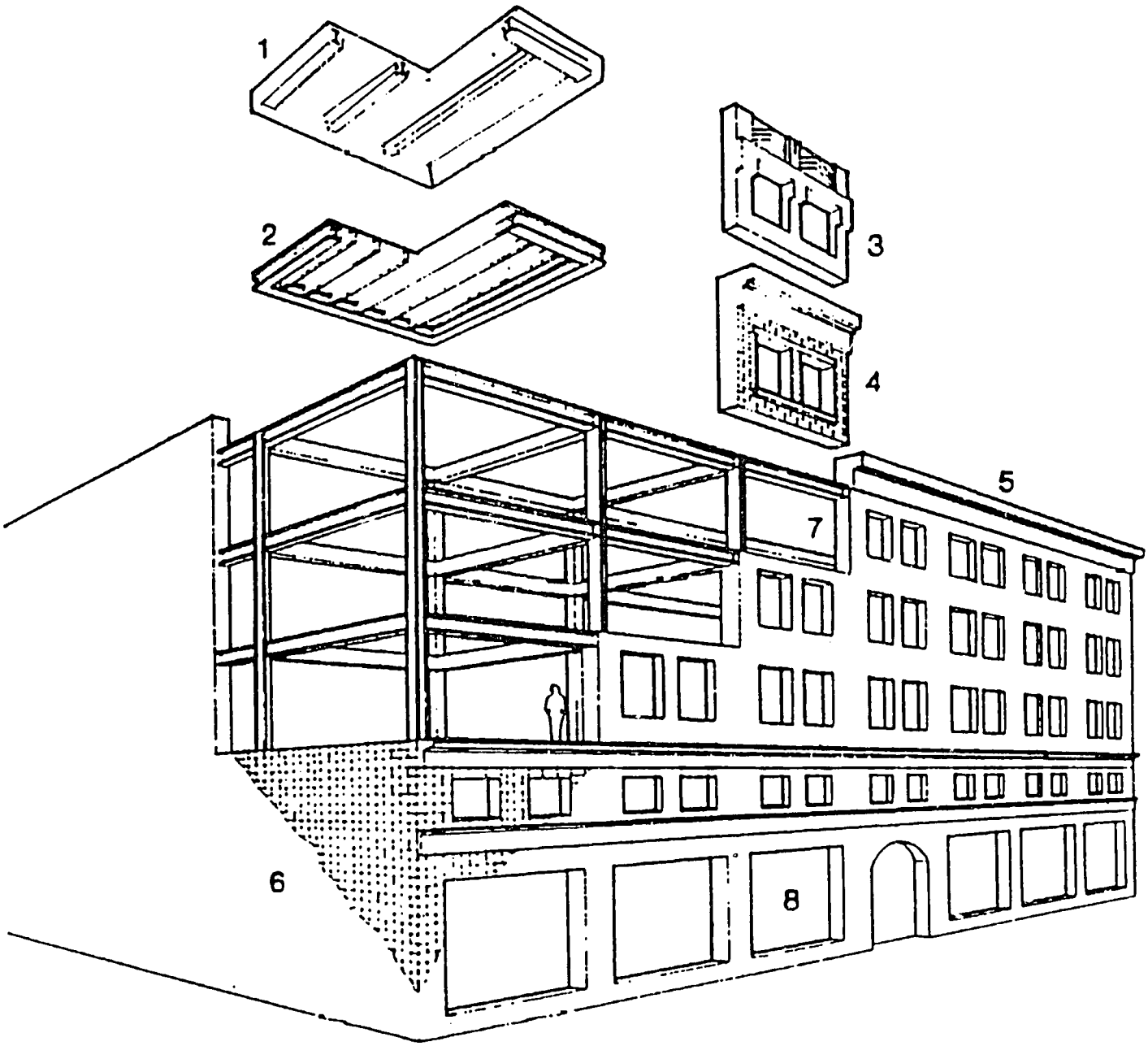
306

STEEL FRAME WITH URM INFILL

BF 6

Roof/floor span systems:
1. steel framing with concrete cover
2. wood floor joist and diaphragm (diagonal and straight)

Wall systems:
3. non-load-bearing concrete wall
4. non-load-bearing unreinforced masonry cover wall



Details:
5. unreinforced and unbraced parapet and cornice
6. solid party walls

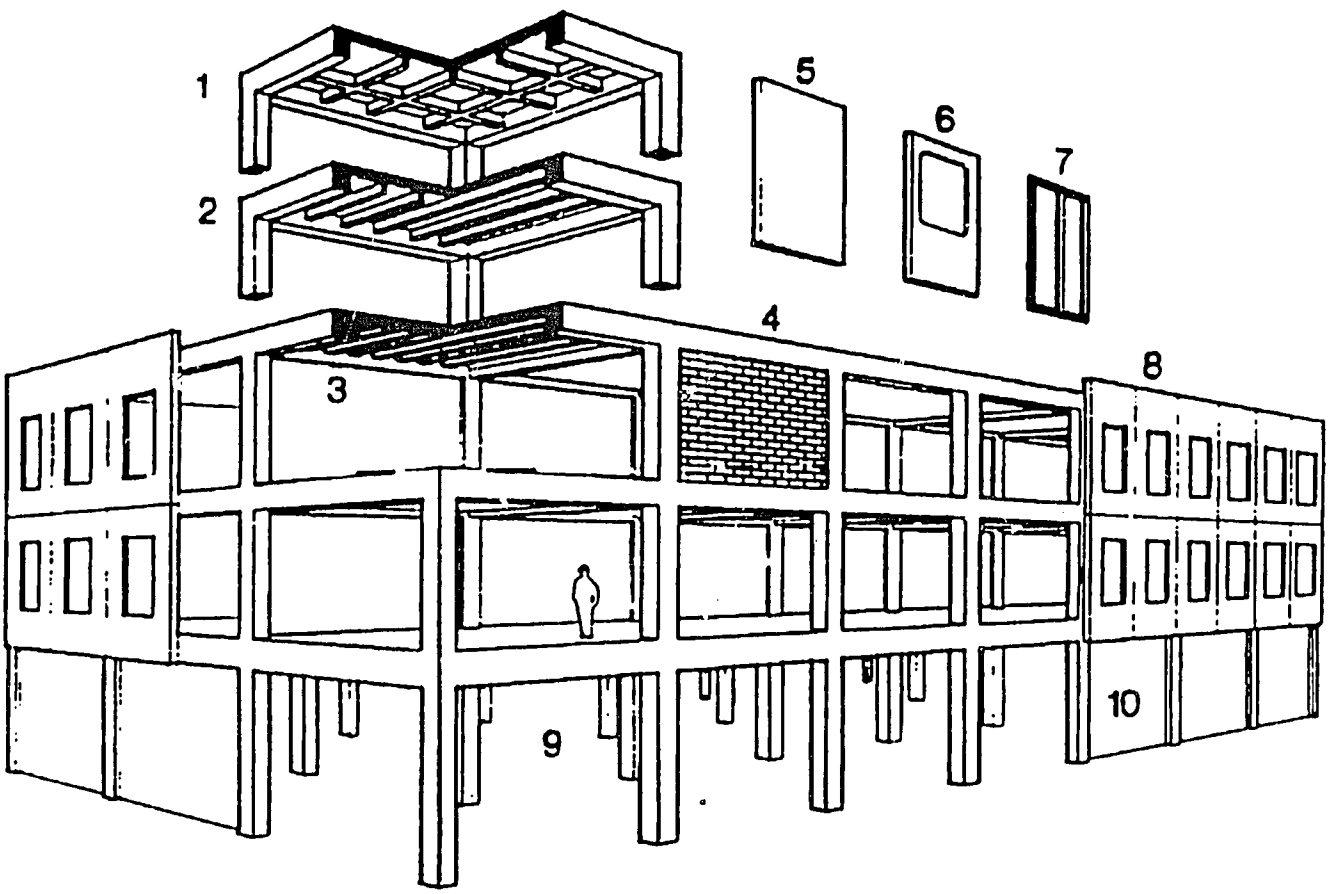
Openings and wall penetrations:
7. window penetrated front facade
8. large openings of street level shops

306

CONCRETE MOMENT RESISTING FRAME BF 7
C1

Roof/floor diaphragms:
1. concrete waffle slab
2. concrete joist and slab
3. steel decking with concrete topping

Curtain wall/ non-structural infill:
4. masonry infill walls
5. stone panels
6. metal skin panels
7. glass panels
8. precast concrete panels



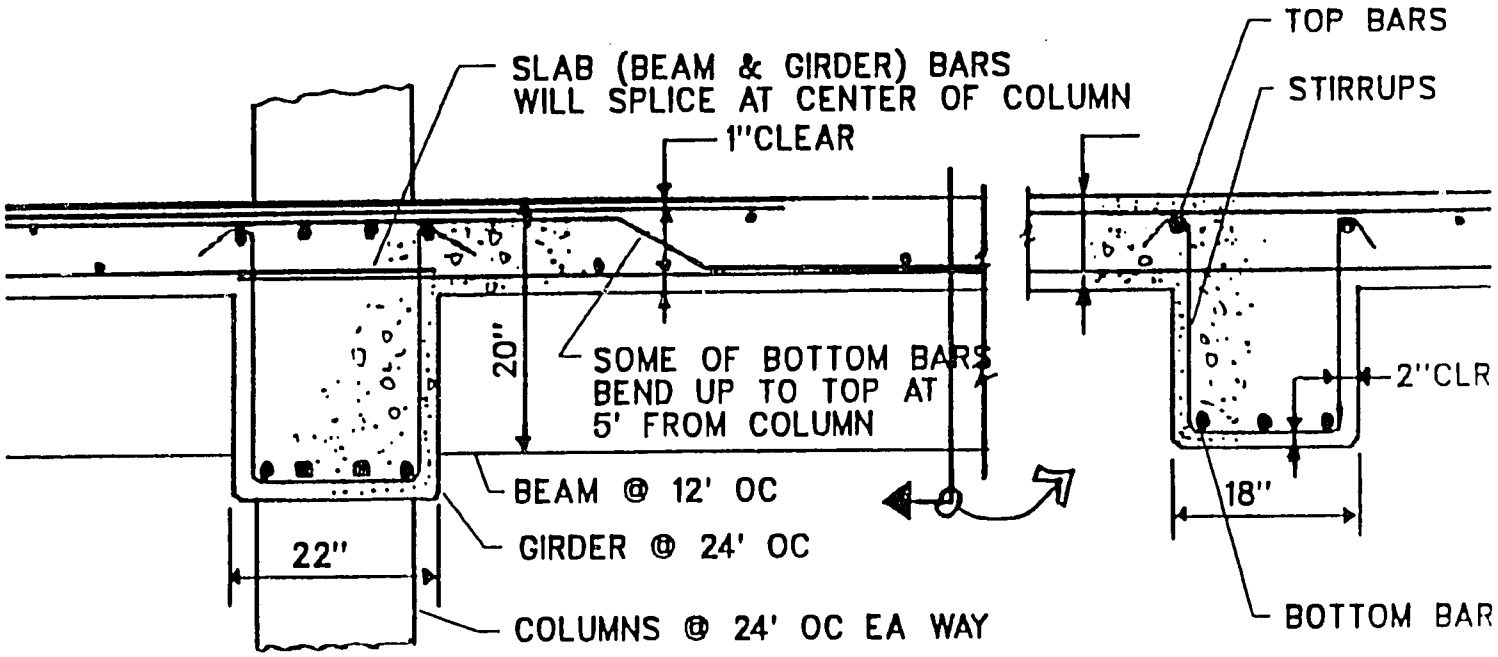
Structural system:
9. distributed concrete frame

Details:
10. typical tall first floor (soft story)

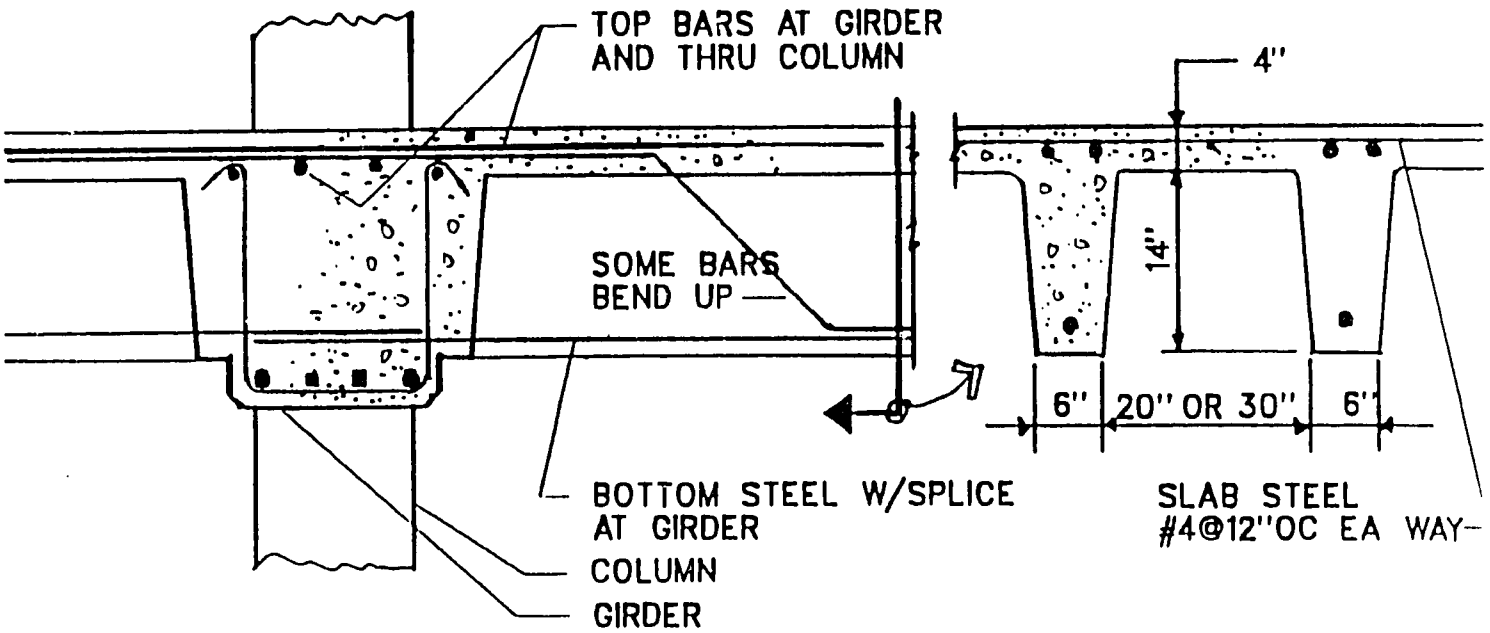
307

CONCRETE FLOOR CONSTRUCTION
TYPICAL OF OLDER CALIFORNIA FRAMING

BF 8



SLAB, BEAM, & GIRDER



PAN JOIST AND GIRDER

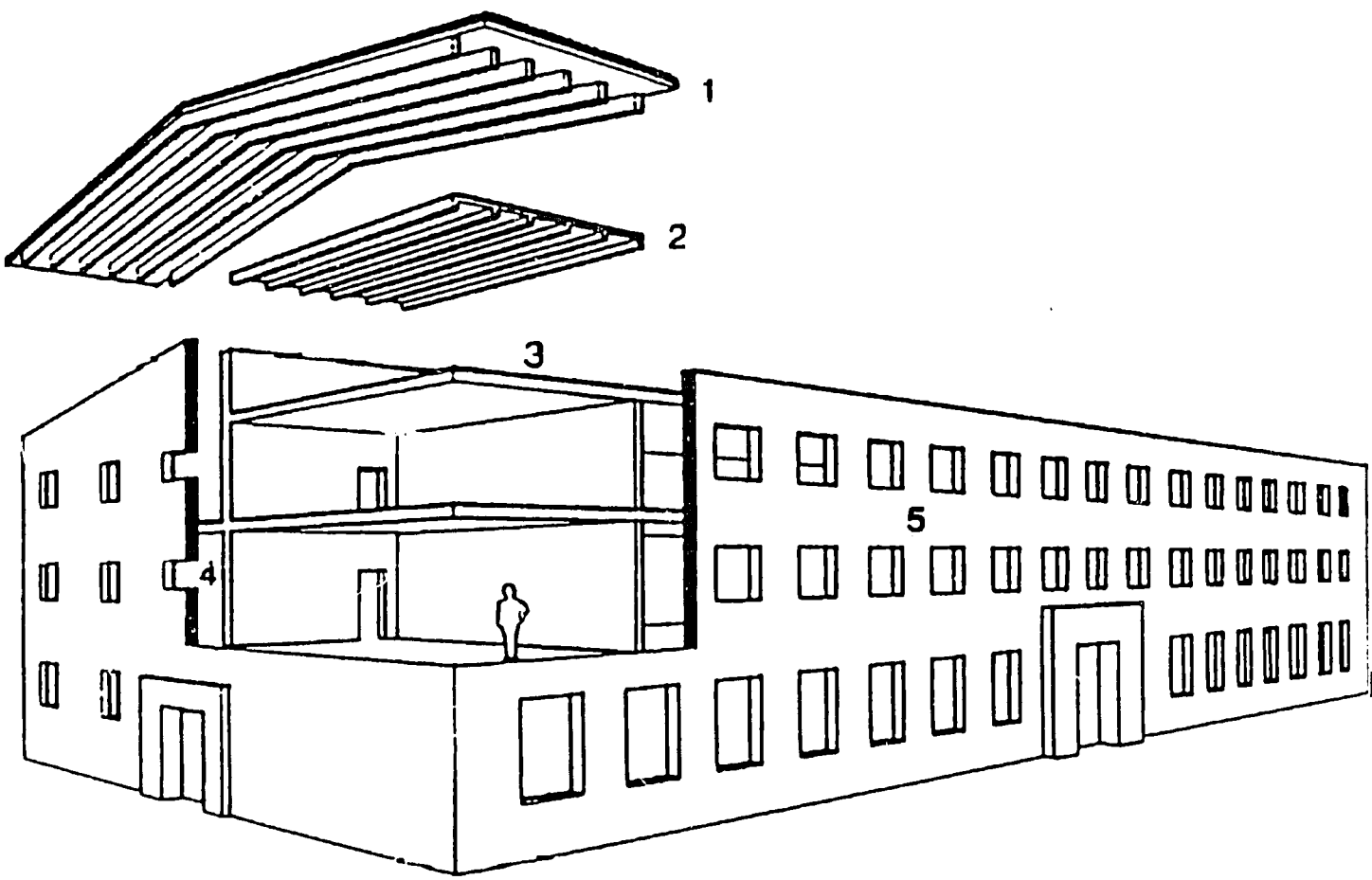
98

CONCRETE SHEARWALL BLDG • C2

BF 9

Roof/floor span systems:
1. heavy timber rafter roof
2. concrete joist and slab
3. concrete flat slab

Wall system:
4. interior and exterior concrete bearing walls
5. large window penetrations of school and hospital buildings



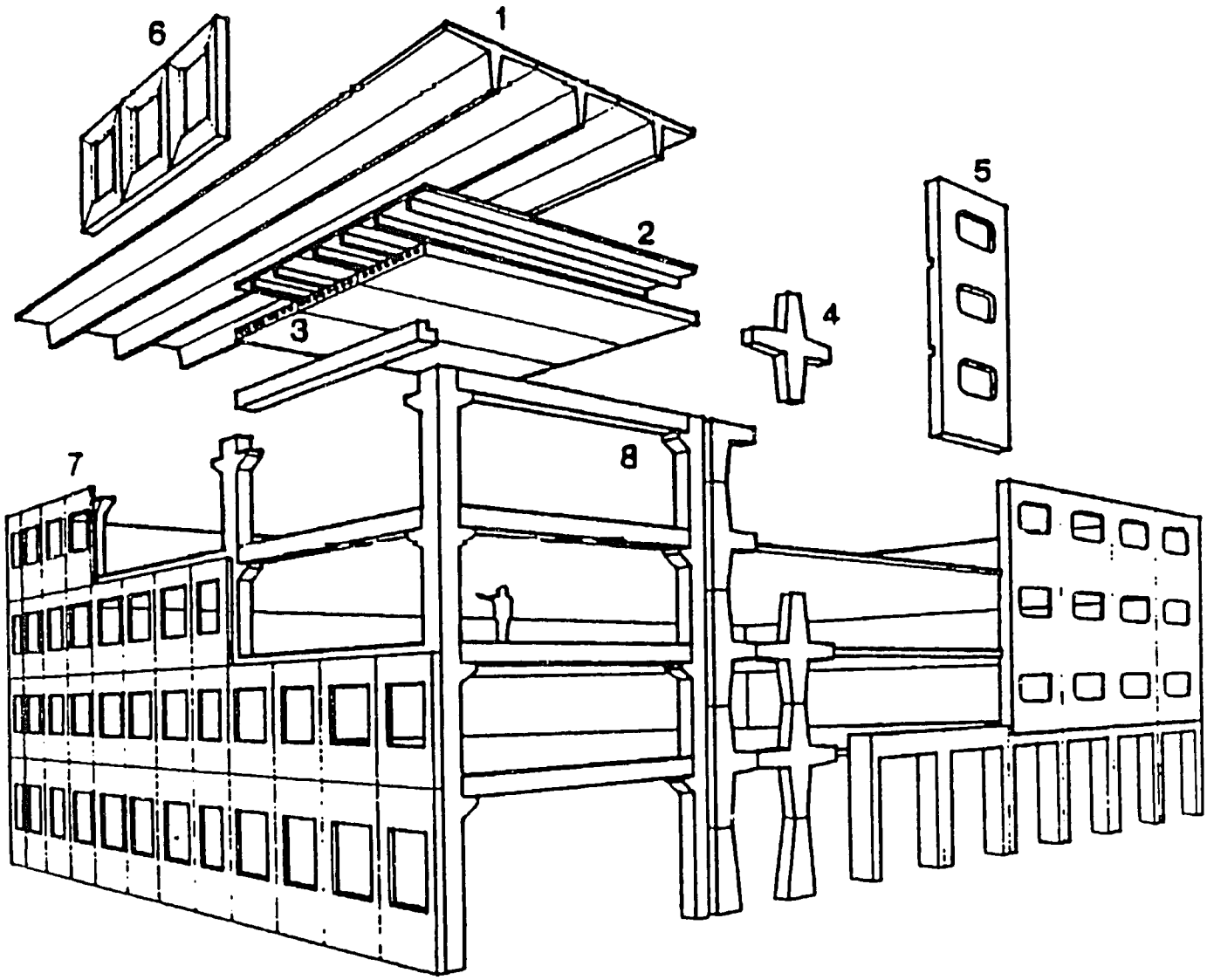
-309

PRECAST CONCRETE • PC2

BF 10

Roof/floor span systems:
1. structural concrete "T" sections
2. structural double "T" sections
3. hollow core concrete slab

Wall systems:
4. load-bearing frame components (cross)
5. multi-story load-bearing panels



Curtain wall system:
6. precast concrete panels
7. metal, glass, or stone panels

Structural system:
8. precast column and beams

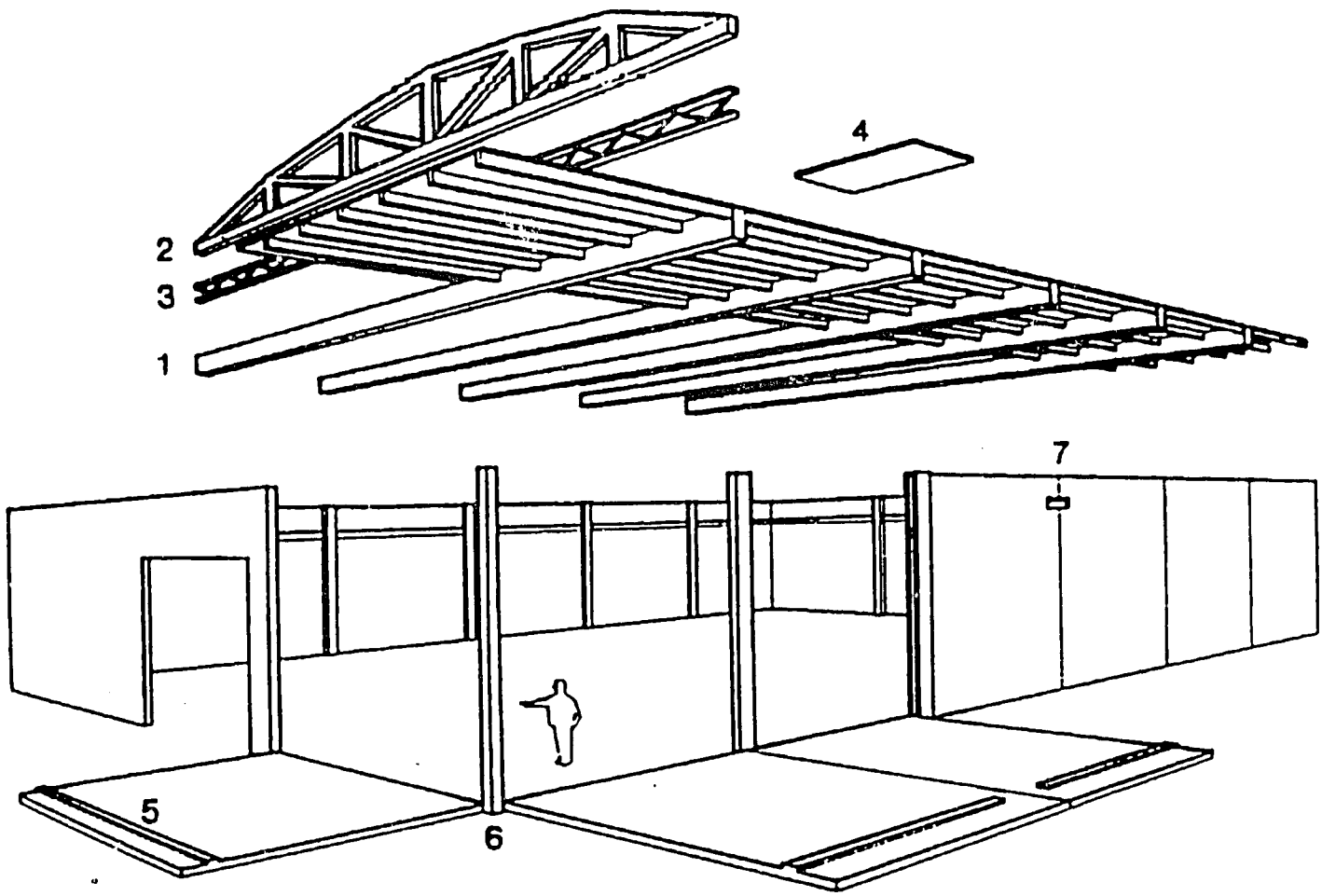
PRECAST CONCRETE FRAME W/ SHEARWALLS

TILT–UP CONCRETE WALL BLDGS • TU

BF 11

Roof/floor span systems:
1. glue liminated beam and joist
2. wood truss
3. light steel -web joist

Roof/floor diaphragms:
4. plywood sheathing



Details:
5. anchor bolted wooden ledger for roof/floor support

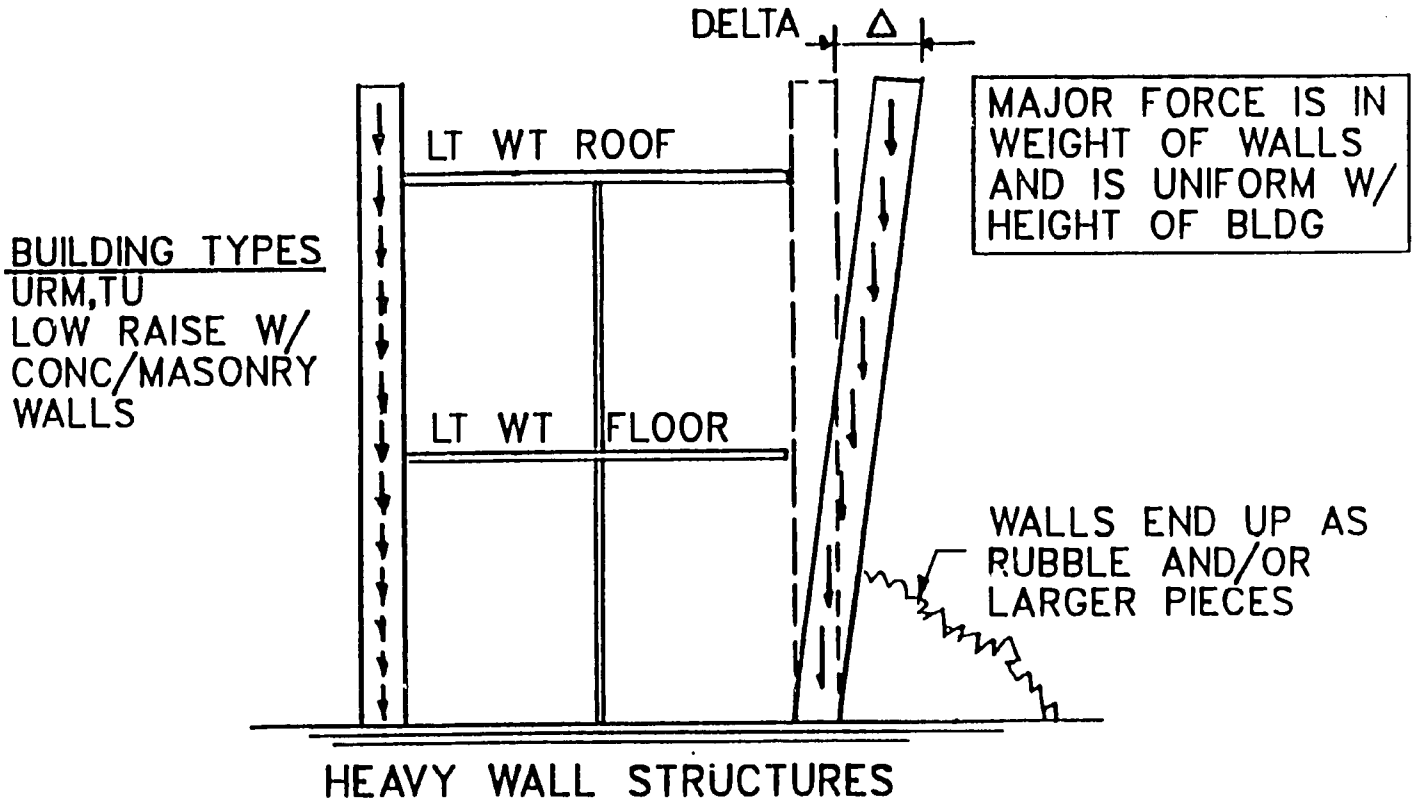
Wall systems:
6. cast-in-place columns– square, "T" shape, and "H" shape
7. welded steel plate type panel connection

ONE STORY TILT–UP BUILDING (ALSO MAY BE 2 OR 3 STORY)

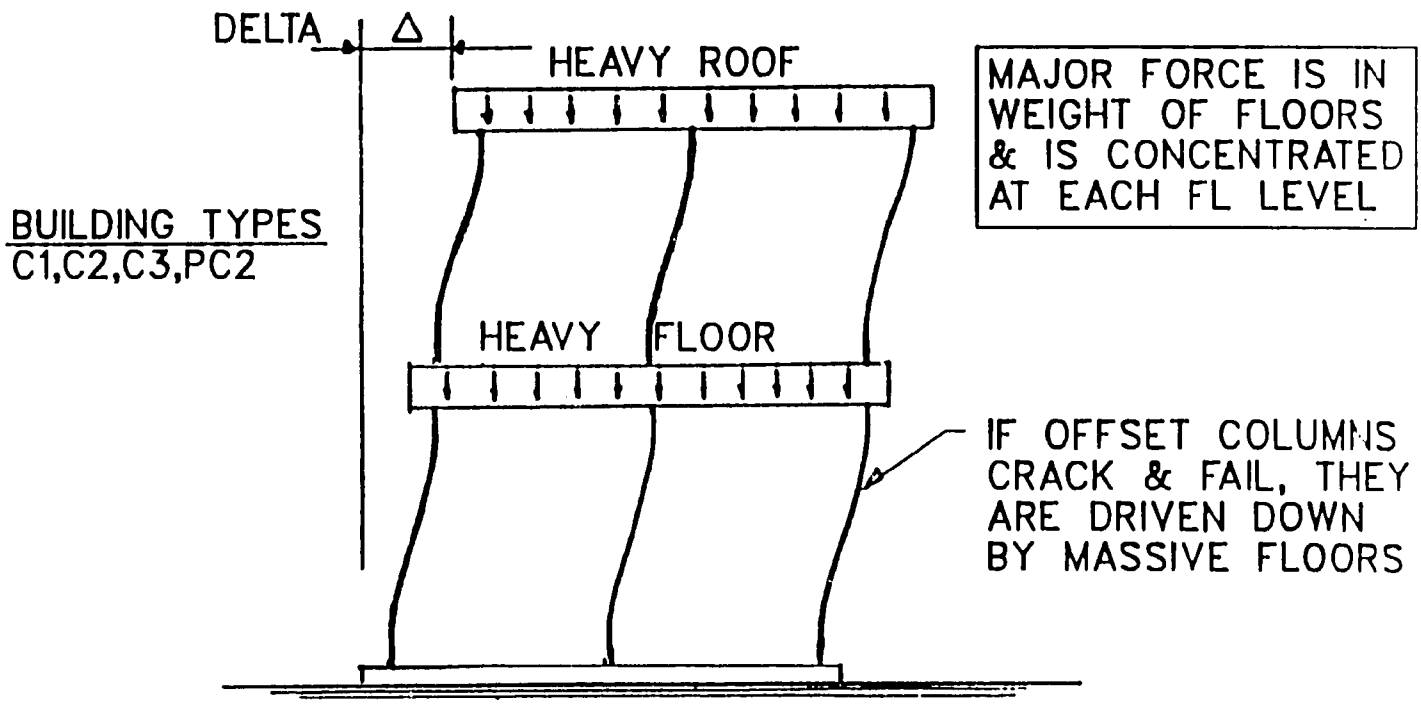
.311

STRUCTURAL FAILURE TYPES

BF 12



HEAVY WALL STRUCTURES



FRAME STRUCTURE W/ HEAVY FLOORS

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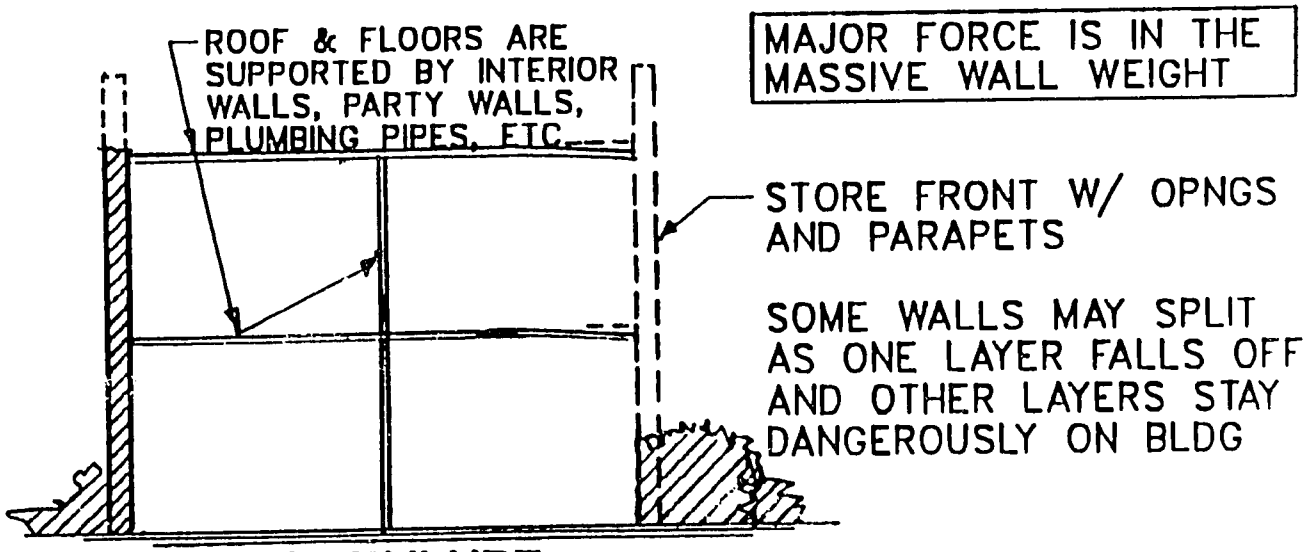
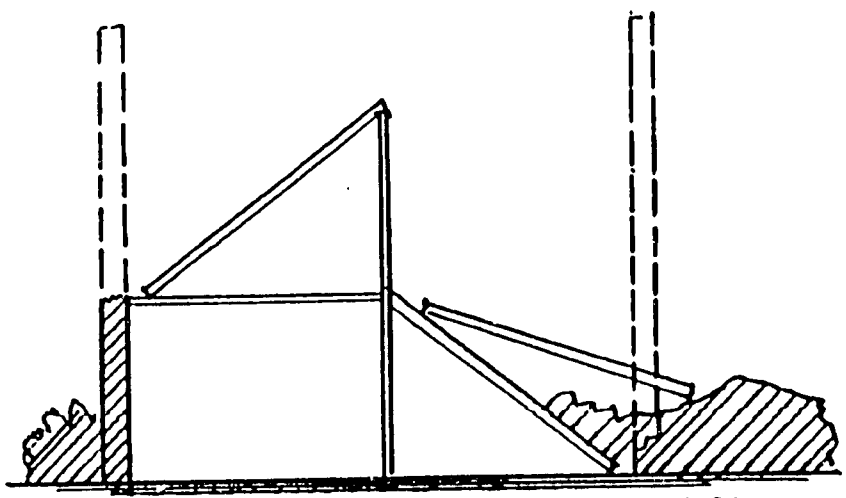
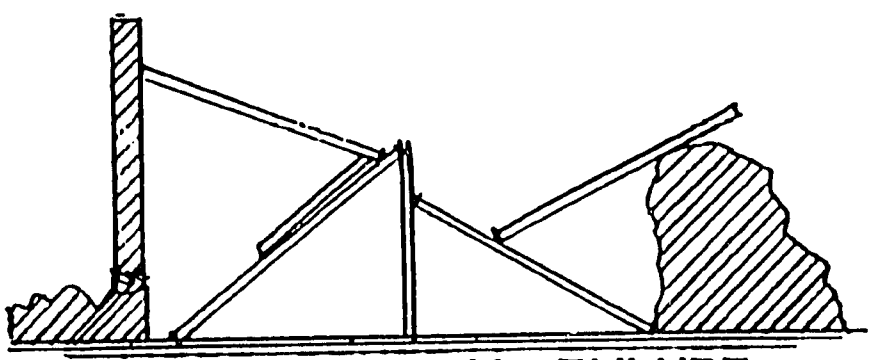
URM FAILURES



TYPICAL FAILURE



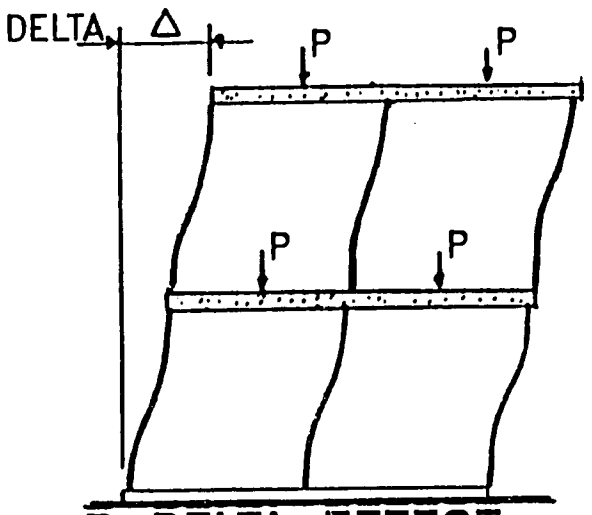
MORE WALLS COLLAPSE



MORE GENERAL FAILURE

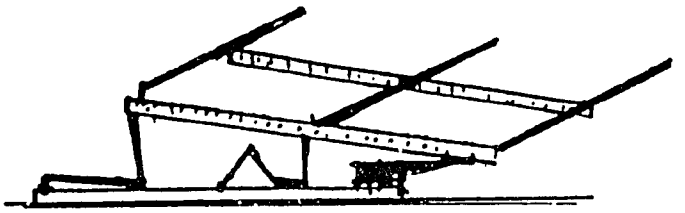
CONCRETE BUILDING FAILURE TYPES

BF 14

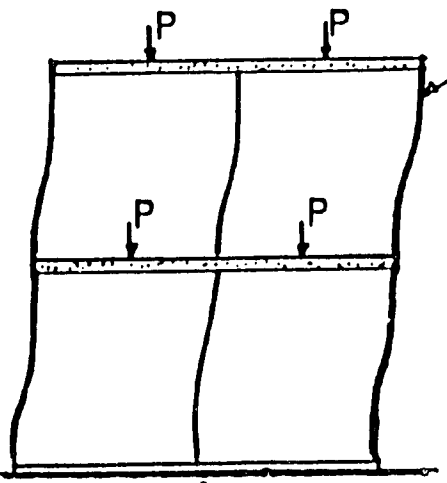


MAJOR FORCE IS IN THE MASSIVE FLOOR WEIGHT

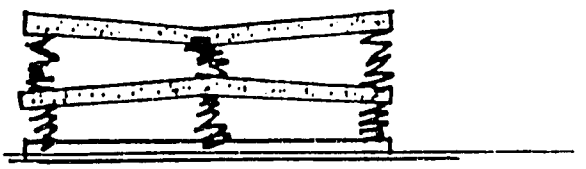
LOAD P IS OFFSET SO LARGE A DELTA THAT IT KEEPS GOING OVER



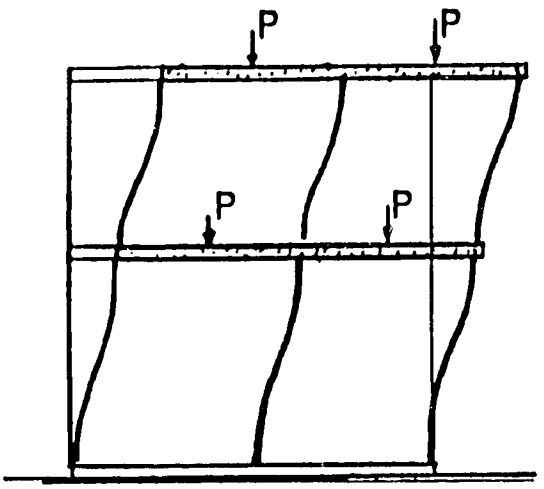
P-DELTA EFFECT

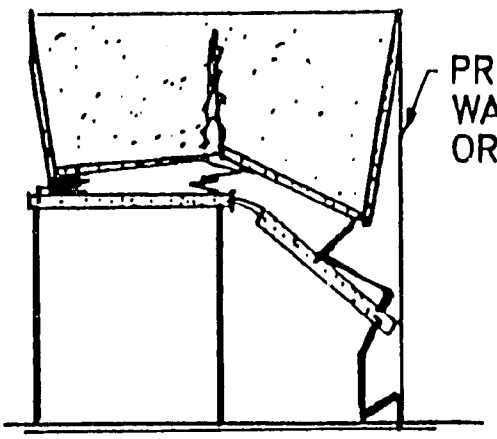


CONCRETE IN COLUMNS IS OFTEN NOT WELL ENOUGH CONFINED BY REBAR TIES AND WHEN CONC FALLS OFF THE VERT REBAR POPS OUT



COLUMN/JOINT FAILURE



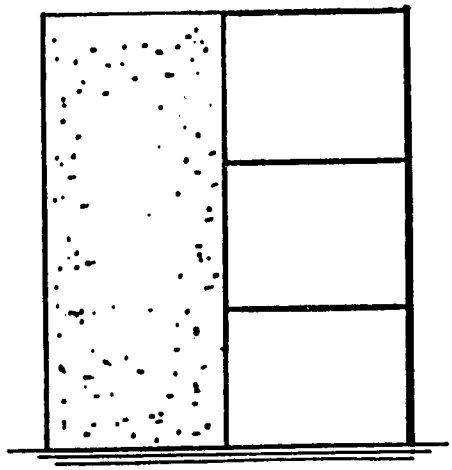


PROPERTY LINE WALLS ON TWO OR THREE SIDES

TORSION EFFECT

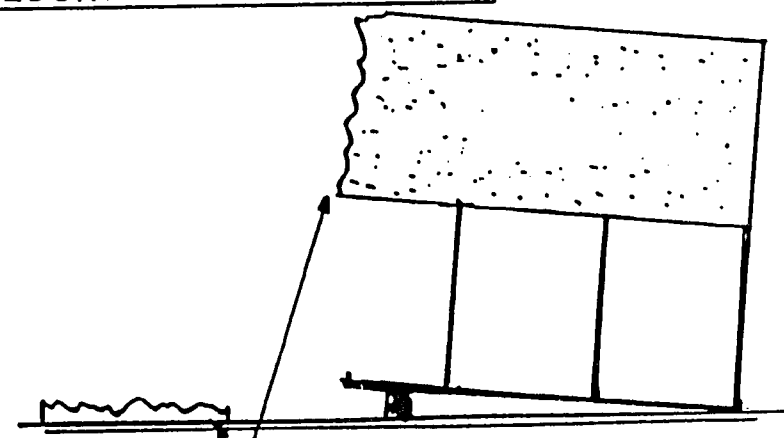
CONCRETE BUILDING FAILURE TYPES

BF 15

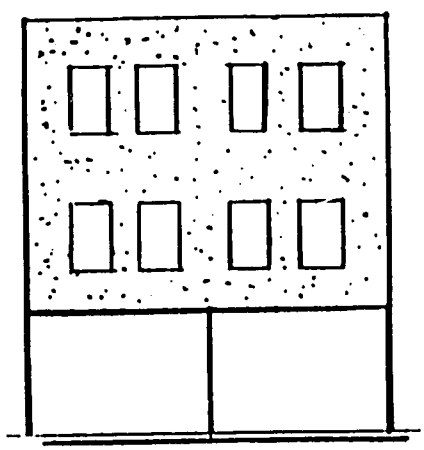


OVERTURNING

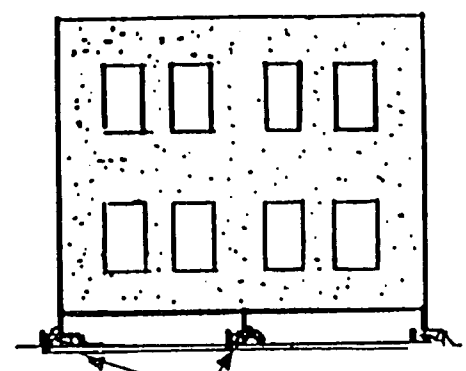
WEIGHT IS ABOUT EVENLY DISTRIBUTED BETWEEN FLOORS AND WALLS



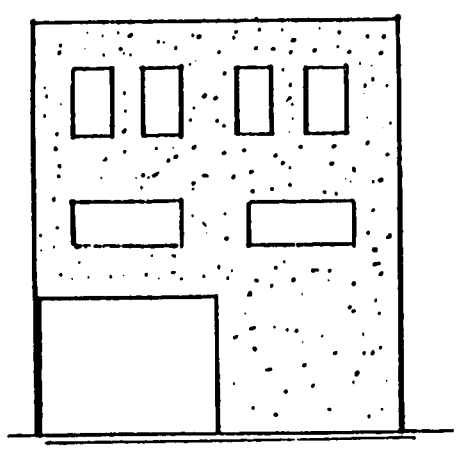
FAILED SHEARWALL OR FOUNDATION FAILURE



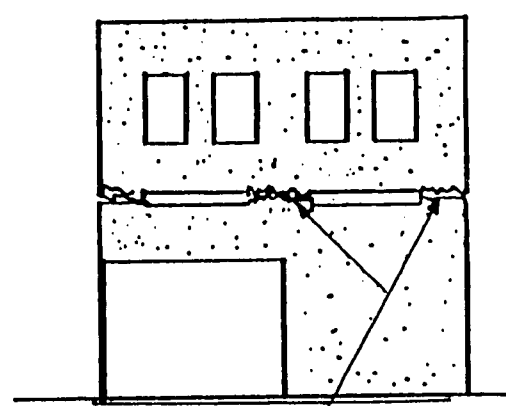
SOFT 1ST STORY



FAILURE OF 1ST STORY COLUMNS



SHORT WALL COLUMN



FAILURE OF COLUMNS & POSSIBLE COLLAPSE OF STORY

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IV. SHORES AND SHORING

A. Definition - Temporary support of structures during construction, demolition / reconstruction, and after collapse.

1. Vertical and or lateral support to hold structure up - keep it in place.

2. Opposing lateral support - to keep trench hole etc. from filling in.

B. Considerations For Design / Selection of Shoring Method

1. Weight to be supported - concrete / masonry weight is 125 - 150 PCF, normal concrete floor 100 - 150 PSF, wood floor 10 - 20 PSF, etc.

2. Condition of structure to be supported - solid concrete slab, broken slab, masonry rubble - Determines spreading system needs.

3. Condition of foundation of shoring - solid ground, slab on ground, floor over basement below, rubble.

4. Availability of shoring materials - pre plan, local contractors, foreign location.

   a) For collapsed structures want light, portable, adjustable, reliable, and forgiving shoring system

5. Shoring system is like double funnel.

   a) You collect load thru funnel, get it into the posts / struts, then you need to distribute it out into the supporting structure below. You need to do both.

   b) Shoring wants to be passive and gently support not move the structure, or cause sudden failures.

      (A heavily loaded wood post can punch thru a concrete slab etc.)

6. Collapsed buildings can contain lateral as well as vertical instability.

   a) If structure is partly supported by tension structure-like system, horizontal forces are often induced in remaining structure.

b) Collapses that have large remaining pieces can be extra dangerous. Interconnected pieces may depend on each other for support. A complicated balancing act to be wary about.

c) Total load of structure above can be relatively easily calculated, but where individual load concentrations are being applied is often difficult to determine. A shoring system that will give warning of overload is therefore most desirable.

B. Types of Shores

1. Vertical Posts / Columns -

a) Single wood posts

> Unless very short strength depends on buckling. Does not vary much with different species of wood. (See SH1)

> Short posts (4x4 less than 5 Ft., 6x6 less than 8 Ft.) depend on crushing strength which can vary 100 percent depending on closeness of grain and species.

> Douglas Fir (west) and Southern Pine (south east) are normal structural wood types.

> Wood made adjustable by wedges, cutting, and screw type steel foot.

b) Steel Pipes (See SH2)

> Depend on buckling strength

> Are normally adjustable by screw end or sleeve and pin and have square plate feet

> Tilt up wall braces up to 30 Ft. long (normally used as lateral brace)

c) Adjustable jacks - screw, ratchet (SH2)

> Usually short (1 to 2 Ft.) Have rated capacity

> Normally need something to spread load at top and bottom

> Extendible trench shores - screw from 1 to 4 Ft.

> Automobile jacks (one available in every car)

d) Hydraulic and Air Trench Shores (SH2)

> Medium length 2 to 4 Ft.

> Rated, but low capacity under air pressure (After pin is inserted - have good capacity)

> Light weight and adjustable

2. Multi Member Vertical Shores (SH2)

a) 4 wood post laced frame

> Spreads load at top and bottom

> Has lateral bracing to reduce buckling potential of individual posts and provide some lateral bracing

> Can customize to location

> Takes time to build

b) Cribbing (SH1)

> Multi piece wood laid on side and crossed. Spreads load well and has many load transfer surfaces

> Has lateral stability depending on width to height. Should make individual pieces about 3 ft. long for 9 ft. high crib (Height about 3 times width) but pieces should not be less than 2 ft. long

> Crushing strength of side loaded wood is only 1/3 to 1/2 of end loaded, but crushing failure is slow and gives warning. This makes this method desirable. It has forgiveness and will tell you when it's overloaded.

> Very adjustable

c) Large multi post systems

> Built up wood systems

> Steel / aluminum frames - two pipes laced together to make frame. Frames then connected together to make four or more laced posts.

> May be too complicated to consider

d) Scaffolding systems (SH5)

> Readily available from const. supply company.

> Metal systems, comments same as for (c)

3. Other Vertical Supports

a) Air bags -

> Uniform pressure for gentle support of structure.

> Very adjustable

> Not puncture proof - look out for metal points

b) Air Shores - See previous: (1. Vertical Posts, d.)

c) Tunnel Liner Plates - (SH3)

> Assembled segments form hollow circular shaft

> Design assumes uniform load from top and uniform support from bottom.

> Time consuming to install correctly

> Not too useful around big chunks of concrete or existing odd shaped cavity

> Have been used in underground rescue

d) Steel and concrete culvert sections - non adjustable tunnel liner

4. Lateral Bracing Shores (SH4)

a) Standard fireman's raker shore

> Need to be a attached to wall or will have to rely on friction to keep from slipping. It will move up wall

> 4x4 over 8 Ft. can more easily buckle than crush. Needs to be braced <u>in-out</u> direction and in <u>left-right</u> direction.

> Probably not useful in large concrete bldgs

> Same system could be used with 6x6 posts to greatly improve strength, but with improved strength the spreading system on the wall and bottom end bearing of brace become critical.

b) Tilt Up Wall Braces (See SH4)

> Available up to 30 Ft. long

> Rated capacity and are adjustable

> Anchor bolt (drill-in) each end for stability

> Ground end needs a foundation or slab

> Can act in compression or tension (tension depends on weight and connection of foundation.

5. Lateral - Opposing Shores

a) Trench shores - consist of shores plus sheathing and or beams

> Adjustable screw -- air shore -- air bags

> Wood and shim systems -- Pipe shore w/ jack

b) Collapsed Building - hold concrete slabs apart. Keep opening stable

> Can use same systems as for trench shoring, but must consider how the spreading forces will be resisted by rest of collapsed structure.

> Overly aggressive shoring can cause shifts of large heavy sections.

D. SUMMARY FOR COLLAPSED STRUCTURE SHORING

1. Shores want to be strong, light, portable, adjustable, and reliably support the structure as gently as possible.

2. Best system at this time is cribbing since it is :

a) made from many light pieces that are adjustable

b) relatively wide and stable. Will spread the load.
c) Is a slow failure system that will give warning so strength may be added or area cam evacuated.

3. Systems need to be tested in order to determine best methods to resist:

a) Loads on sloped surfaces above and below

b) Loads during large aftershocks

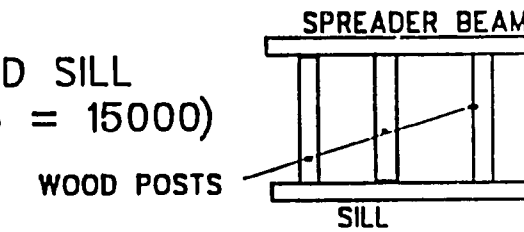
VERTICAL SHORES

SH 1

1. PLAIN SINGLE WOOD POSTS – 4X4 OR 6X6 • CAPACTY IN LBS

HEIGHT (FT)	6	8	10	12	14	16	18
4X4	12000	8400	5200	3600			
6X6	30000	30000	30000	22000	16000	12000	9800

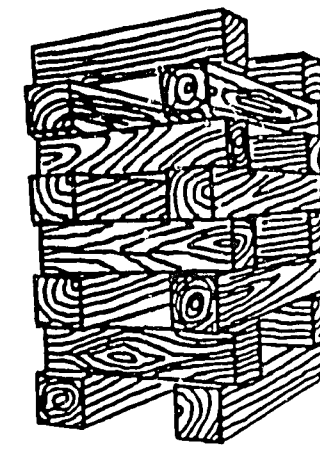
2. WOOD POSTS WITH SPREADER BEAM AND SILL
(MAXIMUM EA 4X4 = 6000 LB , EA 6X6 = 15000)



3. WOOD CRIBBING 4X4, 6X6 LAID FLAT

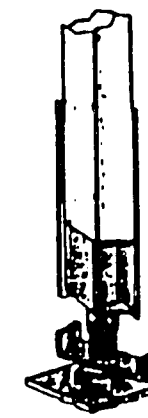
LIMIT BASED ON 500 PSI
CROSSGRAIN BEARING
4X4 CRIB CAPACITY = 24000 LBS
6X6 CRIB CAPACITY = 60000 LBS

NOTE • IF USE 3 MEMBERS PER LAYER
WILL DOUBLE THE CAPACITY



4. ADJUSTABLE 4X4 WOOD POST
(METAL BASE W/SCREW)

9000 LB MAXIMUM CAPACITY



ALL VALUES GIVEN HAVE A 2 TO 1 SAFETY FACTOR
FOR DOUGLAS FIR & SOUTHERN PINE WITH GOOD GRAIN

REMEMBER THAT WOOD STRENGTH CAN VARY GREATELY
DEPENDING ON SPECIES, CLOSENESS OF GRAIN, KNOTS, ETC.

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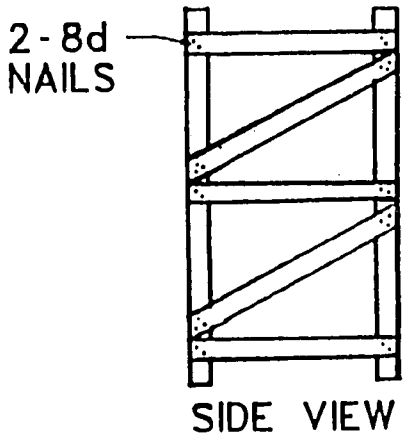
SPECIAL VERTICAL SHORES

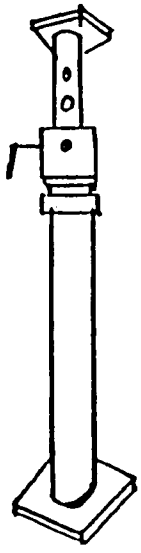
1. LACED POSTS



4 POSTS AT 3' TO 4' APART
EACH WAY IN SQUARE PATTERN

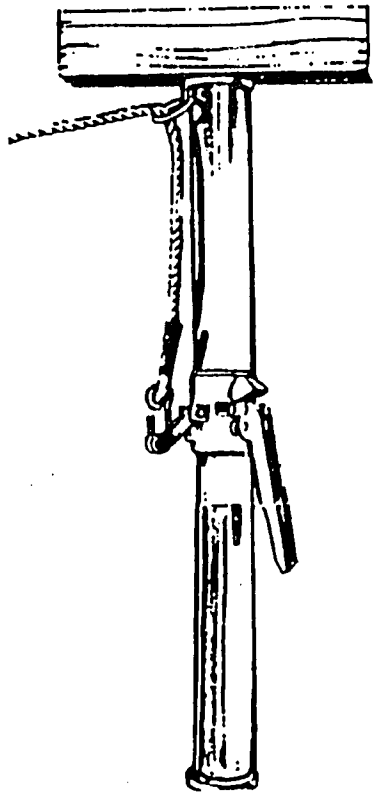
4X4 POSTS W/1X4 LACING
CAPACITY IS 48000 LB

2. ADJUSTABLE PIPE SHORES



- RENT FROM CONCRETE SUPPLY CO
- CAPACITY IS BASED ON PIPE DIA AND HEIGHT USED
- CAPACITY OF 2"INSIDE DIA PIPE THAT IS 10FT LONG = 8000 LB
- LARGE ADJUST W/PIN IN HOLE
  SMALL ADJUST W/SCREW COLLAR

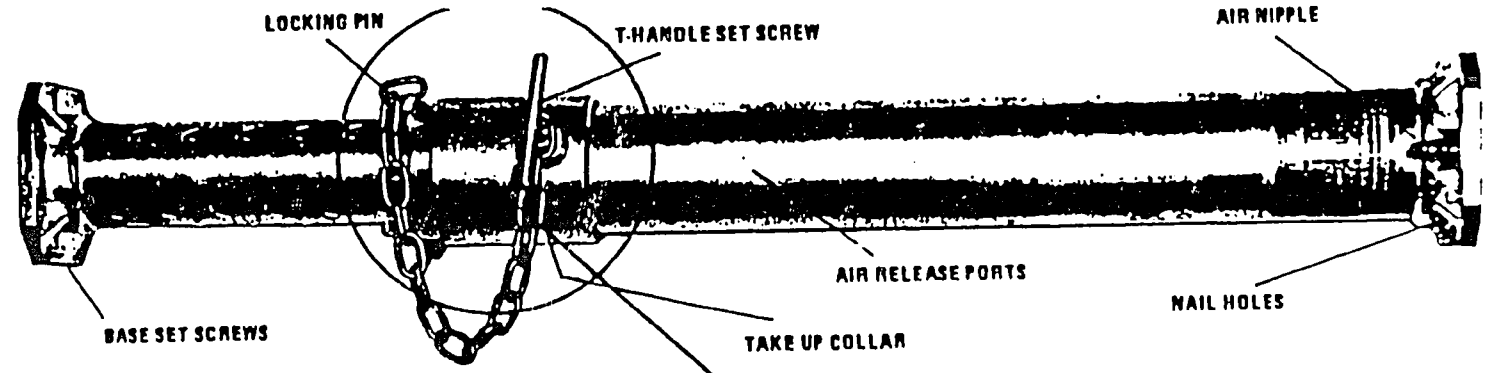
3. JACKS

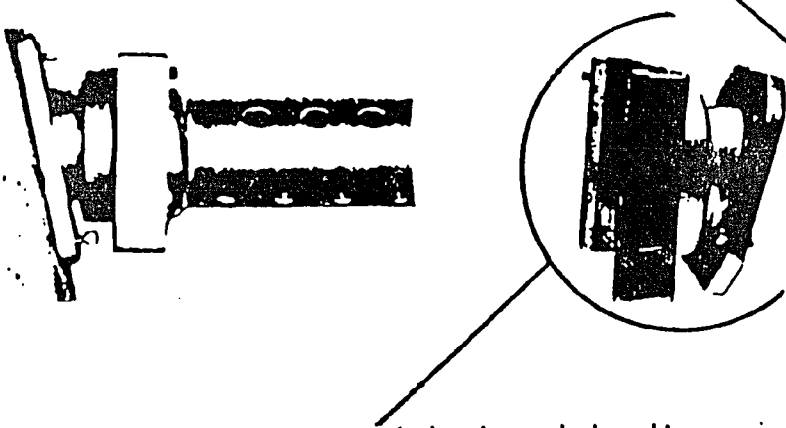


- SCREW TYPE
- HYDRAULIC TYPE
- RETRIEVABLE, HYDRAULIC, YIELDABLE MINE ROOF TYPE

SPECIALTY SHORES

• AIR SHORE •





The unique aluminum collar assures total mechanical take-up. Once the collar is secured, and the pneumatic pressure is released the AIRSHORE becomes a fixed mechanical strut.

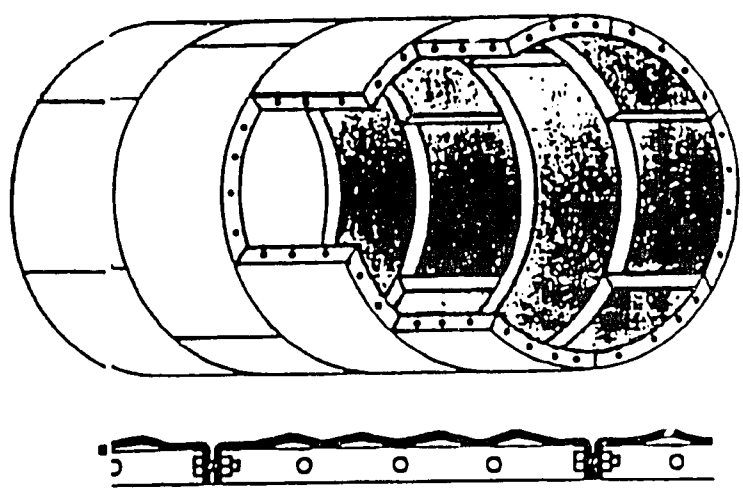
AIRSHORE struts operate from 100 PSI to 350 PSI providing thrust from 700 lbs. to 2,450 lbs.

Constructed of lightweight high tensile strength aluminum the AIRSHORE strut is capable of withstanding extreme pressure. Independent Engineering Company tests confirm a crush strength of 32,000 lb. while supporting a 400 lb. centre line load without slippage.

AIRSHORE Slip-on swivel ends are designed to fit any standard AIRSHORE base. Set screws provide positive bite into shoring members.

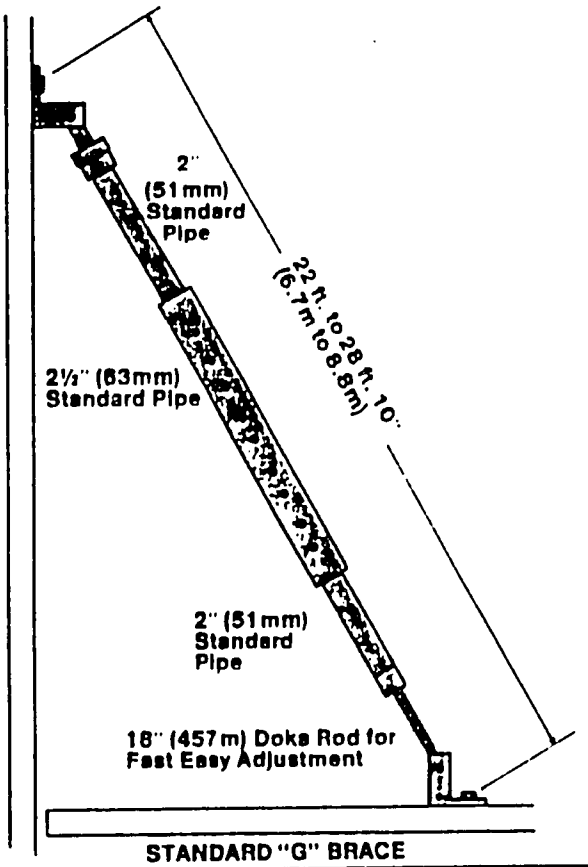
TUNNEL LINER PLATES

- ONLY USEFUL IF EVENLY FILLED ALL AROUND
- LIGHT WEIGHT – ASSEMBLE FROM 2FT SEGMENTS



AIR BAGS

COME IN VARIOUS SIZES • WARNING LIFTED OBJECT NEEDS BRACING



STANDARD "G" BRACE

STANDARD "G" TILT-UP BRACE

Order No. (263) 45-730

Burke's Standard "G" Brace is designed for use with large tilt-up panels. Major adjustments within 12 inches (305mm) of the insert are quickly made with sliding "L" pins. Fine adjustments then can be made utilizing the heavy-duty screw rod. Panels up to 30 ft. (9.1m) high are normally braced without knee braces or cross lacing

Brace Weight: 155 lbs. (70kg)

BIG "G" TILT-UP BRACE

Order No. (263) 45-700

The Big "G" Brace is a Standard "G" Brace with a longer center pipe section. It is intended for use with panels over 30 ft. (9.1m) high. The Big "G" adjusts from 24 ft. to 39 ft. (7.3m to 11.8m). On very tall panels, knee braces and cross lacing can be used to increase brace spacing.

Brace Weight: 214 lbs. (97kg)

LITTLE "G" TILT-UP BRACE

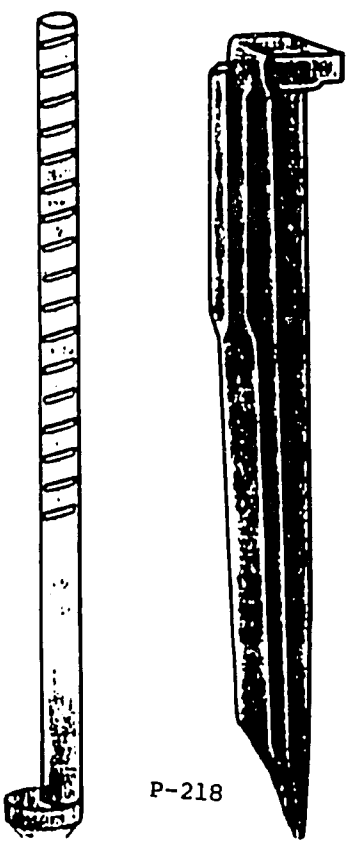
Order No. (263) 45-239

The Little "G" Brace is a Standard "G" Brace with a shorter top inner pipe section. It is intended for use with panels up to 28 ft. (8.5m) high. The Little "G" adjusts from 14 ft. to 20 ft. (4.2m to 6.1m).

Brace Weight: 122 lbs. (55kg)

SUPER BOLT

Order No. (267) 45-475



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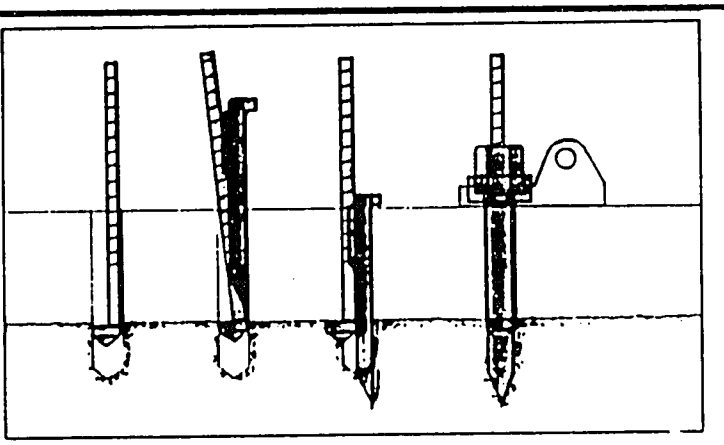


Super Bolt is a simple, economical and reliable method of securing tilt-up braces to the slab. It develops strength equivalent to a cast-in-place insert, yet is as easy to install as a drilled expansion bolt. Super Bolt fits slabs from 3½" to 7½" (89mm to 191mm) nominal thickness.

The economical Burke Super Bolt can be reused over and over again. When bracing is no longer needed, the bolt strips easily from the slab. Just pull up the wedge and remove the bolt. There are no bolt ends to cut out or expensive hardware left in the slab.

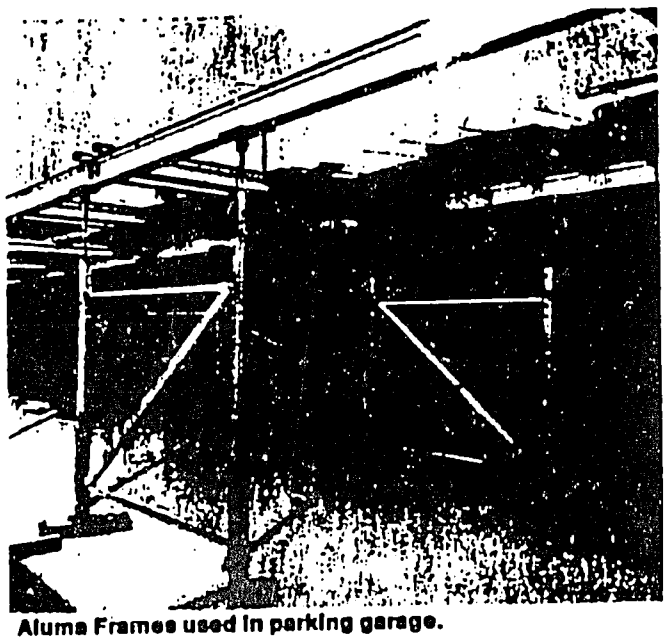
The bolt design assures positive engagement to the slab every time. Insert the bolt in a 1¼" (32mm) hole drilled through the slab to the sand or aggregate beneath. The lip of the bolt must face directly opposite the opening of the brace shoe slot. Make sure the bolt lip engages the bottom of the slab. Insert the wedge next to the bolt on the side opposite the lip and hammer it all the way into the hole so that the removal handle touches the slab. Slide the brace shoe around the bolt and tighten the hex nut. Slip the nut lock over the hex nut to secure it.

Quality materials guarantee strength and durability. The bolt section is a high tensile strength steel forging. The wedge is high strength cast ductile iron. Together they provide consistent safety and dependability job after job.

ALUMA FRAME

Group Order No. 130

Aluma Frame Features Highest Load/Weight Ratio on the Market



Aluma Frames used in parking garage.

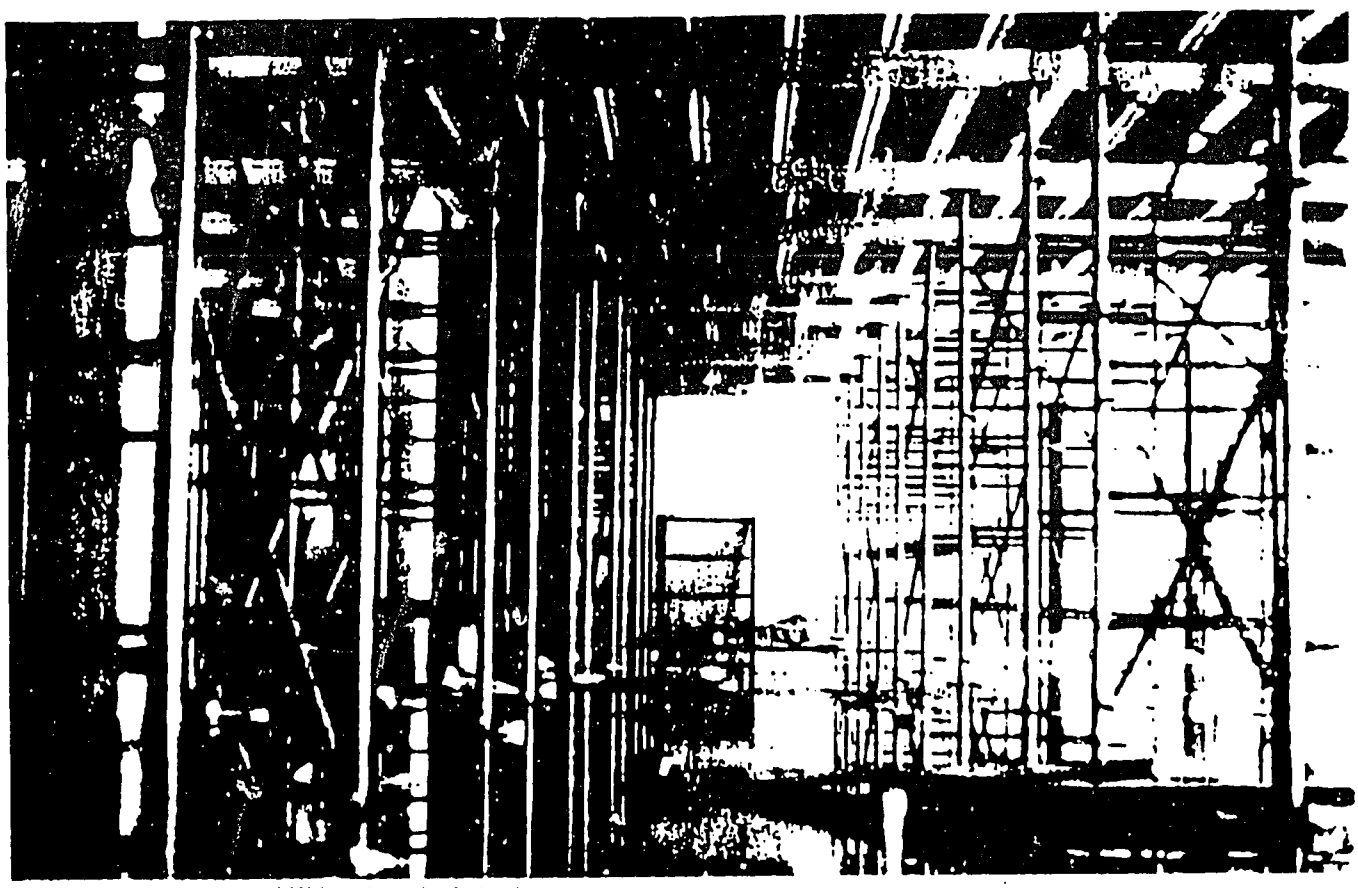
Lightweight aluminum shoring systems are easy to move around the job site. More importantly, the Aluma Framu carries more load per frame than conventional systems, vastly increasing the coverage per frame.

With a capacity of 18,000 lbs. (8 tonnes) per leg, 36,000 lbs. (16 tonnes) per frame based on a 2.5:1 safety factor and a weight of only 42 lbs. (19kg), the Aluma Frame is adaptable to both light and heavy construction projects.

The Aluma Frame increases coverage by 55 to 80%. A contractor will require fewer Aluma frames compared to conventional equipment because the Aluma Frame supports 280 sq. ft. (26m²) per tower compared to 180 sq. ft. (16.72m²) per conventionally framed tower (based on a 8" (203mm) slab).

Aluma frames are available for sale or rent in three sizes:

6 ft. wide x 3 ft. high (1.83m x .91m)
6 ft. wide x 5 ft. high (1.83m x 1.52m)
6 ft. wide x 6 ft. high (1.83m x 1.83m)



Stationary application of Hi-Load vertical shoring system.

5 PHASES OF URBAN HEAVY RESCUE

UHR 1

SPONTANEOUS

- UNSKILLED NEIGHBORS, COMMUNITY RESPONSE TEAMS/PERSONS REMOVE LIGHTLY TRAPPED & OR INJURED VICTIMS. PROBABLY GREATEST NUMBERS & BEST SURVIVAL RATE.

LIGHT IN PLACE RESCUE

- SEARCH ELEMENT SHOULD PRIORITIZE SITE TO BETTER MAKE RISK VS REWARD JUDGEMENTS.
- RESCUE PROCEEDS USING EXISTING CAVITIES, SMALL VERTICAL HOLES/SHAFTS, BASEMENTS.
- SOME SHORING SHOULD BE DONE TO PROVIDE PROTECTED AREAS.

HEAVY CAREFUL REMOVAL

- SPECIFIC PIECES OF HEAVY CONSTRUCTION ARE REMOVED TO ACCESS LOWER CAVITIES. THIS PRESENTS GREATER DANGER TO ENTUMBED VICTIMS, AND PROCEEDS SLOWLY.

BODY RECOVERY

- USING HEAVY LIFTING EQUIPMENT TO REMOVE LARGE BUILDING PIECES EMPHASIZING MINIMUM RISK TO WORKERS.

DEMOLITION

THEME OF USAR

- SAVE TRAPPED VICTIMS WHILE MINIMIZING THE RISK TO THEM AND THE SEARCH AND RESCUE TEAM MEMBERS

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D. FACILITY DESCRIPTION

Assessment Report # _____

	Lateral support system	Exterior walls	Roof diaphragm	Horizontal bracing	Interior bracing and/ or shear walls	Non-bearing partitions	Floors	Stairs	Other	Undetermined
Concrete										
Precast concrete										
Reinforced masonry										
Unreinforced masonry										
Steel frame										
Metal deck										
Wood										
Other										
Undetermined										

1. Number of stories _____
2. Number of basement levels _____
3. Pre-1934 design ?
   Yes ☐ No ☐ Unk ☐
4. Primary occupancy:
   Government ☐ Hotel/motel ☐
   Hospital ☐ Commercial ☐
   School ☐ Industrial/mfg ☐
   Office bldg. ☐
   Other _____

E. STRUCTURAL DAMAGE OBSERVATIONS (D.O.)

Damage Scale:	0 None (0%)	1 Slight (1-10%)	2-3-4 Moderate (11-40%)	5 Severe (41-60%)	6 Total (Over 60%)	NA Not Applicable	NO Not Observed

	D.O.
1. Exterior walls	____
2. Frame (general condition)	____
3. Frame members	____
4. Frame connections	____
5. Roof framing	____
6. Interior bearing/shear walls	____
7. Partitions (non-bearing)	____
8. Floor(s) ____ ____ ____	____
9. Stair(s) ____ ____ ____	____
10. Elevator ____ ____ ____	____
11. Glass	____
12. Mechanical equipment supports	____
13. Electrical equipment supports	____
14. Other ____ ____ ____	____

F. ESTIMATE OF DAMAGE

1. Approx. bldg. area ( ) ____
2. Est % of bldg. damaged ____
3. Est. damage valuation $ ____

G. FALLING HAZARDS

	Appar. Hazard	No Appar. Hazard	Unknown
1. Parapet walls	____	____	____
2. Ornamentation	____	____	____
3. Chimney (s)	____	____	____
4. Floor ____	____	____	____
5. Roof structure	____	____	____
6. Equipment	____	____	____
7. Other ____	____	____	____

H. SOIL OR GEOLOGICAL DAMAGE

	Appar. Hazard	No Appar. Hazard	Unknown
1. Settlement	____	____	____
2. Liquefaction	____	____	____
3. Landslide	____	____	____
4. Faulting	____	____	____
5. Other ____	____	____	____

I. REMARKS (Including identification of "Other" items in sections D, E, G, and H)

_____

_____

_____

_____

_____

BASIC BUILDING SEARCH PLAN

UHR 2

1. RECONNOITER SITE
   - FIND STRUCTURE TYPE
   - OBTAIN PLAN / DRAW CRUDE PLAN
   - ENGINEER REVIEW BUILDING
   - INTERVIEW NEIGHBORS

2. PRIORITIZE SITE
   - AVOID FALLING HAZARDS
   - SHORE WHERE PRACTICABLE
   - CALLOUT/LISTEN SEARCH
   - CONDITION OF BASEMENT

3. INITIAL SEARCH
   - SEND OUT SEARCH DOGS AS FAR AS CAN
   - USE OTHER SENSORS IF AVAILABLE
   - USE EXISTING VERTICAL SHAFT OPENINGS
   - USE EXISTING HORIZ OPNGS W/ GREAT CARE
   - SEARCH FROM STABLE AREAS TO UNSTABLE
   - RE PRIORITIZE VS POTENTIAL LIVE VICTIMS

4. LIGHT SAR
   - CUT VERTICAL OPENINGS AND RE SEARCH
   - AVOID UNSHORED OVERHEAD STRUCTURES
   - SEND DOGS OUT AS FAR AS CAN
   - CONTINUE PROCESS – CUT OPNG/RE SEARCH
   - SHORE AREA TO GIVE MEDICAL AID

5. HEAVY SAR
   - RE SEARCH AFTER NEW OPNGS ARE MADE
   - CHECK EXIST SHORES AFTER REMOVAL OF EACH LARGE PIECE OF CONCRETE

UHR SAFETY ENGINEER CHECK LIST

UHR 3

1. TYPE OF STRUCTURE
   - USE ATC-20 FORMS W/ SPECIAL ATTENTION ON FALLING HAZARDS

2. TYPE OF COLLAPSE
   - PANCAKE, SOFT 1ST STORY
     TORSION TYPE
     OVERTURNING
     PARTIAL FLOORS (UPPER, MID)
     OTHER

3. LOCATION OF VOIDS
   - BETWEEN FLOORS
     BASEMENT
     BUILDING SHAFTS

4. LOCATION OF ACCESS
   - CUT HOLES FROM TOP
     BASEMENT (READ SHEAR/TENSION CRACKS)

5. QUALITY OF VOIDS
   - LARGE COMPETENT SLABS W/ CONC BLKS
     SMALLER BROKEN CONCRETE
   - CONDITION OF SUPPORTING STRUCTURE UNDER COLLAPSED AREA

6. SHORING AID
   - WEIGHT, HEIGHTS TO SHORE
     EVEN, UNEVEN SUPPORT
     COMPETENT, INCOMPETENT SLAB TO SHORE
   - WHAT SUPPORTS SHORES- GROUND, OR IS THERE A FLOOR BELOW W/ MIN. CAPACITY

TYPE OF COLLAPSE VOID COVERING

UHR 4

1. MOSTLY INTACT SLABS, BEAMS & SLABS, JOIST & GIRDER CONCRETE LAYERS • CAN BE SHORED & CAN READ CRACKS TO DETERMINE MOST DANGEROUS AREAS

2. BADLY BROKEN REINFORCED CONCRETE FLOORS • ARE MORE DIFFICULT TO SHORE & SHOULD MAKE SAFE HAVEN AREAS USING DOUBLE ROW OF SPREADER BEAMS SUPPORTED BY SHORES ON SILL BEAMS

3. LARGE PIECES OF PRECAST CONC W/ BROKEN JOINTS • HAVE LARGE NUMBER OF DANGEROUS, UNKNOWNS & POTENTIAL OF SHIFTING LARGE UNSTABLE PIECES

4. POSTTENSIONED CONC PIECES W/ LOOSE CABLES • JUMBLED MASS OF CLOSELY SPACED LARGE TO SMALL PIECES OF UNREINFORCED CONCRETE

5. UNREINFORCED MASONRY RUBBLE • SMALL VOIDS ARE POSSIBLE. MUST CONSIDER THAT RUBBLE WILL FLOW INTO EXCAVATION OR TUNNEL. USE TUNNEL LINER PLATES OR OTHER SUPPORT SYSTEM WITH SHEATHING, SPREADER BEAMS, SHORES IN BOTH HORIZ & VERT DIRECTIONS

EVALUATION OF UNCOLLAPSED, DEBRIS LOADED FLOORS

1. LOADED BY PIECES OF CONC COLUMNS, BUT WITHIN FUNNEL SHAPE OF COLUMN BELOW • LOWER POTENTAL FOR SHEAR FAILURE

2. BEAM AND GIRDER INTERSECT AT COLUMN • DIAGONAL TENSION CRACKS WILL BE WARNING OF SHEAR FAILURE

3. UNIFORMLY LOADED FLAT/WAFFLE SLAB • PUNCHING SHEAR (RAPID) FAILURE IS POSSIBLE. HEAVY SHORING AROUND COLUMN IS REQUIRED

URM BUILDING SEARCH ITEMS

1. CALLOUT/LISTEN SEARCH MAY BE EFFECTIVE DUE TO LOWER DENSITY OF WOOD FLOORS.

2. VERTICAL ACCESS THRU WOOD FLOORS SHOULD BE EASY AND LEAST DANGEROUS. AVOID CUTTING LARGE BEAMS AND MORE THAN TWO JOIST IN A ROW.

3. DOGS MAY BE ABLE TO SCENT THRU CRACKS IN WOOD FLOORS IF THEY ARE NOT HEAVILY COVERED.

4. AVOID CUTTING WALLS • HOLES CAN GREATLY REDUCE STRENGTH OF POORLY CEMENTED WALLS. THE WALLS MAY BE PRINCIPLE VERTICAL STABILITY ELEMENT.

5. BEWARE OF ROOF/FLOOR JOIST/BEAMS THAT ARE NOT SITTING ON THEIR ORIGINAL FLAT LEDGES. THEY CAN SLIDE DOWN WALLS AND PRODUCE OUTWARD FORCES AS THEY MOVE TO FIND NEXT STABLE POSITION.

6. BASEMENT MAY PROVIDE GOOD ACCESS BUT SHOULD SHORE FOR SAFETY. FAILURE OF WOOD COLUMN OR BEAMS CAN BE SUDDEN.

7. REMAINING UNCOLLAPSED WALLS MAY BE AFTERSHOCK FALLING HAZARDS. EITHER AVOID THEM OR USE RAKER SHORES (MAY NEED TO SHORE BOTH IN & OUT DIRECT.)

8. BEWARE OF ALL FALLING HAZARDS INCLUDING: SPLIT AND/OR PARTLY SPLIT MULTI THICKNESS BRICK WALLS. MUST CONSIDER MOST REMAINING BUILDING PARTS AS UNATTACHED & READY TO FALL.

CONC FRAME BLDG ITEMS

UHR 6

1. NOT LIKELY TO HEAR CALLOUT OF VICTIMS THRU CONC

2. DOGS WILL INDICATE DIRECTION OF SCENT WHICH MAY BE FLOWING AROUND LARGE SLABS BACK & FORTH ACROSS BLDG. BEST TIME FOR DOGS IS EARLY AM & AT DUSK WHEN SCENT IS RAISING.

3. IN PARTLY COLLAPSED BLDG (UPPER FLOORS, ETC) IS VERY IMPORTANT TO CHECK FLOORS THAT SUPPORT COLLAPSE LOAD. READ CRACKS TO DETERMINE IF MORE AND PROGRESSIVE COLLAPSE IS PROBABLE. HEAVY & MULTI STORY SHORING MAY BE ONLY SAFE PROCEEDURE.

4. BASEMENT MAY PROVIDE GOOD ACCESS BUT EVALUATE LOAD ON IT AS IN 3.

5. FOR ACCESS CUT SLABS MIDWAY BETWEEN BEAMS &/OR COLUMNS. CHECK FOR THINNEST SLAB AREAS (PAN JOIST & WAFFLE SLAB RIBS MAY BE 20" TO 30" CLEAR BETWN

6. DONT CUT CONC COLUMNS (USUALLY DONT NEED TO)

7. AVOID CUTTING CONCRETE WALLS (VERTICAL STABILITY) FRAME MAY HAVE BRICK OR OTHER INFILL WALLS THAT MAY BE CUT IF NOT SUPPORTING LOADS.

8. BEWARE OF ALL FALLING HAZARDS.

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PRECAST CONC BLDG ITEMS

1. NOT LIKELY TO HEAR CALLOUT OF VICTIMS THRU CONC

2. DOGS WILL INDICATE DIRECTION OF SCENT WHICH MAY BE FLOWING AROUND LARGE SLABS BACK & FORTH ACROSS BLDG. BEST TIME FOR DOGS IS EARLY AM & AT DUSK WHEN SCENT IS RAISING.

3. IN PARTLY COLLAPSED BLDG (UPPER FLOORS, ETC) IS VERY IMPORTANT TO CHECK FLOORS THAT SUPPORT COLLAPSE LOAD. READ CRACKS TO DETERMINE IF MORE AND PROGRESSIVE COLLAPSE IS PROBABLE. HEAVY & MULTI STORY SHORING MAY BE ONLY SAFE PROCEEDURE.

4. CUTTING OF CORED SLABS & TEE SLABS SHOULD BE DONE AT EDGES. CUT 1/2 OF HOLE IN EACH OF TWO ADJACENT PRECAST PIECES.

5. DONT CUT COLUMNS

6. WALLS MAY BE CUT W/CARE. CUT ACCESS HOLES IN MIDDLE OF PRECAST PANEL. CONSIDER SHORING & CHECK WALL WELDED JOINTS FOR SIGNS OF MOVEMENT.

7. BEWARE OF LARGE PANELS/SLABS THAT ARE DISCONNECTED FROM EACH OTHER. THEY MAY SHIFT WHEN LIFTING/SHORE LOADS ARE ADDED.

8. BASEMENTS MAY NOT BE GOOD ACCESS. SHORE IF USE.

9. PRECAST CONCRETE WILL OFTEN WEIGH ABOUT 70% OF NORMAL (150PCF) CONCRETE.

INTERNATIONAL WORKSHOP ON EARTHQUAKE INJURY EPIDEMIOLOGY FOR MITIGATION AND RESPONSE

Organized by the Department of Civil Engineering of the Johns Hopkins University in Baltimore,Marylnd,USA

July 10-12,1989

SEARCH AND RESCUE(SAR) OPERATIONS AFTER EARTHQUAKES

A System approach

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Introduction:

In spite of the considerable efforts carried on by National and International organizations(both Official and Voluntary) for bringing prompt relief to disaster victims,there is a growing realization that such action falls far below expectation[1] One of the importants outcomes is that disaster cannot be dealt with improvisation.

The previous Venezuelan experience in Search and Rescue (SAR) operations after earthquakes(Peru-1970,Nicaragua- 1972, Guatemala-1976, Argelia-1980 and Mexico-1985) has shown that SAR operations have started well after the "Golden twenty four hours"[2] from the impact time; also the research done on the victims survival rate indicates a sharp decrease 48 hours after the event(Less than 40 % of the trapped persons

(1) Ecole de Santé Publique:Seminar on the Ecology of Natural Disasters-Brussels,Belgium,7-10 December 1971.

survived at Italy-1980- and Tangshan,China-1976-Eartquakes)[3] In adition the SAR operations are not coordinated using an Rescue Coordination Center(RCC),neither the diaster zones is sectorized to be asigned to specific SAR forces(SAR Units or SRU); even more,the different rescue teams working specific buildings are not under the direction of an On scene Commander(OSC),to direct SAR efforts in the most efficient and fast way to locate and recover the likely trapped persons. To add more problems it is well known the fact that the so called SAR forces involved,had few or no previous experiences in SAR operations after earthquakes;they also work without SAR Plans and Manuals wich are the key to follow standards and up to date procedures to effectively conduct the different SAR missions faced.All this problems may be strongly minimazed utilizing a System approach of the SAR activity after earthquakes,adapted from the one presented in the National Search and Rescue Manual in use by the U.S.Coast Guard and the Military Forces for emergency handling of the aircraft,marine and land incidents. This SAR System approach calls for an arrangement of components activated as needed to efficiently and effectively assist persons in potencial or actual distress,also the SAR System provides the recognazing of specific SAR stages,wich define the nature of the SAR assistance provided at any particular time.

During tha Guatemala earthquake(4-Feb.1976)there was a first approach to this SAR System,when the US,Guatemalan and the Venezuelan SAR Forces worked togheter at the La Aurora International Airport(at Guatemala City),establishing an Rescue Coordination Center(RCC) to follow SAR operations and to coordinate the aditional SAR efforts in the different villages destroyed.

(2)Noji Eric K: Training of search and rescue teams for structural collapse,1989.
(3)Noji Eric K: Training of search and rescue teams for structural collapse,1989.

Another approach of this SAR System was undertaken after the Armero,Colombia mud avalanche(13 November 1985),using the facilities of the Maiquetia RCC(Simón Bolívar International Air port) at Venezuela, to brief the French Rescue Units(Two Puma Helicopters going to the disaster area from Pointe a Pitre, Guadalupe and Cayenne,French Guiana).The SAR crews received also area maps of the region under emergency and special info of on route risks they were assisted to refueling and to rest over night.

Components of the SAR System:

A.Organization:That is the division of SAR responsability into geographic areas and regions(SRR),to provide centralized control,coordination and effective use of all available SAR facilities.Each area having his own SAR Coordinator and SAR PLan.

-A centralized Rescue Coordination Center (RCC) within each defined Region.

-A SAR Mission organization for each defined area and Region.

B.Resources:That includes the international Organizations, domestic agencies and the resources available for SAR response.

C.SAR Communications:The ears of the SAR System,including

1.Emergency communications,wich will be used by the distress personnel(sounds,voice in urban areas and color markers,smoke,paint signals in rural environment).

2.Communications facilities:Used in the early stages of the SAR effort to facilitate the receiving of the information related to the Earthquake,and to allow for coordination between participating services,agencies and other SAR forces.

3.SAR mission communications:Includes the communications with the SAR Home Base,On site comms with the field base and direct communications between the rescue parties inside the buildings been worked,and are essencial to provide coordination and control during SAR operations.

4.SAR mission messages:These are essencial to pass actions requiered by the participating SAR Units or agencies involved(Search and Rescue Action Plans),and wich are released by the SAR Mission Coordinator(SMC),other pur pose is to keep the SMC informed of the on scene mission progress and conditions(SITREPS),this messages are addressed to the SMC by the on scene commander(OSC).

D.Emergency Medical Services:This component provides for the capability to lifesaving and life sustaining services to survivors located;survivor evacuation and transport (MEDEVAC),and for the Medical facilities to receive and treat succesfully the injured survivors.

E.Documentation:This component of the SAR system provides for operational efficiency,creates statistical data and information for SAR case studies and official chronological records wich are vital when the SAR efforts may be put over the table by families or other participants.

The specific SAR stages are:

1.Awareness:Correspond to the first receipt of information by the SAR system of an actual or potential SAR situation.

This stage provides for the reception and recording of information, the collection of SAR incident data and the use of incident processing forms,to ensure that relevant information is not overlooked.

2.Initial Action: In this stage the SAR system begins response,and may include SMC designation,incident evaluation,SAR facilities alert and in some special conditions a primary deployment of SAR forces to scene.

An special consideration should be given to the terrain in wich the SAR efforts will be accomplished(Low land,high land,tropical area,valleys,others), and also to the prevailing on scene weather conditions(cold temperatures,heavy rain,low overcast,wind velocity and direction) because this variables will determine the type of SAR resource deployed and possibles delays on the response.

3.Planning: Covers basically the development of operational plans for SAR and final delivery of survivors.In this stage,wich may by conducted with specific operational actions,a primary importance is given to the determination of datum(the most probable location of the search subject,in some cases corrected for drift forces if they are aplicable).

The datum computed will be affected by some errors,like for example the one's obtained from the use of different types of detectors,this errors should be introduced in the final development of the search area for the desired datum computed.

During this process a search plan will be applied to cover the search area with a high probability of detection(POD).The POD is a measure of the desired search results prior to a search,or the search results actually obtained.The POD will be a funtion of the sweep width(W)(wich is a measure of the detection capability based on target characteristic and the detection equipment in use),and the track spacing(S)(wich represents the distance between two adjacent parallel search legs).

It is ver clear that the sweep width should be stablished in the SAR operations after earthquakes, for different equipments and conditions:Use of search dogs teams,sound position fixer kits,bore hole cameras,carbon dioxide sensors,infrared detectors and others.

4.Operations: Includes the deployment of SAR units to search and rescue the objetives involved.Search operations should start with the least possible delay,beginning with SRU briefing , SRU transit to the search area,SRU arrival on scene and search actions.

Rescue operations consist of the subject sighting(survivor located under the debries), on scene relief ,medevac,final delivery,return to base and debriefing.

5.Mission conclusion:Is the final stage of the SAR incident;will include the redeployment of SAR forces,once the objectives have been located or because of the reaching a point were the survival expectancy y to low to affort aditional risks for the SAR teams.Will also include return of SAR units tobase,and reseting of all equipments for another mission.

Of course adecuating the general SAR system to the specific case of SAR after earthquakes is extensive and multidisciplinay task; in this paper will be present some primary approaches dealing specifically with the SAR operations stage.

Priority for coordination of Internacional SAR teams:

Accepting that the accomplishing of SAR operations after earthquakes is a multinational effort(conditons wich has been well demonstrated in the past disasters already mentioned),an international response is vital to work against the short time available to retrieve the burried surviviors,for this reason the following steps

are suggested:

a.Multilateral agreements between the different countries wich may be involved in combined SAR operations,that will allow the previous acceptance of International SAR teams by the country affected by the earthquake.

b.Establishing Rescue Coordination Centers for the specific case of SAR operations after Earthquakes or better including this type of incident in the already existing RCCs,this action will permit the inmediate recption of the incoming SAR teams,including their mission briefing,assignement of working frecuencies and of search areas

c.Adoption by the international SAR teams of common working frecuencies(unicom) and compatible communications equipments to work with coordination,command and control at the disaster .

d.Organize combined excercises with the different international SAR teams,to know their capabilities,specific skills,type of equipment,local terrain,building conditions and principally to have a previous personal contact wich will turn out in better underestanding and coordination in real disaster work.

The operational component in SAR after earthquakes:

1.SAR Team availability:Accepting that there exist a full previous clearance to enter the disaster zone,one of the problems faced is the lack of around the clock SAR forces for an inmediate deployment.This calls for the creation os special SAR teams,like the one already organized by the OFDA at the U.S a given the name of "Disaster Response Team(DART).This units should be located at or close to an airport facility,including also prepacked equipment and other logistical needs

2.All the SAR team members will have ample support from their primary employers to be asigned to the Team and special provisions will be taken to support their families upon departure.

3.Aircrafts suitable to transport the SAR team to scene should be available on a very short notice,previous agreement with the Air Force,Commercial airlines or preasigned aircrafts should be considered to speed up the deployment of the Team.

4.SAR team alert: The SAR team alert will be accomplished on receiving information from the Seismic Centers of a severe event occurence wich according to the epicenter obtained may have generated severe damage on urban or populated rural region.

5.Disemination of the seismic alert may be accomplished by and agreement(that may be already on effect) with the Aeronautical Telecommunications Fixed Networks(AFTN Services),wich runs a very fast computarized network(printed) wich joins all the international airports of the world.

6.Deployment of the SAR teams:That is a key decission, because it is frecuent that the precise information on the damage and consecuently in the need of SAR teams deployment is not going to be available in a very short time, because of the damage received by the communications facilities of the disaster area.It is strongly recommended that,once a Seismic Network gives information of a seismic event of high magnitude and is determined in the RCC that the given epicenter location falls within a heavy populated region, to deploy a first SAR team with ample communications capabilities specially SATCOMMS and to stage this Team at the closest airport of the suspected disaster zone(normally a neighbor country) that will provide more accurate information from the potencial disaster zone and in case of positive evidence of a disaster,a very short arrival time to scene once the clearance is given.This approach is specially recommended when the SAR team is at great distance of the reported epicenter(SAR Teams of the US/Central and Southamerica in relation to the earthquakes of Al Assnam/Argelia,Italy and Armenia/URSS).

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7.SAR Teams arrival to the disaster zone:The first activity will be the contac of the RCC or Disaster Coordination Center at the arrival airport,receive debrefing,maps (if not already available by the SAR team) and search area asignement.If the situation reports given by the OSC working in the area so indicate,there may be taken the decission to increase the SAR forces,calling for aditional - support and some specific equipments(It is strongly recommended that the SAR team includes in its resources all terrain land vehicles, and at least one observation/utility helicopter like a Bell 206B or a Hughes 500D-The experiences of Guatemala and Al Assnam/Argelia had shown that this air facility is vital to the SAR effort,specially when the impact area as a widespread coverage that includes several villages(Guatemala,Peru earthquakes).

NOTE: A communications post with overseas coverage(HF Radio or SATCOMMS) is a must at this primary airport of arrival,aditional radio communications will be installed to link this post with the field base close to the disaster zone(in rural earthquakes there is the need to put one HF equipment in each affected village in wich the SAR operations are under way.

8.On Scene Search:There are to considerations to be analized: a.An Urban type earthquake(Mexico,Managua-Nicaragua and Popayan-Colombia) in wich there will be numerous trapped persons in complex buildings and b.An Rural type earthquake (Gautemala,Peru) where the trapped persons will be easy located,but they will by scatered in an extense region with lack of adecuate medical facilities.

a.On Scene search in Urban types earthquakes: 1.- setting of the field base(or operation center). 2.- :Recconaissance of the assigned area and selection of the working buildings. 3.-Dispatch of SAR personnel to the selected buildings. 4.-Setting of the Command Post and securing the working place(without loosing contac with local people). 5.-Search and elimination of special threats(fire,gas,radiation,electricity,others). 6.-Debrief of neighbours,-: survivors and familiy members of the building under search. 7.-Inicial search of open sites partially covered with rubble and start of markins of the

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sites already searched. 8.-Using previous information on possible trapped persons,maps and the identification of voids/spaces with high survival probability,make a systematic search for survivors using the most adecuate detector to reduce the extension of the searched site.9.-Opening of tunnels/crawlways with the help of available maps or drawings,if not availables make an aproximate drawing of the site with indication of the magnetic north and the scale used,locating the voids and the routes of the tunneling. 10.-Mark the searched tunnels and voids reached,to avoid duplicate efforts by your own or others participating SAR teams.11.-According to the findings/results of previous search efforts,analysis of the information retrieved at field and the detectors data,decide if search should be discontinued to start working other buildings.

b.The on scene search in rural type earthquakes will be very short,normally the local survivors will have already clear the partially burried survivors and the strong need will be emergency medical treatment,life support and final delivery(MEDEVAC) to a suitable Hospital. Setting of Helispots with wind indicator and marking the landing area with big letters given the name of the place(Village) will be very important to save time for the participant helicopters(At Guatemala the soccer field were marked with lime).In fact in this area the SAR operations will be mostly a rescue activity.

9.On Scene Rescue:Inmediate asses survival condition and if neccesary iniciate lifesaving and lifesustàning measures.If in doubt request MD advise via radio.

-Make a short debrief of the survivor to check for others survivors or missing persons.

-Accomplish adecuate proping of openings while releasing the survivor from the burried site,in the mean time maintain the aproved shifts of rescue workers.

-During the extrication process,give aditional life support measures if situation warrants.

-Before moving the survivor to the surface and if his physical conditions permits,perform another debrief also check for vital signs and pass info to the on scene commander.

-Finish removal of survivor from tunnel and complete with the help of the EMT/MDs the emergency care,transport the survivor to a field medical unit or to the asigned hospital facility.

-Mark the tunnels entrances with clear information continue the rescue efforts if other persons have been located or if negative shift to other places occording to the OSC decison.

-If leaving the building,fill apropiate documentation,including final plotting of sites where survivors and or corpses have been located.

NOTE: SAR FORCES SHOULD NOT BE USED TO RECOVER CORPSES,THE ONLY CORPSES TO BE RECOVERED WILL BE BECAUSE THEIR ARE BLOCKING THE EXIT OF SURVIVORS.

Some serious unanswered questions in SAR operations after earthquakes:

1.For how long the SAR effort should be last?

The past experience show a period of SAR activity close to 15 days after the earthquake impact.A case by case evaluation may be good consideration for this question.

2.Problems of civil and penal responsability by the SAR personnel involved,specially the practice of medicine(like performing in field amputations)

Standards conventions should be drafted and adopted whenever and wherever a given Country o several countries decide to deploy SAR teams to another country at the latter' s request.This convention should define the rights and obligations of the personnel making up the SAR teams.

3.How to control the widespread income of some volunteer organizations wich arrive on scene without any notice and with lack of expertise and adecuate equipments?

With the Rescue Coordination Concept,the SAR Mission Coordinator will have the capability to give specific instructions to customs officers to arpove or nor the entrance of undesired teams wich have not previously contacted the RCC to recieve adecuate clearance to participe in the SAR effort

4.What protective measures sholud be taken on behalf of the SAR members against the psychologicals desorders wich arise after the participation on a SAR operation after earthquakes?

Some indications of minor to serious disorders have been observed in SAR participants and it is not really known if this situation may bring ireversible damage to SAR members wich frecuently are involved in disasters.Violent behavor ,sleepless and depression are some of the effects observed; in addition to debriefing and "ventilating"with co-workers for several months after the incident it appears that there exist a limit of "Disaster dosis" that may be accepted in a certain period of time,this "Disaster dosis" varies with subject personnality, SAR trainning received,previous experience and other factors,strong importance should be given to this matter if SAR teams are likely to receive excesive "disaster dosis" wich may due an irreversible damage to them.

Some critical variables wich need to be addressed:

1.The dynamic damage after earthquakes:The SAR operations after earthquakes may be seriously hampered by the "dynamic damage " that is the fire spread in the impact zone(Managua City,Nicaragua,1972),also the occurence of havy destructive avalanches,wich creates victims than the proper earthquake(Peru earthquake in 1970 destruction of Yungay and the town

of Ramrahirca by a massive avalanche from the Huascaran peak).

2.Another crital variable is the occurence of severe aftershocks after the main impact,this strongly jeopardize the security of the SAR teams involved,been subjected to high risk to their livves,the problem is that this aftershocks occur just during the "Golden twenty four hours" o the first days after the main impact,when the SAR efforts are in full effect.

-Guatemala eartquake aftershock occured on Feb. 6th,1976 (that is 50 hours after the main shock)

-Al Asnam,Argelia eartquake aftershock occured on October 10th,1980 (2 hours after main shock)

-Mexico City earthquake aftershock ocurred on Sept. 19 1985(That is 36 hours after the main shock)

3.Other interesting critical variable is the widely variation of persons trapped according to the time of day.day of week when the main impact occurs. This creates quite different search problems due to the change of type of construction involved.

-Impact at night time results in concentration of survivors/trapped persons in residential buildings, Hotels and Hospitals.

-Impact on daylight: Has two important variables:

a.Working day:High concentration of survivors at Offices, Factories and Schools.

b.Holiday:High concentration at restaurants,Movie theaters Houses and other recreational places

Conclusions:

SAR operations after earthquakes conforms a stage of the so called SAR system wich should be supported by several components to become effective.

For a successful SAR operations after earthquakes there is a need to develop an specific SAR Manual and to organize thevarious components already indicated,also SAR plans should be prepared for every SAR region considered,especial enfassis should be given to the trainning and the resources of the SAR teams and finally because of the international respon sability create by the earthquakes,is neccesary to prepare multilateral agreements wich will resolve several unanswered questions of the SAR operations .

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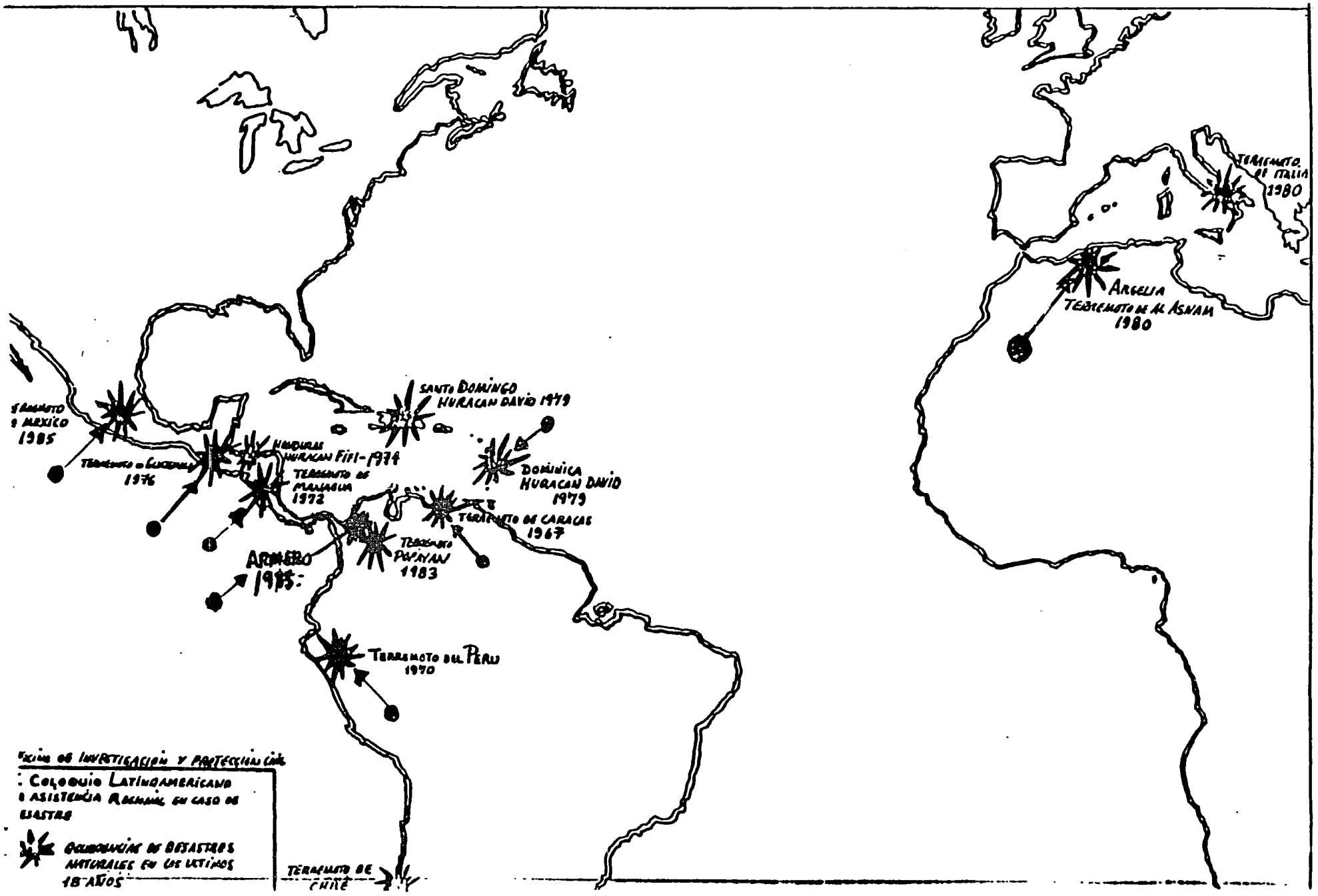
TERREMOTO DE MEXICO 1985
TERREMOTO DE GUATEMALA 1976
HONDURAS HURACAN FIFI-1974
TERREMOTO DE MANAGUA 1972
SANTO DOMINGO HURACAN DAVID 1979
DOMINICA HURACAN DAVID 1979
TERREMOTO DE CARACAS 1967
TERREMOTO POPAYAN 1983
ARMERO 1985
TERREMOTO DEL PERU 1970
TERREMOTO DE CHILE
ARGELIA TERREMOTO DE AL ASNAM 1980
TERREMOTO DE ITALIA 1980
Colloquio Latinoamericano
Asistencia Mutua en caso de desastre
Ocurrencia de desastres naturales en los ultimos 18 años

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VENEZUELA EXPERIENCE IN MAJOR DISASTERS

COUNTRY	DISASTER	ON SCENE	TRANSPORTATION TO AREA	TEAM	EXPERTISE	COMMUNICATION	REMARKS
PERU 31-MAY-1970	EARTHQUAKE	0+30 HRS	DC-8 COMMERCIAL	15	RESCUE MEDICAL	NO	
NICARAGUA MANAGUA 23 DEC. 1972	EARTHQUAKE	0+35 HRS	C-130 VENEZUELAN AIR FORCE	30	FIRE FIGHTING RESCUE MEDICAL	1 HF HAM RADIO 4 VHF PUBLIC SERVICE	EXTENSIVE FIRE AT THE CITY
GUATEMALA 4 FEB 1976	EARTHQUAKE	0+18 HRS	C-130 VENEZUELAN AIR FORCE	40	RESCUE MEDICAL HELICOPTER OPS. COMMUNIC.	HF-(1) RF-280 6 HF STOVER 150 2 VHF AERONAUTICAL 6 VHF PUBLIC SERVICE	-ESTABLISHED COMMS. NET AT 6 TOWNS LINKING WITH GUATEMALA CITY OPERATN CENTER -AIRLIFTED ONE STATION WAGON AND TWO MOTORCYCLES -RENTED: ONE VAN -BUYED: 4 BICYCLES -WORKED WITH US AND GUATEMALA TEAMS.
DOMINICA ISLAND AUGUST-SEPTEMBER 1979	HURRICANE DAVID	0+24 HRS	KING 90 C-130 KING 200 GRUMMAN 159 COMMERCIAL VENEZUELAN AIR FORCE OIL COMPANIES	40	RESCUE HELICOPTER OPS. MEDICAL COMMS.	1 HF RF-280 4 HF 2 VHF AERONAUTICAL 8 VHF PUBLIC SERVICE 1 COMMS. VEHICLE	WEATHER CONDITIONS DELAYED ON SCENE ARRIVAL. STAGED AT MARTINIQUE, FORT DU FRANCE AIRPORT. AIRLIFTED ONE ALOUETTE III HELICOPTER FROM VENEZUELAN AIR FORCE -ALSO ONE BLAZER COMMUNICATIONS VEHICLE WITH FULL HF VHF (30-75 MHZ) UHF AND TELETYPE, VHF AERONAUTICAL
ARGELIA EL ASNAM 10 OCT. 1980	EARTHQUAKE	0+3 DAYS	DC-8 COMMERCIAL	41	RESCUE COMMS.	4 HF-280 RF 4 HF-PRC-77 6 VHF-FM	-ARRIVED TO LATE FOR RESCUE -USED ITALIAN HELICOPTER (LAMA) FOR AERIAL RECONNAISSANCE [illegible] TRANSPORTATION

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COUNTRY	DISASTER	ON SCENE	TRANSPORTATION TO AREA	TEAM	EXPERTISE	COMMUNICATION	REMARKS
MEXICO CITY MEXICO 19-20 SEPT-1985	EARTHQUAKE	0+48	BOEING 707 COMMERCIAL	30	RESCUE COMMS.	1 HF RF280 1 HF HAM R.	DELAY DUE TO LACK OF CLEARANCE - USED US RESCUE TEAM RADIOS - WORKED WITH US TEAM, GERMAN THW TEAM, UNITED KINGDOM TEAM AND MEXICAN RESCUE GROUPS
COLOMBIA ARMERO 13 NOV. 1985	MUDSLIDE	0+72 HRS	DC-10 COMMERCIAL AND WEST GERMAN AIR FORCE	25	RESCUE COMMS HELICOPTER OPS.	1 HF-RF280	PROBLEMS OF SECURITY AT DISASTER AREA DUE TO INTERNAL [redacted] CONDITIONS

MEXICO EARTHQUAKE

SEPTEMBER 19, 1985

SAR ASSISTANCE

COUNTRY	ASSISTANCE	ARRIVAL DATE	0 + HORAS	TYPE OF TRANSPORT.	SPECIAL EQUIPMENT	RESCUE MED OTHERS PERSONNEL	TOTAL	OTHERS EQUIPMENTS	PULL OUT DAYS
WEST GERMANY FED	SAR	SEPT 21 SEPT 23	48 96	B747 C-130 USAF	12 DOGS 2 RESCUE TRUCK	61	63	1 SPECIAL VEHICLE	9
ARGELIA	SAR	SEPT 23	96	-		19	19		
BRASIL	DEMOLITIONS EMT	SEP 24	196	C-130	FIELD HOSPITALS	45 40	85		15
CANADA	SAR EMT	SEP. 24	120	C 130	COMMS EMT	14	14		
COLOMBIA	EMT	SEP 23	96	B707	EMT		4		
SPAIN	SAR	SEP 23 SEP. 24	96 120		RESCUE EMT	+45	45		
ISRAEL	SAR	SEPT. 22	72	C-130	HYDRAULIC TOOLS	17	17	SOUND DETECTORS RESCUE VEHICLE	15
ITALY	SAR	SEPT. 22	72		12 DOGS	+12	42		9
FRANCE	SAR	SEPT 23	96	B747	19 DOGS	233-42- 100	380	VEHICULO TODO TERR SOUN DETECTORS	9
UNITED KINGDOM	SAR	SEPT 22	72		I.R DETECTOR	6 + 50 INC	56	2 HELICOPTERS	
JAPAN	ENGOPS	SEPT 30	—		SEISMIC RECORDERS	8	8		
EL SALVADOR	SAR	SEPT 28	220			8	18		
NICARAGUA	EMT	SEPT. 24	120						
SWITZERLAND	SAR	22 ?	72		12 DOGS	1	41		9
USA	SAR EMT	SEPT 22	72	C-5 C-130	13 DOGS		200	VIDEO PROBE ULTRASONIC-	13
VENEZUELA	COMMUNICATI. SAR	SEPT 21 SEP. 23.	48 96	B707		24	24		18

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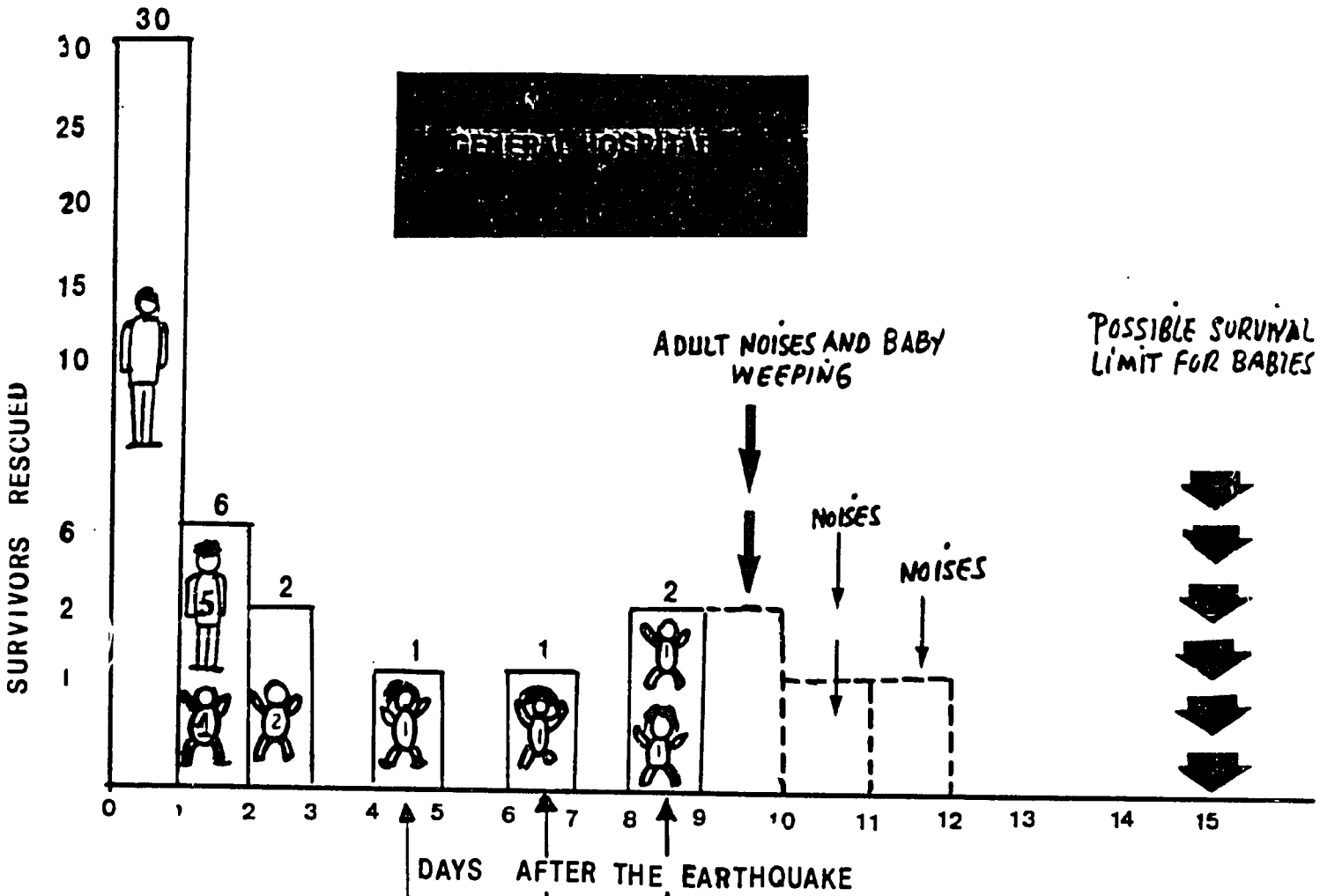
TERREMOTO DE MEJICO

SURVIVORS RESCUED VS DAYS AFTER IMPACT



LOCATED 1400 HRS
GIRL 6 DAYS OLD

LOCATED AT 0100 HRS
GIRL 9 DAYS OLD

LOCATED AT 1000 PM
GIRL 11 DAYS OLD
AND

LOCATED AT MIDNIGHT
BOY 11 DAYS OLD

REPORTING SOURCE: DR. ARTURO CHAVES
GENERAL HOSPITAL

J. LESCAR[illegible] - VENEZUELA

SAR SYSTEM

FOR OPERATIONS AFTER EARTHQUAKES

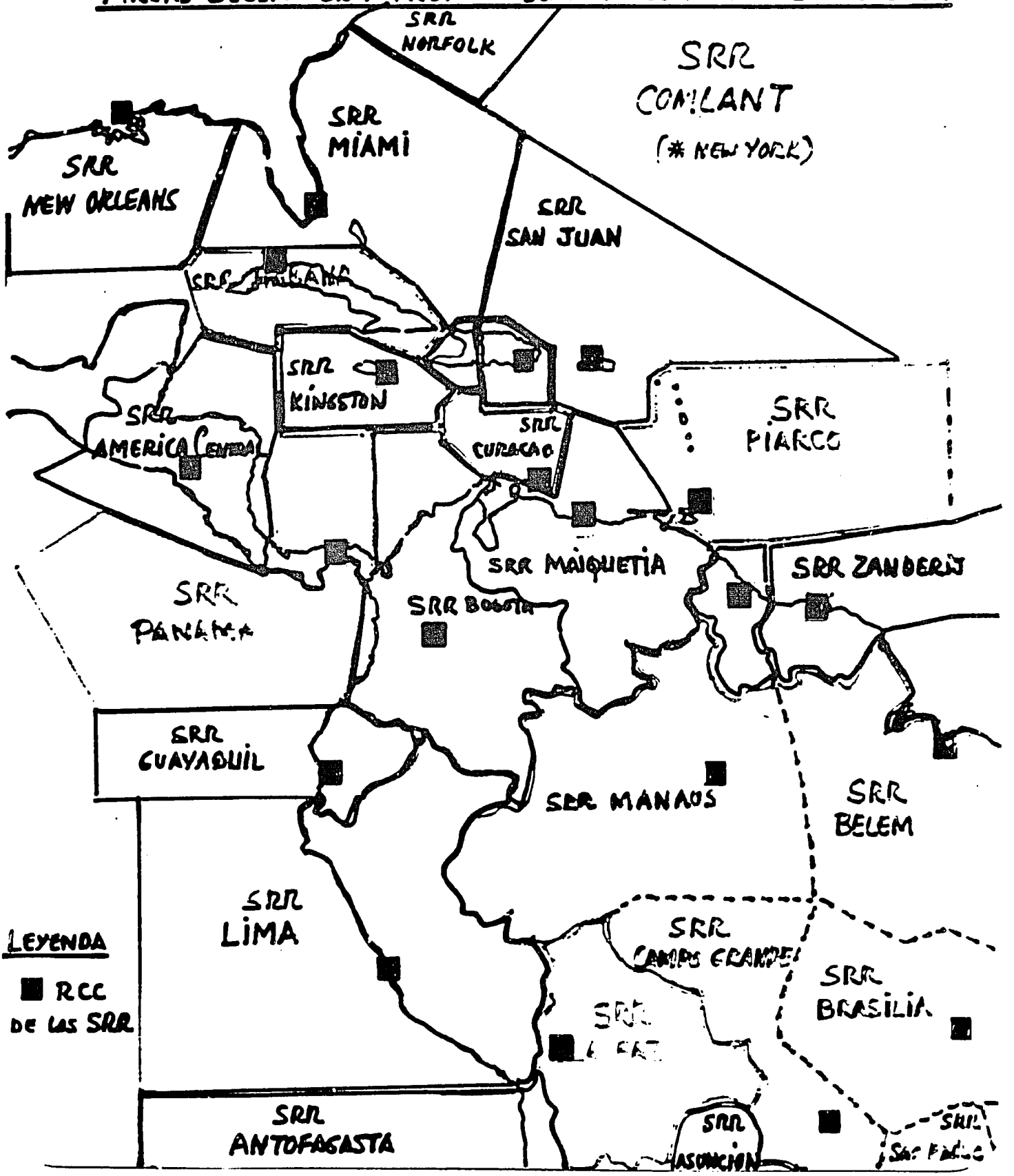
AN ARRANGEMENT OF COMPONENTS ACTIVATED AS NEEDED TO EFFICIENTLY AND EFFECTIVELY ASSIST PERSONS IN POTENCIAL OR ACTUAL DISTRESS

SAR COMPONENTS

1. ORGANIZATION
2. RESOURCES
3. COMMUNICATION
4. EMERGENCY MEDICAL SERVICES
5. DOCUMENTATION

COMPONENTE DE ORGANIZACION

AREAS GEOGRAFICAS Y REGIONES DEFINIDAS DE RESPONSABILIDAD SAR



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SAR STAGES

DEFINE THE NATURE OF THE SAR ASSISTANCE PROVIDED AT ANY PARTICULAR TIME

1. AWARENESS
2. INITIAL ACTION
3. PLANNING
4. OPERATIONS
5. MISSION CONCLUSION

COORDINATION OF INTERNATIONAL SAR TEAMS

1. MULTILATERAL AGREEMENTS: PREVIOUS CLEARANCE
2. ACTIVATE RESCUE COORDINATION CENTERS (RCC)
3. COMMON WORKING FRECUENCIES: COMPATIBLE RADIOS SYSTEMS
4. ORGANIZE COMBINED EXERCISES
5. DEVELOP TRAINING AND EDUCATION STANDARDS

OPERATIONAL COMPONENT IN SAR AFTER EARTHQUAKES

1. SAR TEAM AVAILABILITY: DART - DAR - ESCUSAR
   BASE AT/CLOSE TO AIRPORT

2. FAST TRANSPORTATION OF SAR TEAM: - ACFTS READY ON SHORT NOTICE
   - CONTRACTS OR AGREEMENTS

3. SAR TEAM DEPLOYMENT: DIRECT TO SCENE OR TO A STAGING BASE CLOSE

4. ARRIVAL TO SUITABLE AIRPORT: BRIEFING
   MAPS
   COMMS.
   AREA ASIGNMENT
   COMMS. POST

5. ON SCENE SEARCH: URBAN OR RURAL

ON SCENE SEARCH IN URBAN EARTHQUAKES

1. OPERATION CENTER
2. RECCONAISSANCE OF ASSIGNED AREA - SELECTION OF BUILDINGS
3. DISPATCH OF SAR PERSONNEL
4. SETTING OF THE COMMAND POST - SECURING WORKING PLACE
5. SEARCH AND ELIMINATION OF SPECIAL THREATS: RADIATION AT COLLAPSED HOSPITALS - FIRE, ETC.
6. DEBRIEF OF NEIGHBORS - SURVIVORS - FAMILY.
7. INITIAL SEARCH OF OPEN SITES - MARKING - OF SEARCHED SITES
8. USING ALL THE PREVIOUS INFO (INCLUDING DETECTORS) START TUNNELING TO LOCATE DEEP TRAPPED SURVIVORS
9. FINDING OF SURVIVORS OR DISCONTINUING THE SEARCH EFFORT, FINAL MARKINGS. DOCUMENTATION.

ON SCENE RESCUE

1. ASSESTHE SURVIVOR CONDITIONS - INICIATE LIFESAVING ACTION
2. MAKE SHORT DEBRIEF TO CHECK FOR OTHERS SURVIVOR
3. ACCOMPLISH ADECUATE PROPING OF SITE AND FREE THE SURVIVOR - MAINTAIN APROVED SHIFTS OF RESCUE TEAM.
4. DURING EXTRICATIONS PROCESS GIVE ADITIONAL LIFE SUPPORT IF THE SITUATION WARRANTS.
5. PERFORM ADITIONAL DEBRIEF
6. END REMOVAL OF THE SURVIVOR COMPLETE EMERGENCY CARE AT THE SURFACE AND TRANSPORT SURVIVOR TO FIELD MEDICAL UNIT OR TO ASIGNED HOSPITAL.
7. MARK TUNNEL ENTRANCES AND CONTINUE THE RESCUE OR SEARCH EFFORTS IF SITUATION WARRANTS.
8. UPON LEAVING THE BUILDING FILL DOCUMENTATION "NO CORPSES WILL BE RECOVERED"

SERIOUS UNANSWERED QUESTIONS IN SAR OPERATIONS

1. HOW LONG TO SEARCH: A CASE BY CASE SOLUTION

2. CIVIL AND PENAL RESPONSABILITY: STANDARD CONVENTION IN ADVANCE

3. UNCONTROLLED INCOME OF VOLUNTEERS/OFFICIAL AGENCIES TO THE DISASTER AREA: SMC - CUSTOMS ?

4. WHAT PROTECTIVE MEASURES AGAINST THE POST DISASTER SYNDROME IN THE SAR PEOPLE: "THE CONTROL OF THE DISASTER DOSIS"

[redacted]

1. LACK OF E.O.C. OR CONTACT WITH E.O.C.

2. FEW OR NONE COMMAND POST AT DISASTER SITES

3. COMMUNICATIONS HANDLED IN SEVERAL WORKING FRECUENCIES WITHOUT UNICOM CAPABILITY AND WITHOUT A DISPATCHER

4. INCOMPLETE OR LACK OF ASSESSMENT OF DAMAGE AT THE DISASTER AREA

5. PROFESSIONAL MAN POWER WITHOUT BACKUP TO PROVIDE FOR REST

6. NEED OF OVERALL QUALITY CONTROL OF OPERATIONS BY A MODEL SUPERVISOR WHICH MAY BE IN A POSITION TO RELAY INFO TO E.O.C. OR A PARTICULAR COMMAND POST

7. NEED TO HAVE AN INTERNATIONAL ASSISTANCE COORDINATION CENTER AT THE STAGE AIRPORT SELECTED FOR ARRIVAL OF RESCUE/LIFE SUPPORT RESOURCES.

8. NEED OF A INTERNATIONAL LOGISTICAL CENTER TO RECEIVE AND COORDINATE THE ON TIME DISTRIBUTION OF EQUIPMENT, MEDICAL SUPPLIES AND OTHER RESOURCES TO MORE NEEDED PLACES

[redacted]

(1) DYNAMIC DAMAGE AFTER IMPACT: MANAGUA-1972
YUNGAY 1970

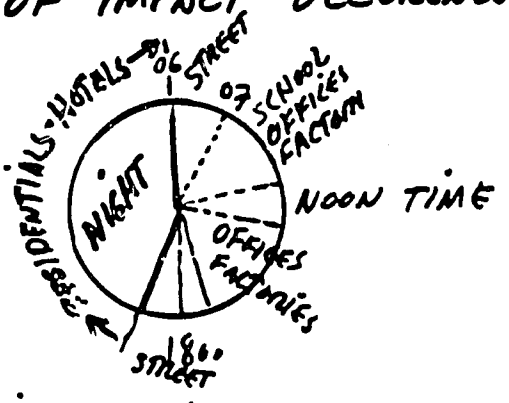
(2) OCCURENCE OF SEVERE AFTERSHOCKS:

GUATEMALA: 50 HRS

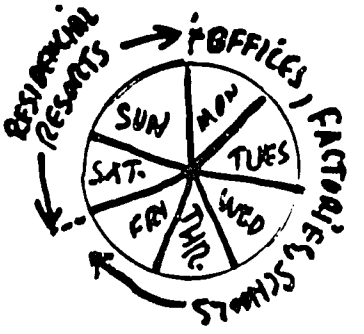
AL ASNAM: 2 HRS

MEXICO CITY: 36 HRS

(3) VARIATION OF TRAPPED PERSONS AND BUILDINGS TO SEARCH DUE TO TIME OF DAY, DAY OF WEEK OF IMPACT OCCURENCE.



TIME OF DAY



DAY OF WEEK

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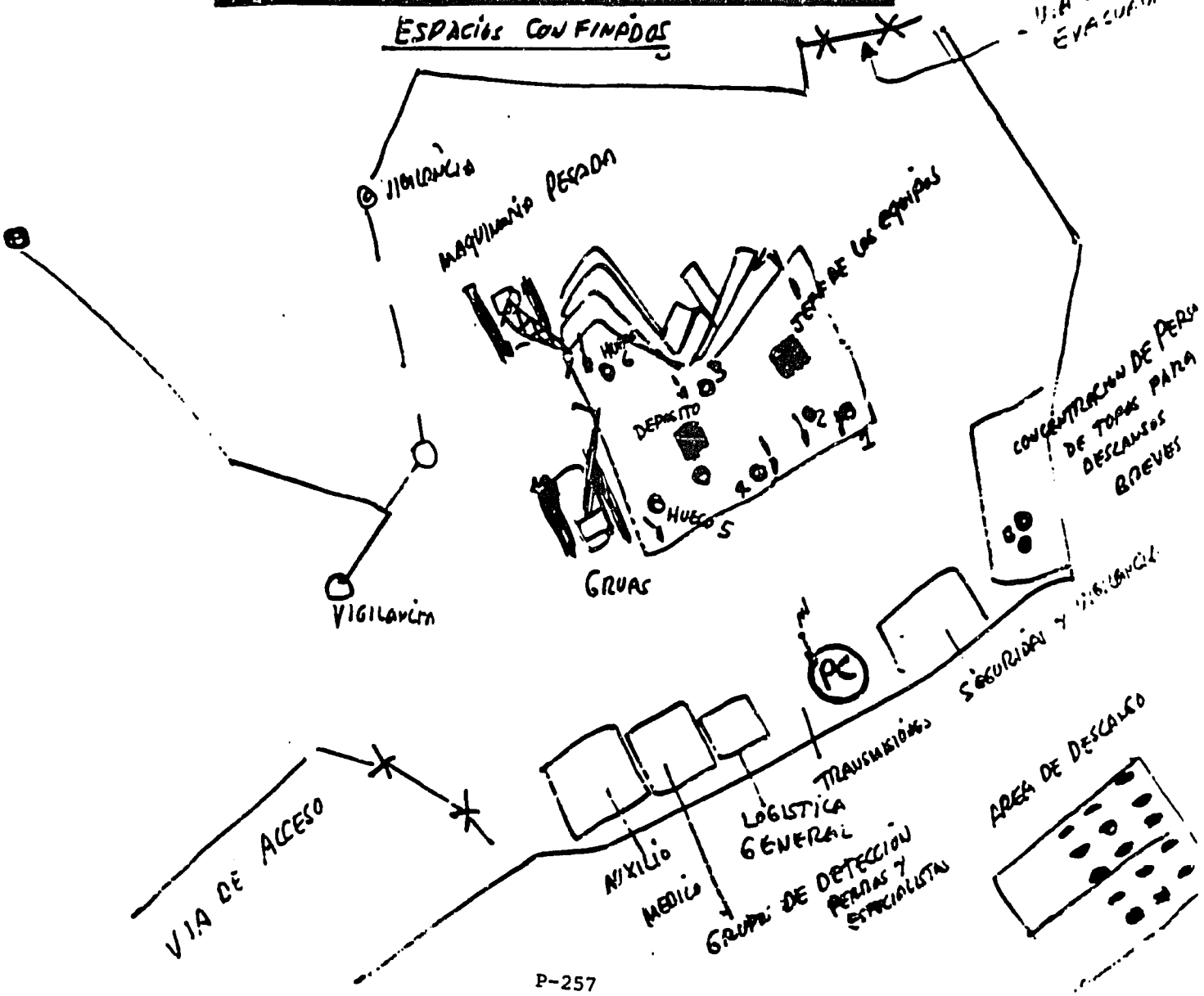
1

ESTRUCTURA ORGANIZATIVA DEL SAR LITORAL

ESPACIOS CONFINADOS



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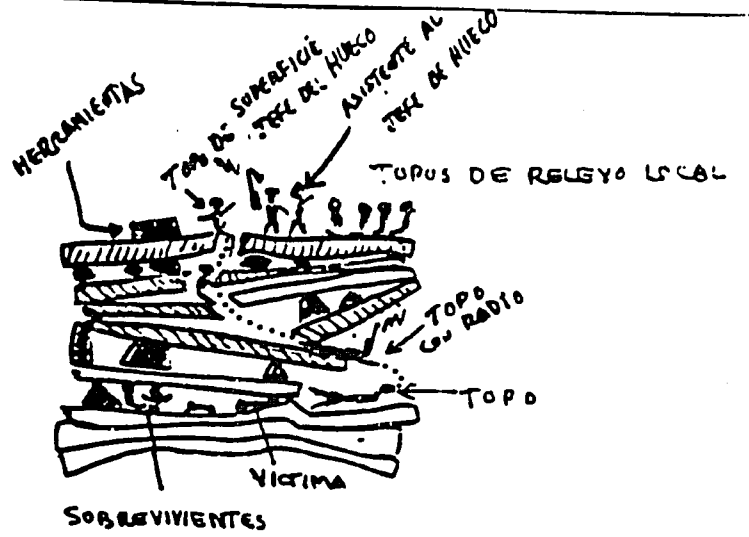
ESPACIOS CONFINADOS - ESQUEMA DE TRABAJO DE UN EQUIPO DE RESCATE EN UNA GALERIA

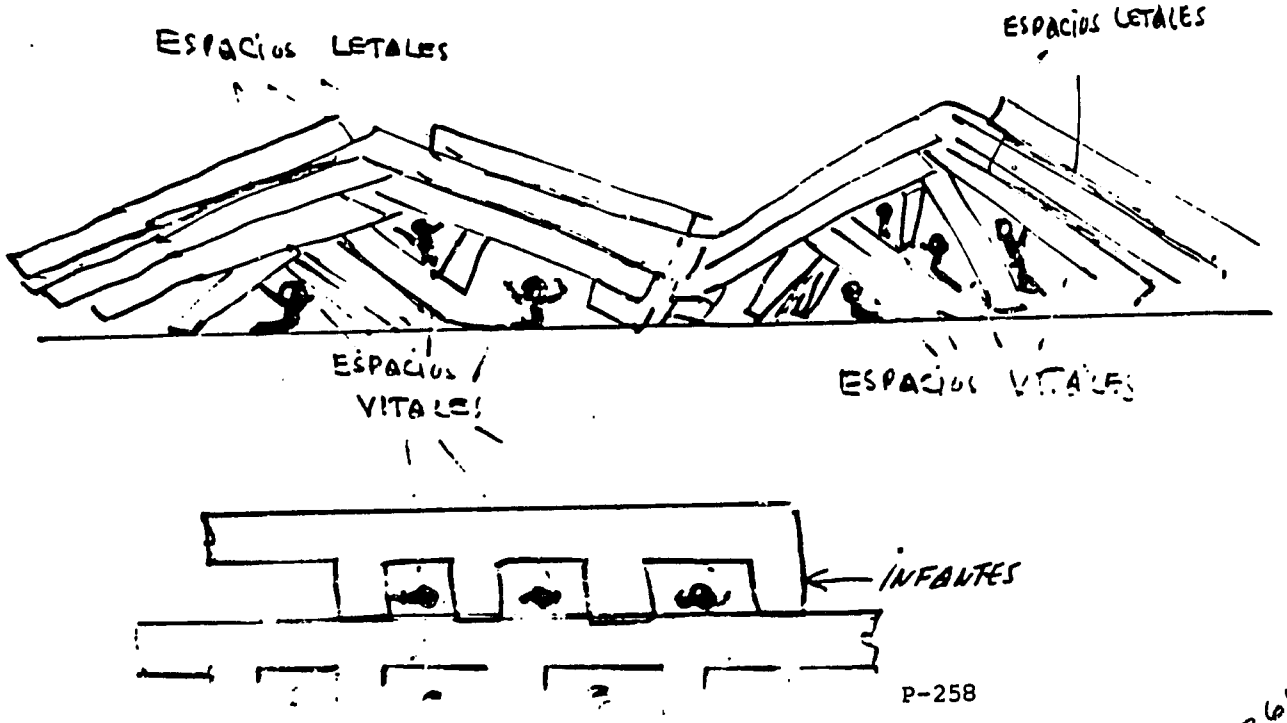


INTEGRANTES: 1 JEFE DE EQUIPO
1 ASISTENTE DEL JEFE DE EQUIPO
1 TOPO DE SUPERFICIE (BOCA DE ACCESO)
3 TOPOS EXPLORADORES
4 TOPOS DE RELEVO LOCAL
1 ENCARGADO DE MATERIALES
1 ASISTENTE DE MATERIALES

TOTAL: 12 PERSONAS

RELEVO DE TOPOS CADA 30 MINUTOS A 1 HORA

RELEVO DEL EQUIPO CADA 12 HORAS



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4

ALGUNOS CODIGOS RECOMENDADOS

20M → X GALERIA HORIZONTAL A LA DERECHA CON 20 METROS Y BLOQUEO

18M → ↓ 7M. GALERIA HORIZONTAL DE 18 METROS Y CAIDA VERTICAL DE 7 MTS

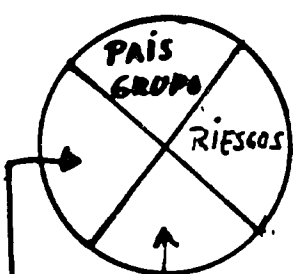
X VIA BLOQUEADA

8 PLACA DEL PISO "OCHO"

R/B REVISADO POR EL CUERPO DE BOMBEROS

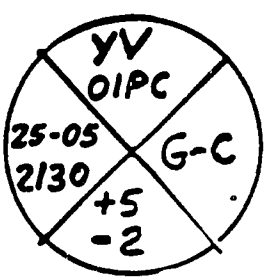
R/FFAA REVISADO POR LAS FUERZAS ARMADAS

R/UMU REVISADO POR UNIDAD DE MANTENIMIENTO URBANO



SOBREVIVIENTES
Y/O VICTIMAS EXTRAIDOS

FECHA Y HORA LOCAL DE LA INSPECCION



HC: ECUADOR
HK: COLOMBIA
I: ITALIA
OB: PERU
ETC....

CODIGO PARA GRANDES DESASTRES

JLS

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A COMPUTER MODEL FOR THE RECOVERY OF TRAPPED PEOPLE IN A COLLAPSED BUILDING: DEVELOPMENT OF A THEORETICAL FRAMEWORK AND DIRECTION FOR FUTURE DATA COLLECTION

Keishi Shiono and Frederick Krimgold

1. INTRODUCTION

Very little was known about the victims injured and trapped in a collapsed building. We do not know how they survive under debris or how they are brought out in the course of rescue activities.

This shortage of knowledge is due to the following two reasons:

1) We still do not have enough data describing comprehensively and completely the events; including the pattern and extent of building damage, the situation of entrapment, injury severity of trapped people, and the effectiveness and sequence of rescue activities.

2) We still do not have any models or theoretical frameworks to represent the events that follow the collapse of buildings. In addition, we have not yet identified any factors that affect the sequence of rescue efforts and, therefore, must be included in the construction of theoretical models.

Collection of data - particularly in the field of disaster studies - always requires a long time. We are currntly able to find good documentation of human casualties due to earthquakes in only a very limited number of publications. It will, therefore, be necessary to spend extensive future effort in completing the accumulation of data.

In contrast, the development of computer models for rescue activities and their sequences does not require as long. It is possible to identify the significant factors affecting the result of rescue activities with only a limited number of experiences. We are also able to assemble the relationships between these factors - knowledge and/or conception elements - into a computer model representing the process that takes place in a collapsed building.

This kind of development is important and useful in directing the method for data collection in future events. Even the most extensive reports of past earthquakes are based on less than comprehensive data collection.

In this study we:

1) Identified factors affecting the recovery of trapped victims from a collapsed building;

2) Integrated the above factors into a computer model; and

3) Applied the model to the case of the Juarez Hospital collapse in the 1985 Mexico City earthquake, to demonstrate its effectiveness in simulating events.

2. FACTORS

The entire event was divided into two aspects, as follows:

1) How the trapped people survived in a collapsed building. This is a problem of survival rate of the trapped people without rescue activities including food and water supply, relief, and medical attention. We have to evaluate survival rate as a funcition of time.

2) How the victims are extricated from a collapsed building. This is a problem of extrication effectiveness affected by: (i) the condition of entrapment (how difficult extrication is for a trapped person); and (ii) the application of rescue resources over time.

These two aspects are discussed separately in the following two sections.

2.1 Survival

(1) "Fade-Away" Function

The function of time used to define the deteriorating health condition of a trapped victim is called "Fade-Away Function." A victim's health condition is measured according to an index termed the "Animation Score," which is assigned by a continuous value between 1 and 0. A score of 1 represents an unaffected condition, or good health, while a score of 0 represents no animation, or death.

The animation score implies a given time period during which a surviver's condition deteriorates toward death. In this sense, it does not necessarily correspond directly to the conventional scale of injury severity scoring. However, a reasonable relationship between the animation score and injury severity will probably be established with the introduction of accumulated knowledge in the field of emergency medicine.

A few examples of the fade-away function are shown in Figure 1. The curves indicate how an affected victim deteriorates toward death during his entrapment. For example, in Figure 1 (a), a person with an initial animation score 5.5 can live for the next 42 hours. He will die after this period of Fade-Away Time (FT).

A victim who is affected severely by the direct impact from the building collapse is given a lower animation score at the moment of entrapment (t=0), as he is closer to death and has a short FT. Among the curves in Figure 1, those indicated by lower numbers, such as 1 and 2, correspond to the fade-away process for such severely affected people.

Even a victim with a very slight injury, which cannot itself be fatal, can die of dehydration or minor bleeging after a considerablly long FT. The curves shown by higher numbers, such as 8 and 9, are indicative of these victims who are slightly affected at the first moment of entrapment.

The general pattern of fade-away function was determined by introducing two parameters, Do and N, which represent (i) environmental factors and (ii) victim's pre-collapse health conditions.

"Do" controls the length of FT. It is conceptually the FT for a person trapped with no injuries who may die of dehydration or exposure. We must also determine Do with due consideration to another environmental factor such as the weight of debris under which a victim is pinned. It is required to include the pattern and extent of building collapse, in addition to weather and other environmental conditions. Among the factors related to stractural damage, the amount and quality of interior space remaining after a building's collapse is significant.

"N" is used to define the rate, or speed, of deterioration of a victim's health condition. The condition deteriorates slowly in a good helth condition and rapidly near death. In the determination of N, the factors that are taken into account in Do are considered.

(2) Survival Rate

Once it is possible to follow the change in an individual victim's health condition over time, we should be able to derive the survival rate for all the trapped victims in a colapsed building as a function of time. This transition requires the

Figure 2 (b) shows examples of the survival rate of trapped victims as derived from the initial distribution of the injured shown in Figure 2 (a). These examples used the same fade-away function shown in Figure 1 (b), the difference in survival rate among these cases is related to that in the initial distribution of the animation scores.

2.2 Rescue

(1) Extrication Difficulty

To understand an entire disaster from the rescue point of view, not only the total number of trapped people but also the information about the difficulty in their extrication is requiured. Extrication difficulty for a particular victim depends primarily on the physical condition of entrpaments which relate to structural type and pattern of collapse.

We initially evaluate extrication difficulty along a three-tiered scale of "easy, moderate and difficult" by the amount of rescue effort needed for the extrication of a trapped victim. This process requires the use of a scale of equivalent man-power based on the man-hour unit, for example, 10, 50, and 250.

The evaluation of rescue resources in terms of man-hour of rescue effoer seems appropriate because it is simple and familiar. When used in isolation, however, the concept of man-hour falls short. Effective rescue activity, particularly in case of heavy rescue, depends on how rescuers are trained and how well they are equipped with sophisticated and heavy machinary. We must, therefore, develop some scheme to evaluate the effect of such variables on an "equivalent" man-hour scale.

(2) Effective Resources

In addition to the evaluation of professional skill and equipment, that of effective man-power is equally signigicant. We have to determine how many of the rescuers surrounding a collapsed building are actually involved in direct efforts including the removing of debris, tunneling, and so forth.

Among the people engaged in rescue activities, a considerablly large portion of rescuers are indirect participants; namely, providing support and management. The proprtion of rescuers doing indirect tasks becomes larger as the total number of rescuers grows. The reasoning for this is that large assembly of rescue teams requires more ancillary support.

Figure 3 depicts the possible correlation between the gross number of rescuers allocated in a collapse site and the effective number of rescuers directly involved in extrication of trapped victims. In this example, approximately 20 percent of the 100 rescuers are directly involved at any point in time. On a larger scale, only 10 percent of the 500 rescuers would be directly involved. As this evaluation was made assuming that rescue efforts are conducted on two twelve-hour shifts, 40 rescuers out of 100, for exmple, correspond to the effective rescue power of 20 percent.

(3) Extrication

Once we are given (i) the number of trapped people classified by the level of extrication difficulty and (ii) the number of rescuers increasing as time goes on, we can calculate the number of people extricated during sequential time segments starting at the moment of building collapse.

Figure 4 (c) shows some examples of extrication processes under different conditions for the initial number of trapped people. The victims were classfied in terms of their extrication difficulty (Figure 4 (a)) and the increase of rescue resources represented by the number of effective rescuers (Figure 4 (b)).

We obtained the results shown in Figure 4 introducing an additional assumption that the rescue effort made in a collapsed building is distributed among the victims trapped in each extrication difficulty level in the ratio of 10:3:1 (easy, moderate, difficult) at any moment during the rescue activity. We used this assumption to include a sequence as follows: in the course of extrication of one person, other victims have better chance to be located and relieved.

3. COMPUTER MODEL

We have thus developed two complementary models: one for survival and one for recovery of trapped victims. It should be possible to assemble them into a comprehensive model to represent live and dead recovery potential from a given collapsed building.

The combination of these two element models is reasonable as long as we can use an assumption that FT (Fade-Away Time) and extrication difficulty for a trapped victim are independent. Although we have to examine this simple assumption more carefully in the future, it is not appropriate at present to assume more complicated situations. Our data are still too limited to support more sophisticated hypotheses.

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A few examples of results from the application of the model to hypothetical collapse situations are shown in Figure 5. Although the results obtained here were based on many assumptions rather than extensive hard data, such results tend to suggest consistency of our model with limited specific field experiences. For example, a higher rate of live-recovery was derived in cases where people were less affected - having higher animation scores at the moment of building collapse - and where rescuers arrived sooner and the rescue effort was more efficient.

The model presented here has attempted describe hypothetical events and reproduce actual events. It is also significant that we have suggested essential factors which effect the outcome of rescue activity. It is necessary and possible for us to refine our model on the basis of future data collection. This data collection in future collapse events can be directed by the valiables identified in the structure of this model.

4. APPLICATION

A useful data set concernig the recovery of trapped victims is available from the Juarez Hospital in the 1985 Mexican earthquake (Krimgold, 1988). The data reported by Rojas Enriquez (1987) are shown in Figure 6 (a) and (b).

We applied our model to the case of the Juarez Hospital. In doing so, we hoped to demonstrate that the model can reviel some of the facts hidden within this complicated event which took place in the collapse of a high occupancy, engineered building.

Figure 6 (b) shows the rate of live-recovery among the total number of extricated people charted by length of period (days) since earthquake occurrence. We calculated the rates using "smoothed" data of live and dead recoveries. We obtained "smoothed" data for a day by; First, making twice the number of the people extircated during the day; Second, adding the number of people extricate during the previous and next day, respecitively; Third, dividing the sum by a factor of four.

A remarkable aspect of Figure 6 (c) is the invaliable rate of live-recovery during the first five days after the collapse. The rate of live-recovery during this period is approximately 70 percent. This suggests that the deaths of the trapped people occured during a short time, probably in the few hours immediately after the collapse. During the latter part of the first day and the following four days, no significant number of deaths occured in the building.

The rate of live-recovery went down, slowly at first and then guradually more rapidly, after day 6. It reached zero in day 9. This suggests that the condition of the trapped victims who escaped immediate death gradually deteriorated during the first five and the following four days, and they died in the period between days 6 and 9.

In order to simulate the survival rate discussed above, we used a fade-away function shown in Figure 7 (a) and the number of trapped victims at the moment of entrapment classified by the animation scores shown in Figure 7 (b). These two assumptions, which we still cannot readly conclude definit or opmtimum, led us to the resulting survival rate function shown in Figure 7 (c).

We originally classified extrication difficulty into three levels. After a trial and error sequence to obtain a good fit between the reported data and our calculations, we gave the score of 8, 30 and 250 man-hours for the three levels of extrication difficulty. These numbers correspond to classifications of easy to difficult, respectively.

Gross and effective rescue power, in terms of the number of rescuers we used in this simulation, were shown in Figure 8. We used the relationship shown in Figure 3 to evaluate effective rescue power.

The number of trapped people in each extrication difficulty level was assumed as 120, 110 and 510, from easy to difficult, respectively. We determined this distribution so as to obtain a good fit between simulated and reported numbers of extricted people by day for the first ten days after the collapse. This determination, therefore, was dependent on the assumption for the allocation of rescue power and the scores given to, and number of, people in each extrication difficulty level.

Figure 9 is a final result of live and dead recovery of trapped victims obtained through our series of trials and errors. This provided a reasonably good fit between the data and the calculation. Even though we need further examination of the given assumptions for various parameters, we can point out that our model has substantially good applicability to the reproduction of observed events.

5. CONCLUDING REMARKS

A computer model to estimate the number of people extricated alive and dead was developed to establish a theoretical point of view to direct the method of data collection in future events. The computer model was applied to the case of a reinforced concrete frame building with high occupancy, the Juarez Hospital, Mexico City, to confirm its appropriateness.

Items to be investigated in a future collapse site, at least suggested from this study, are:

1) Extrication time and health condition of each extricated victim dead or alive. Health condition is to be determined in terms of FT (Fade-Away Time) as well as the conventional measures including the part, type and seriousness of injuries (Injury Severity Score).

2) Arrival time of rescue power, including the number and quality of rescuers and equipment.

3) Type of rescue activities taking place: their duration and extent. Documentations of the number of rescuers and the items and amount of equipment.

4) Extrication difficulty as the period between the detection of a trapped victim and his extrication.

5) Construction type and damage situation of a collapsed building.

Although the following are also necessary to analyze collapse events in our computer model, it is appropriate to determine those factors indirectly through an "inversion" procedure by application of the computer model. Items that are to be determined indirectly are:

1) Number, or distribution, of trapped victims in each category of health condition assigned by animation score at the first moment of entrapment (t=0) - time of collapse.

2) Number, or distribution, of trapped victims in each category of entrapment condition assigned by extrication difficulty.

3) Distribution of extrication effort to trapped people by category of extrication difficulty.

Determination of fade-away functions (assignment of the two parameters, Do and N) is a task that may be achieved through examination of existing data in the field of emergency medicine. We need further introduction of medical scientific information to solve this problem, even if our effort to collect the related data in future collapse sites is still needed.

Acknowledgements

The authors thank Dr. Andrew Coburn of the Martin Center for Architectural and Urban Studies, Cambridge University for his discussions on which this study was based.

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Krimgold, F. (1988); Search and rescue in collapsed reinforced buildings, Proceedings of Ninth World Conference on Earthquake Engineering, Tokyo, vol. VII, pp. 693-696.

Rojas Enriquez, C.A. (1987); El terremoto de 1985 en el Hospital Juarez de la Ciudad de Mexico. Secretaria de Salud, Hospital Juarez II, Mexico D.F.

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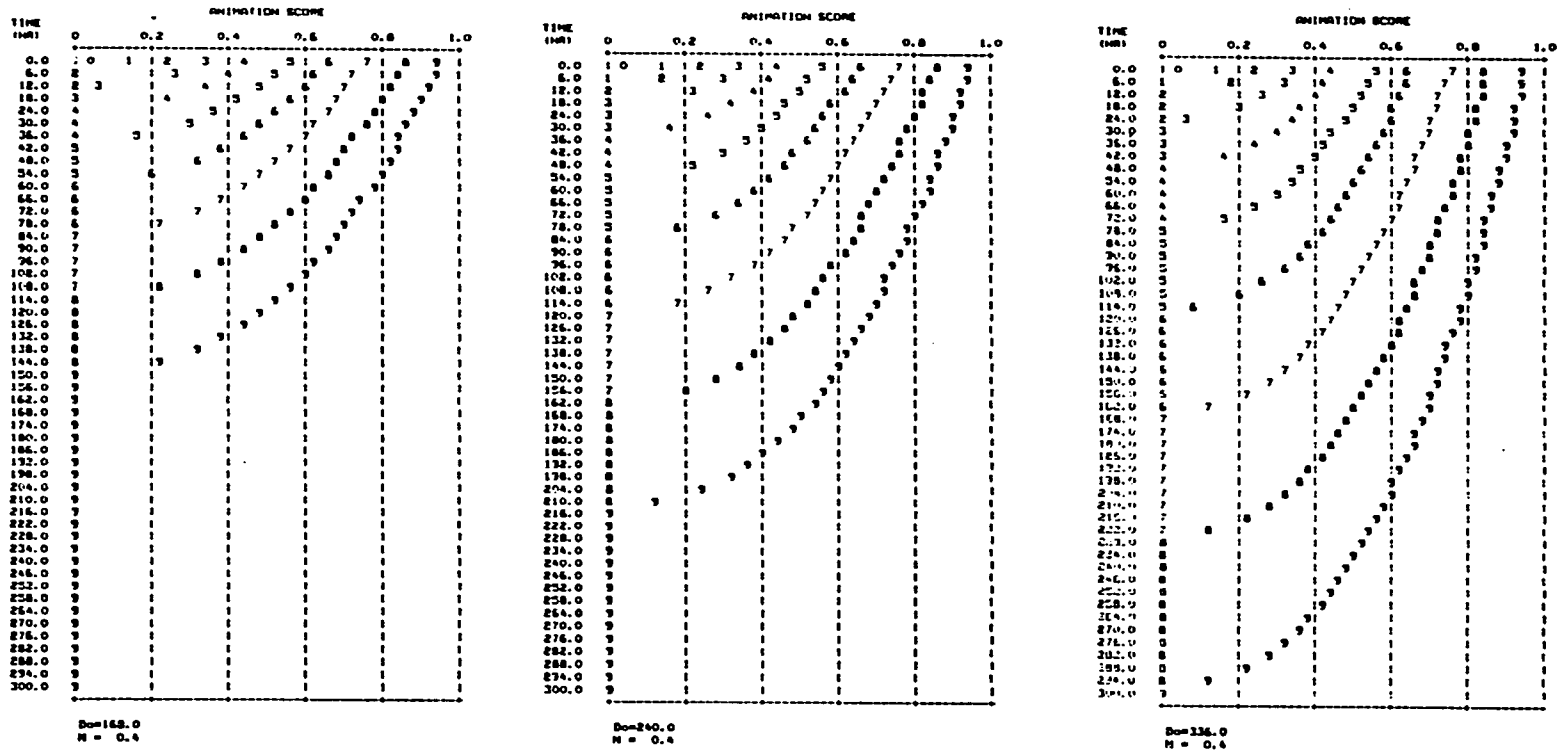
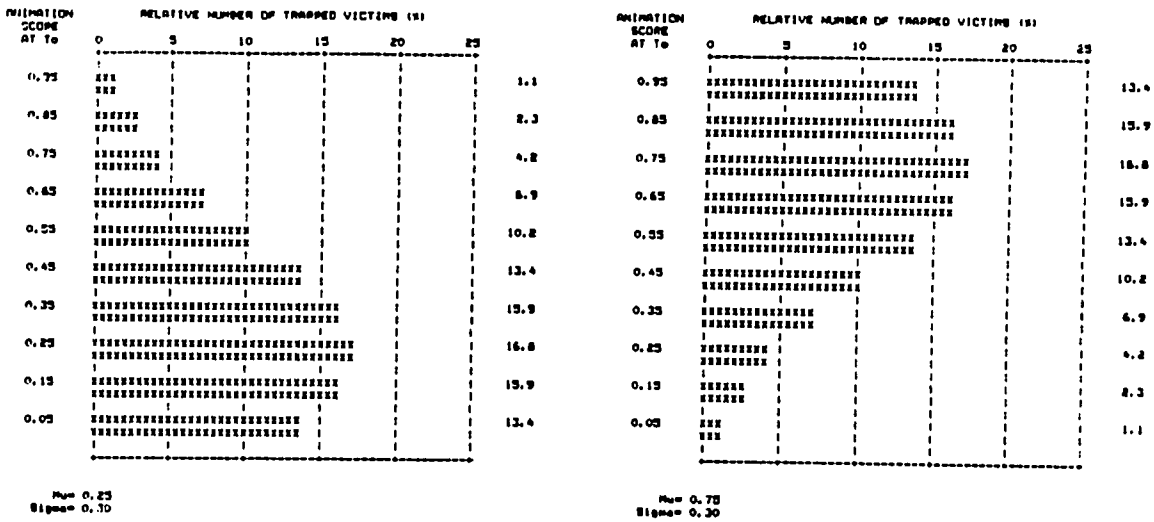
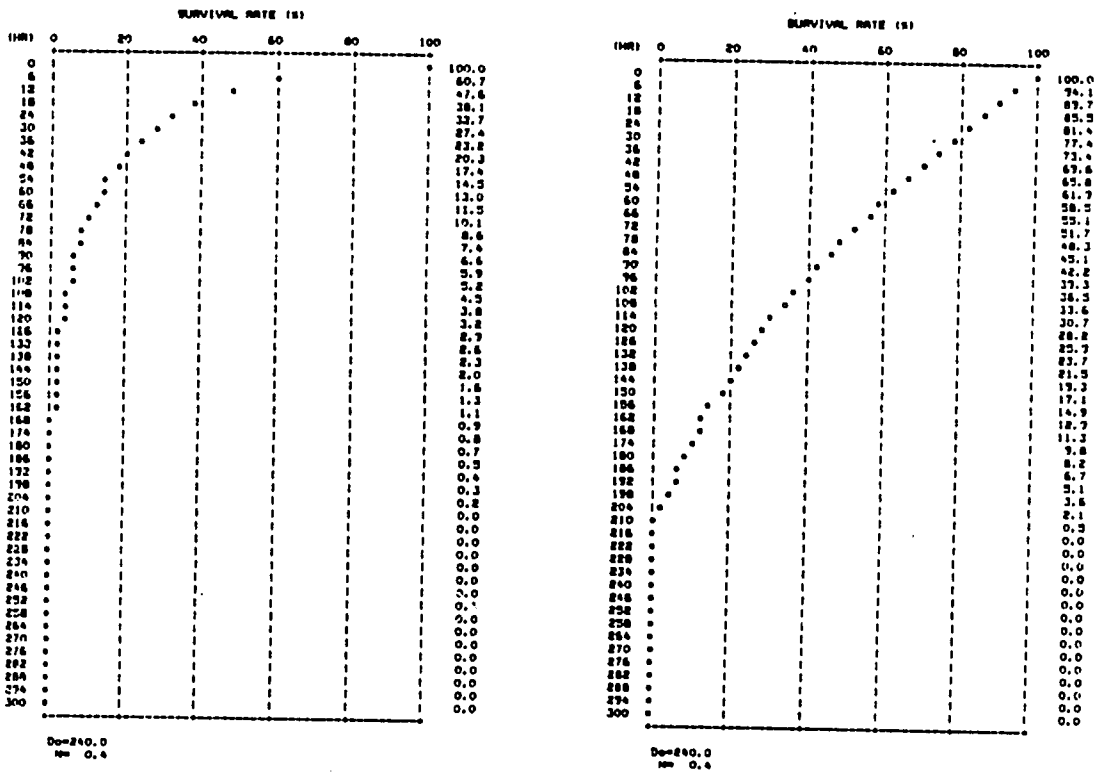


(a) (b) (c)

Figure 1. Fade-away function. There are two parameters that control the general pattern of fade-away functions, Do and N. Do determines the duration during which trapped victims deteriorate to die; N determines the change of rate, or speed of deteriotation with time.



(a)



(b)

Figure 2. Survival rate.

(a) Initial distribution of trapped victims in terms of animation score.

(b) Survival rate as a function of time. The survival rate function is derived from a set of fade away functions and the initial distribution of trapped victimes shown in (a).

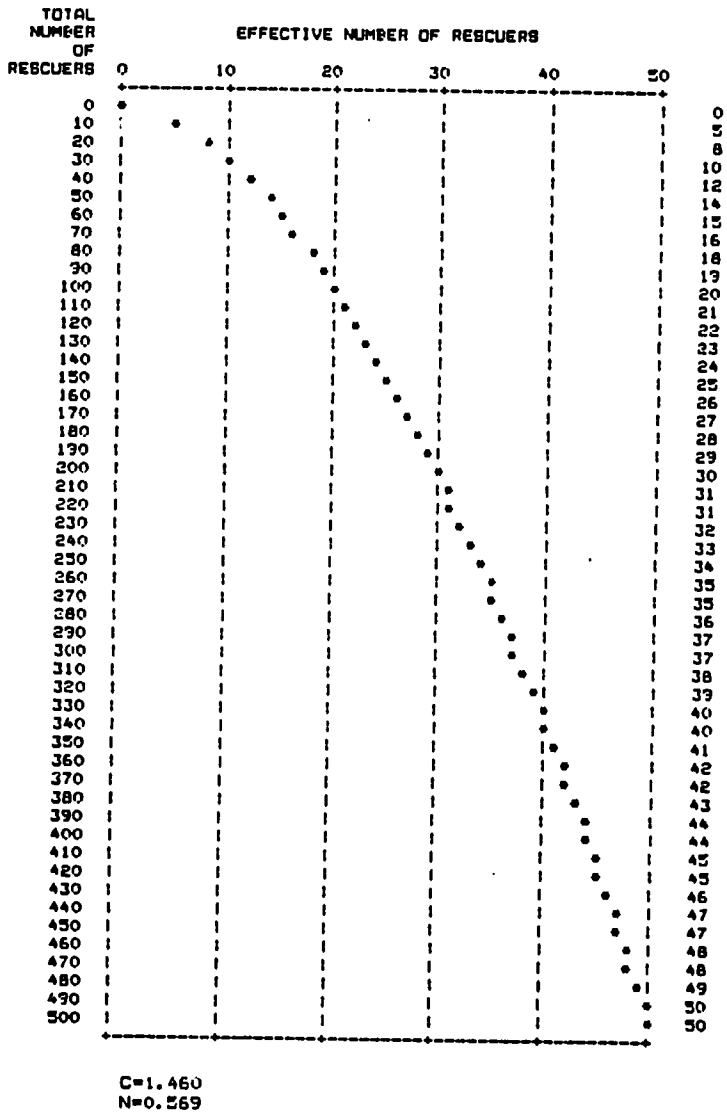


Figure 3. Effective rescue power, an example.
The relationship between the total and effective number of rescuers is expressed by a function as

(effective)=c*(total)^n,

where c and n are constants.

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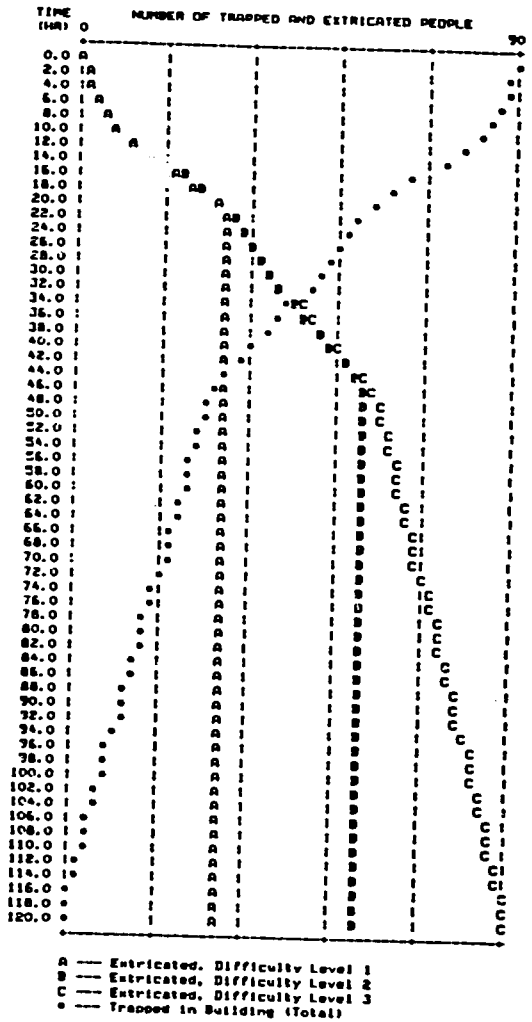
LEVEL OF EXTRICATION DIFFICULTY	EXTRICATION EFFORT NEEDED PER TRAPPED VICTIM (MAN-HOUR)	INITIAL NUMBER (DISTRIBUTION) OF TRAPPED VICTIMS (PERSON)
1	5	30
2	25	30
3	125	30

(a)

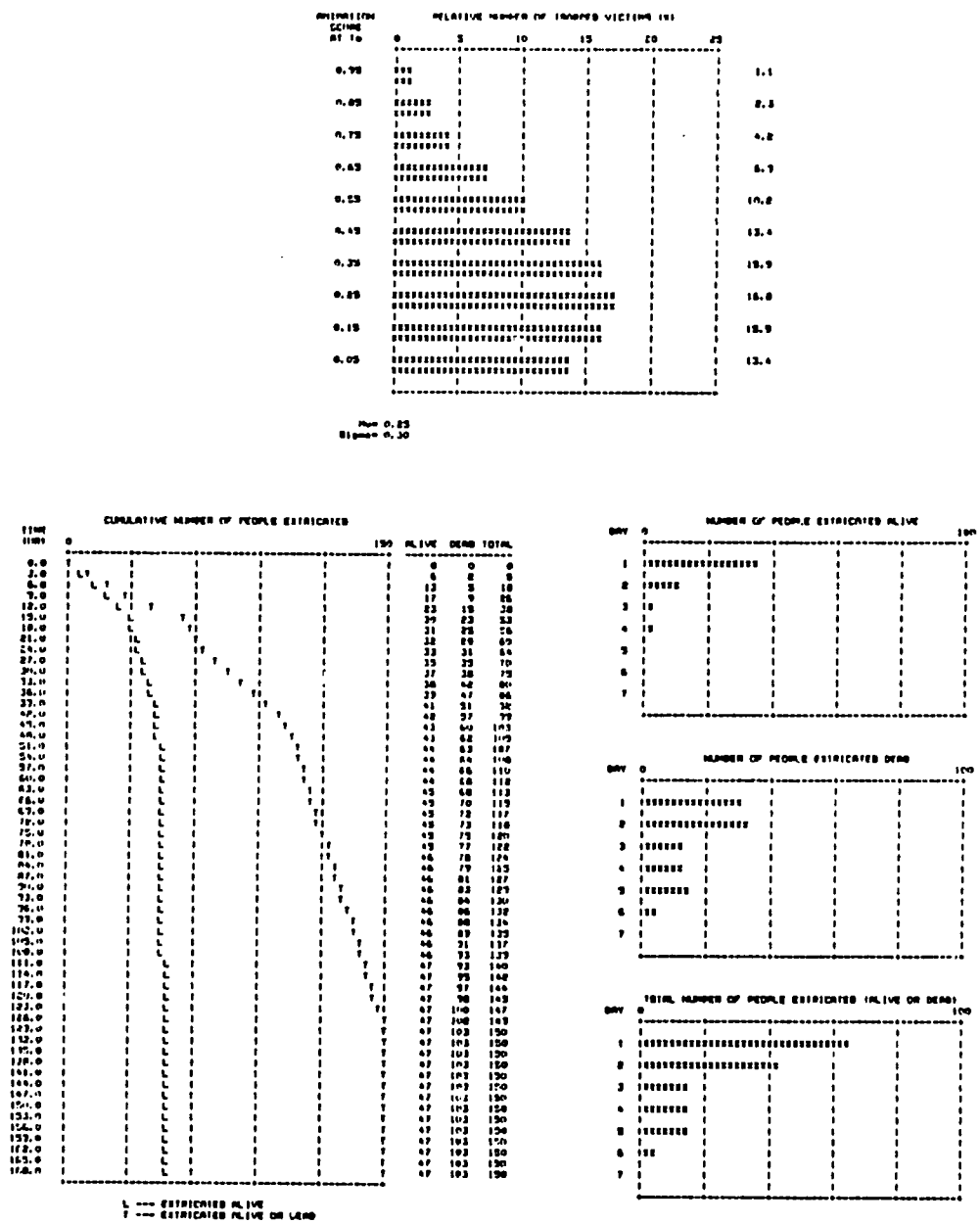
TIME (HR)	EFFECTIVE MAN-POWER	
	ARRIVED	CUMULATIVE
0.0	5	5
6.0	10	15
12.0	20	35
18.0	10	45
24.0	5	50

(b)



(c)

Figure 4. Extrication process.
(a) Number of entrapped people by extrication difficulty level,
(b) Alloction of rescue resources,
(c) Cumulative number of extricated people.

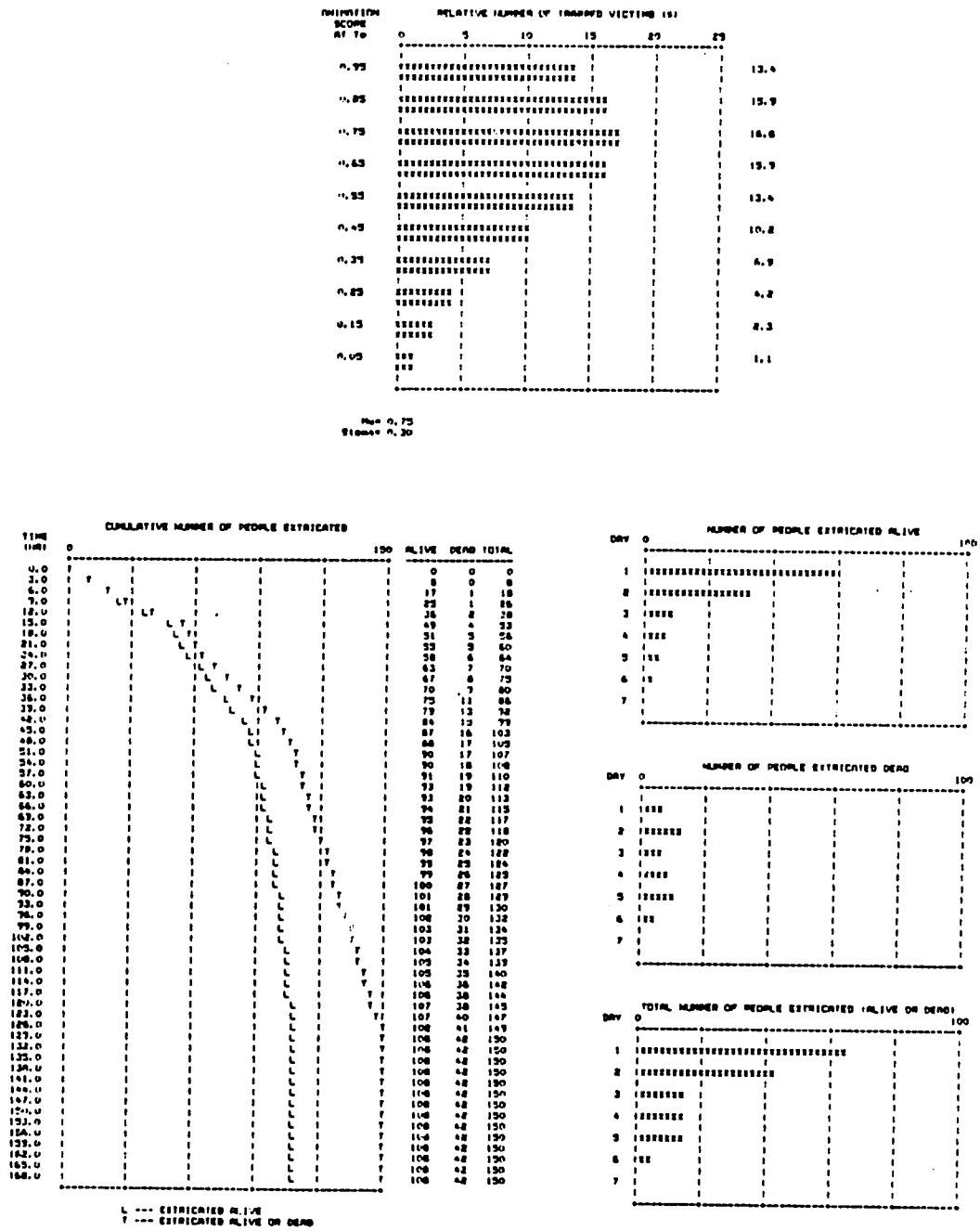


(a-1)

Figure 5. Examples of output.

(a-1) and (a-2): Comparison between cases where victims are more and less affected by the direct impact from building collapse. The same initial distribution of victims by extrication difficulty and allocation process of rescue power are used for the two cases.

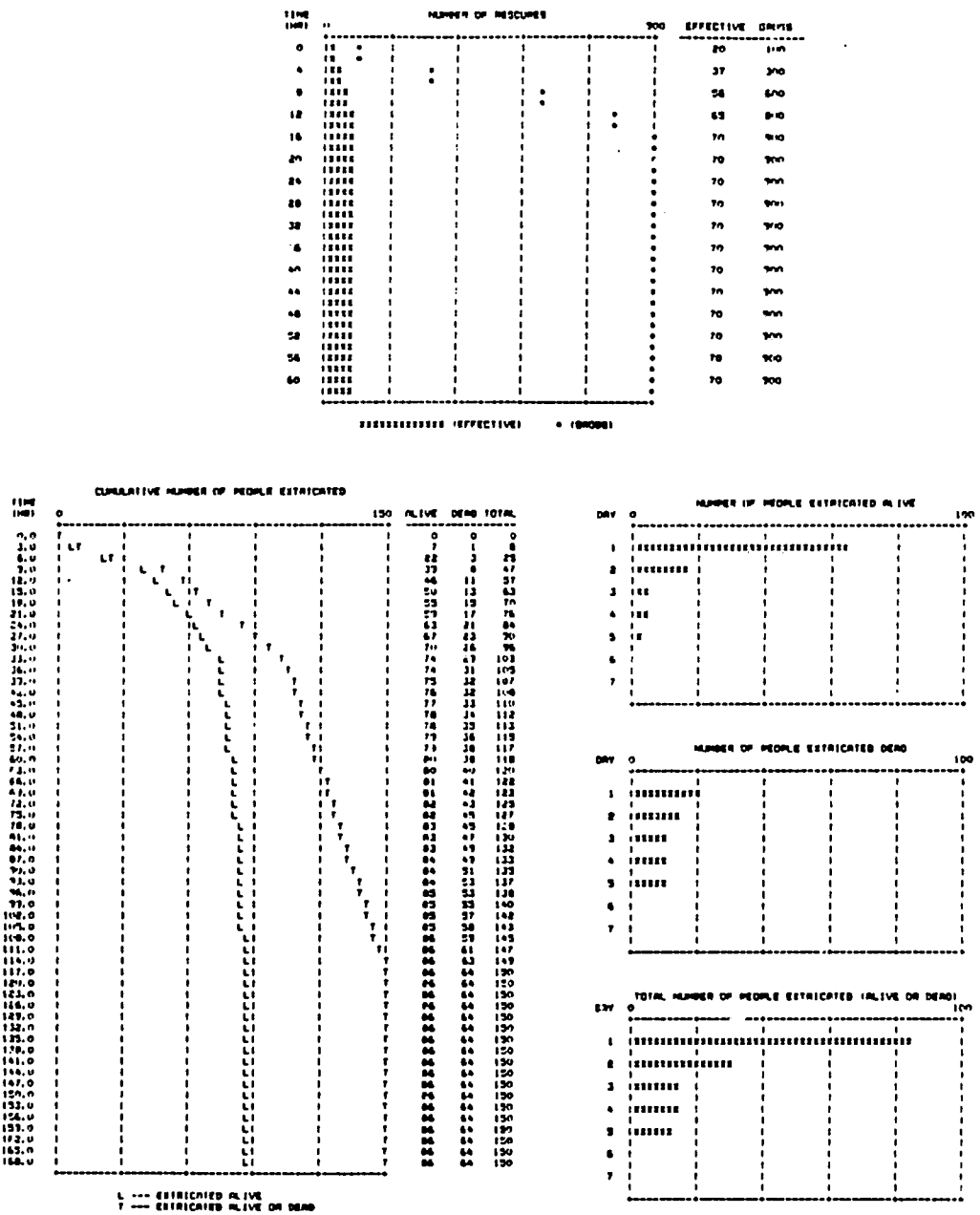
(b-1) and (b-2): Comparison between cases where rescue resources is allocated quicker and slower. The same initial distribution of victims by animation score and by extrication difficulty are used for the two cases.



(a-2)

Figure 5 (continued)

380



(b-1)

Figure 5 (continued)

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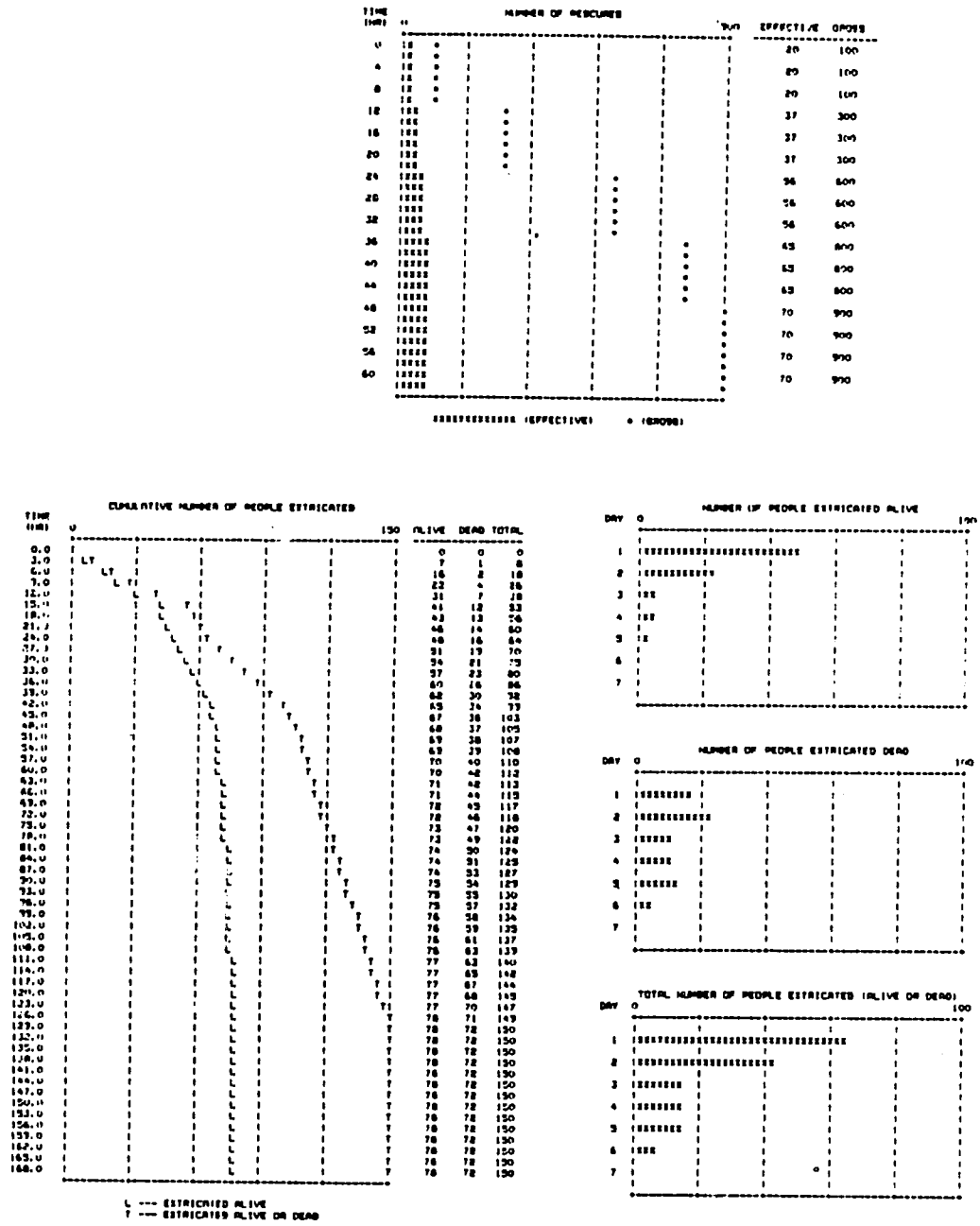

(b-2)

Figure 5 (continued)

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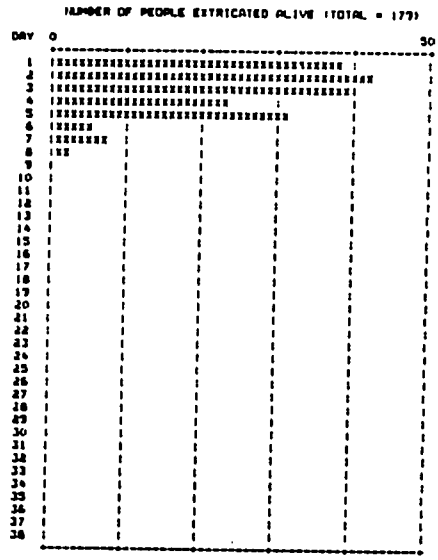
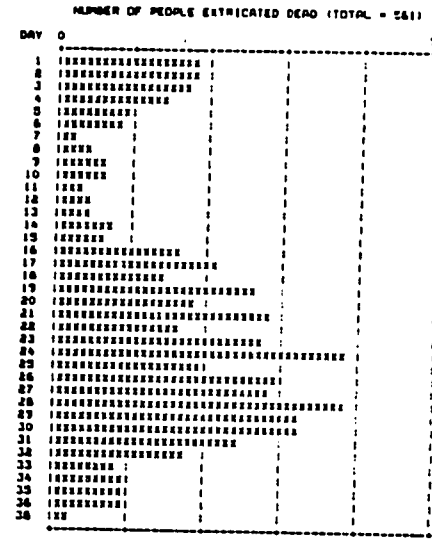


(a)



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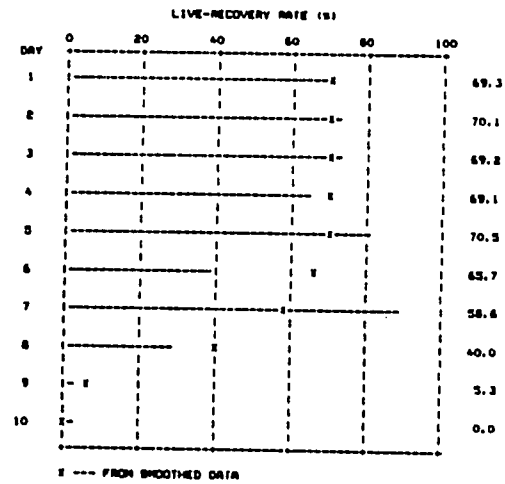
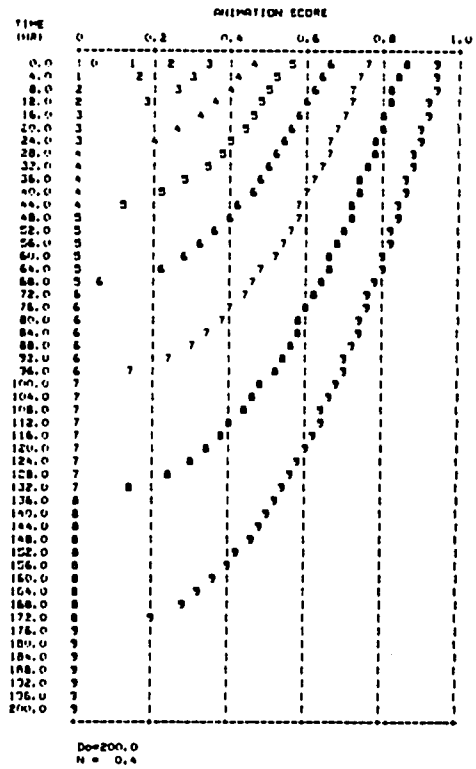
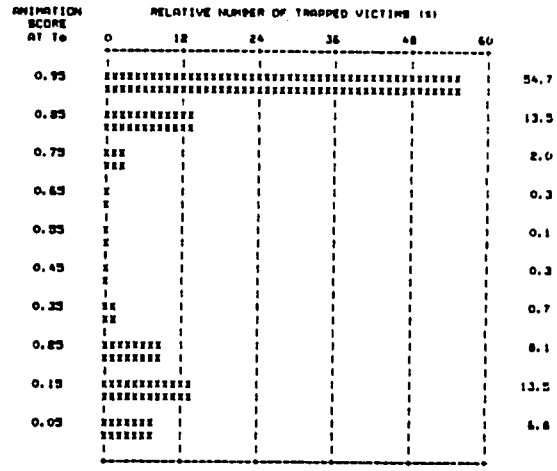


(c)

Figure 6. Recovery of trapped people; Data from the Juarez Hospital, Mexico City, 1985 (after Rojas Enriquez, 1987).
(a) Live-recovery,
(b) Dead-recovery,
(c) Live-recovery rate.



(a)



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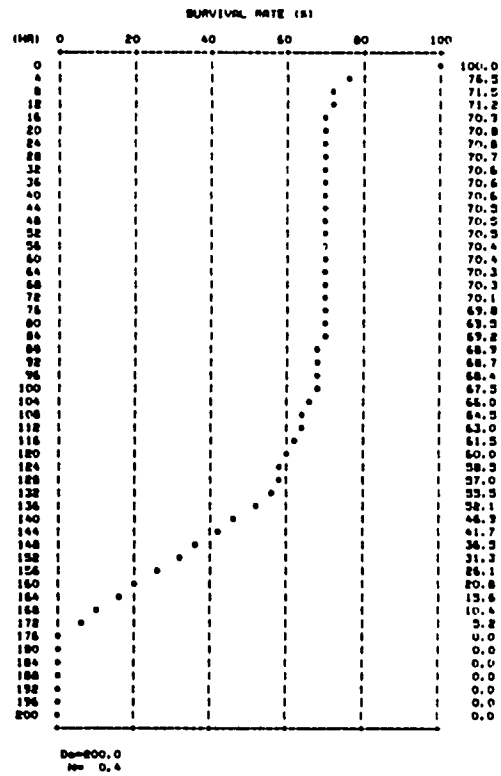

(c)

Figure 7. Survival of trapped victims in the Juarez Hospital
(a) Fade-away functions,
(b) Initial distribution of trapped victims by animation score,
(c) Survival rate.

TIME	ARRIVAL	CUMULATIVE
0	50	50
12	50	100
24	100	200
48	200	400
72	100	500

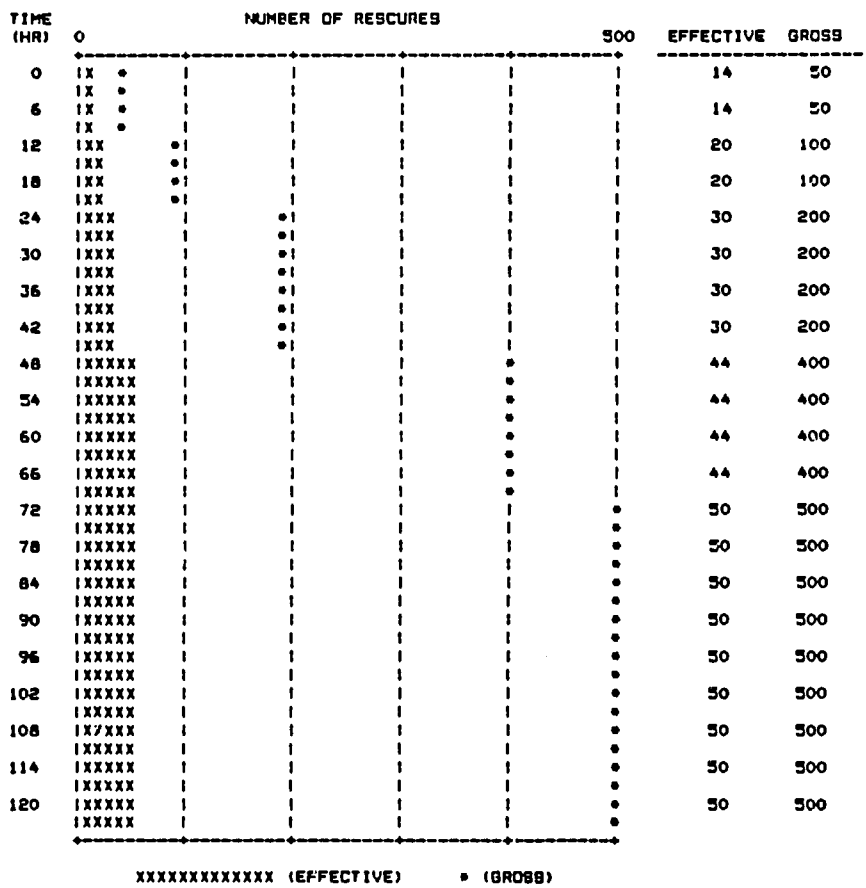

Figure 8. Effective rescue power, an assumption for the case of the Juarez Hospital.

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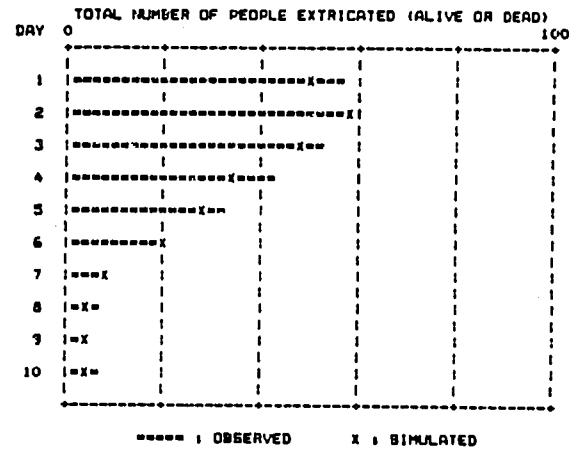
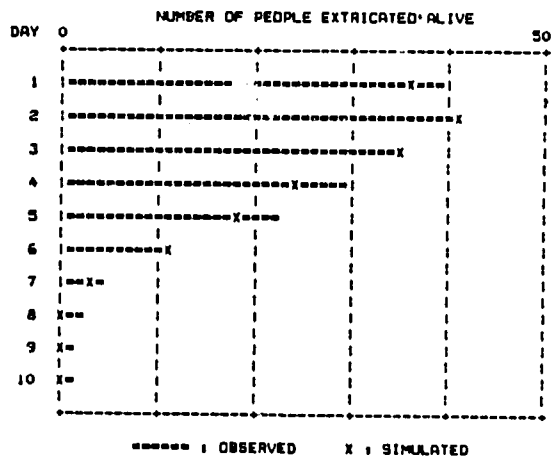


(a)



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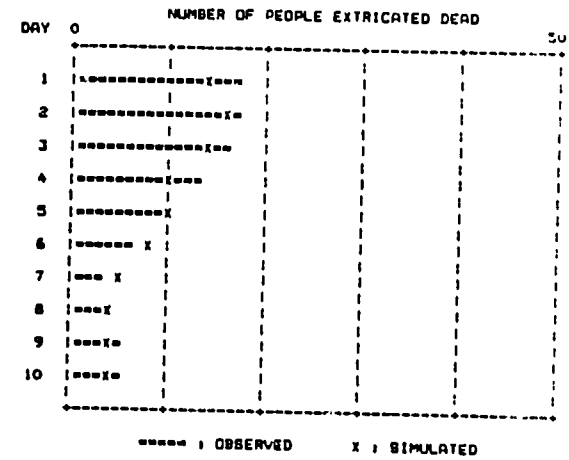

(c)

Figure 9. Simulated daily number of people extricated from the Juarez Hospital.
(a) Total,
(b) Live-recovery,
(c) Dead-recovery.

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GROUND SHAKING

↓

BUILDING COLLAPSE
(High Occupancy, Engineered)

↓

ENTRAPMENT

↓

SEARCH AND RESCUE

↓

RECOVERY (Live - Dead)

↓

TRANSPORTATION

↓

MEDICAL TREATMENT

JUAREZ HOSPITAL, MEXICO CITY, 1985

740 Trapped

↓

179 Live Recovery

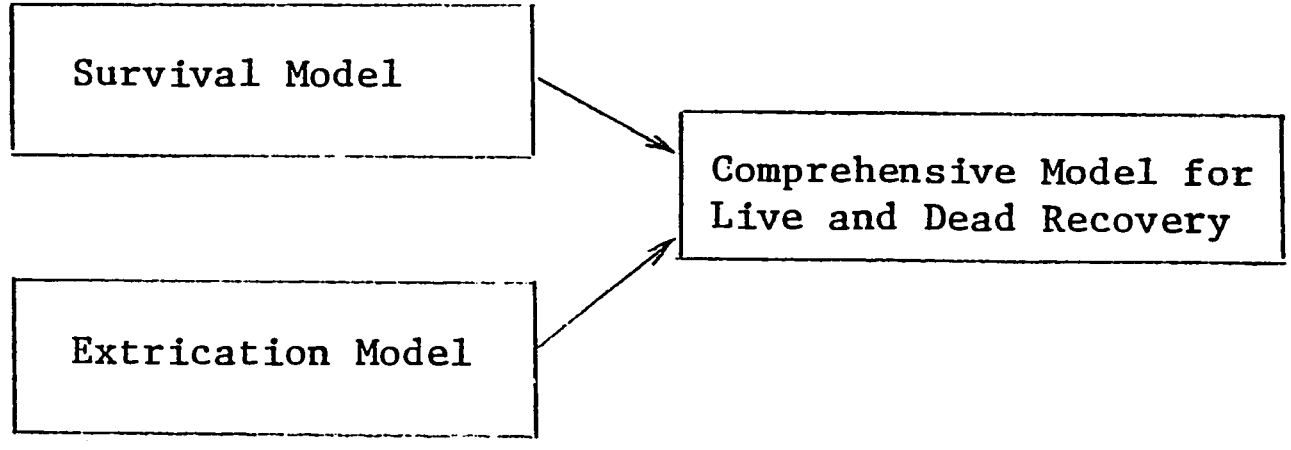
561 Dead Recovery

RECOVERY OF TRAPPED VICTIMS

TWO ASPECTS

1. How do they SURVIVE ?

2. How are they EXTRICATED ?



1. Survival

2. Extrication

---

1. SURVIVAL

(1) One Individual Victim ———— Fade-Away Time

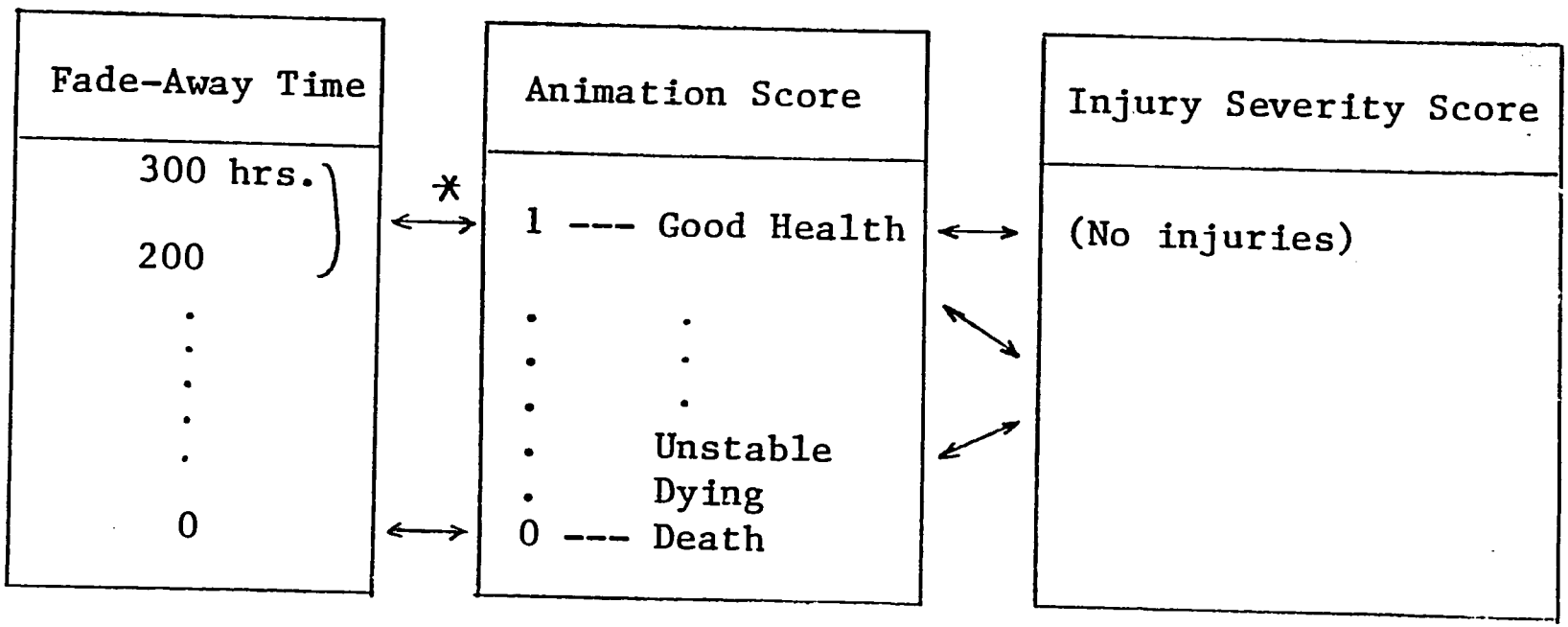
↓ ← *

(2) Victims in a Collapsed Building — Survival Rate (t)

* Initial Distribution of
Animation Score

ANIMATION SCORE

How long a trapped victim can survive. --- Fade-Away Time.



? How to Relate.

* { Condition of Entrapment
Characteristics of Victims

1. Survival

2. Extrication

---

2. EXTRICATION

(1) Rescue Power

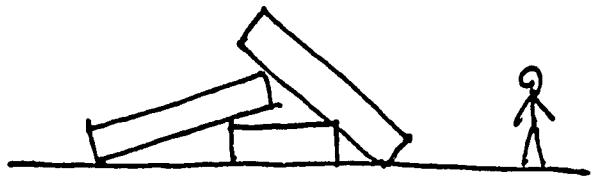
(a) Arrival Time
(b) Effectiveness

(2) Entrapment (Situation of)

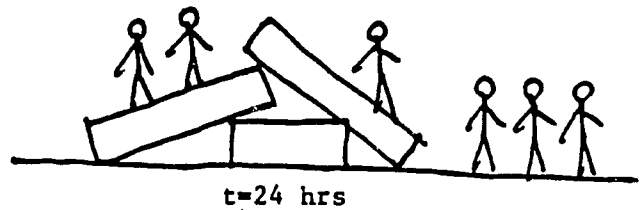
(c) Extrication Difficulty

Affecting Factors (Extrication)

(a) Arrival

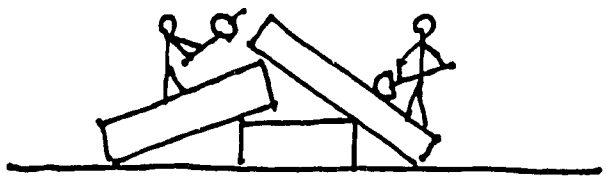


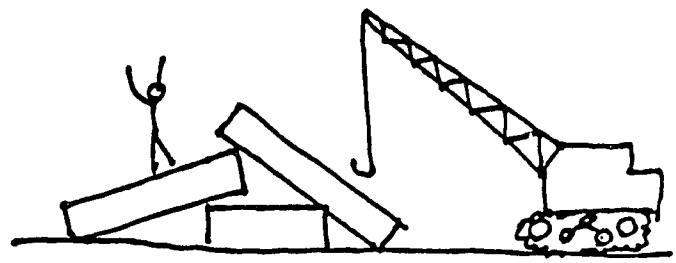
t=0

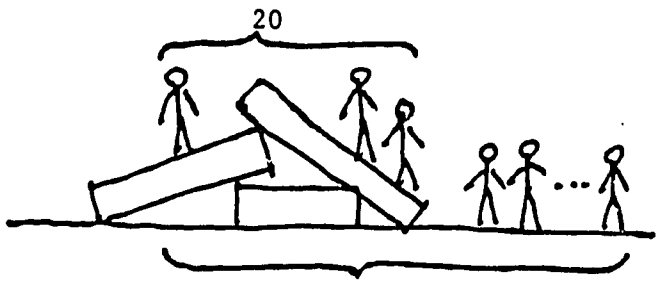


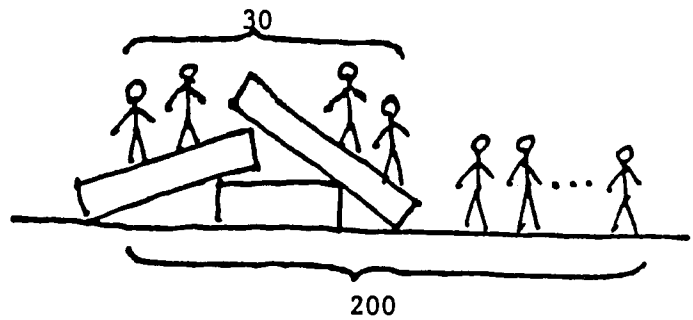
t=24 hrs

(b) Effectiveness

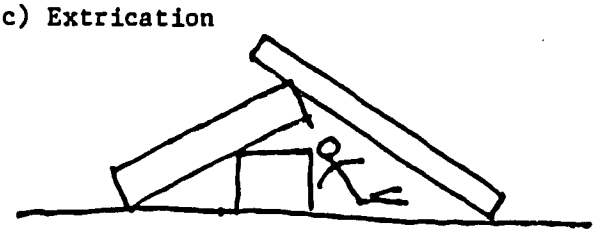








(c) Extrication

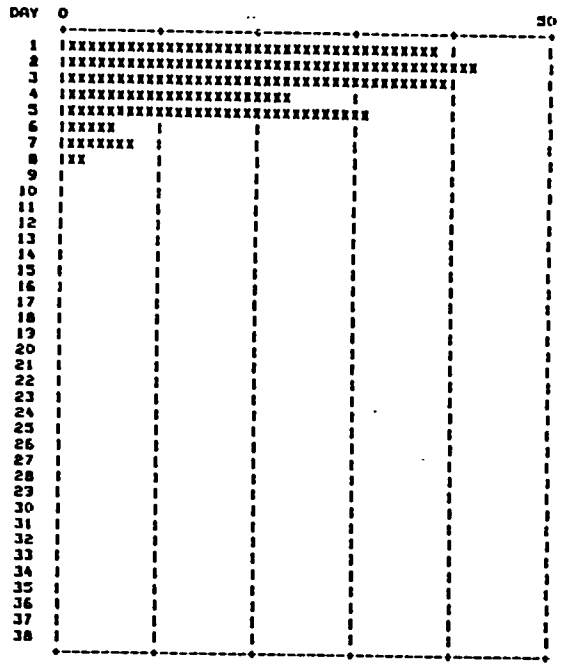


Easy ---------- Difficult

10 man-hours 50 man-hours

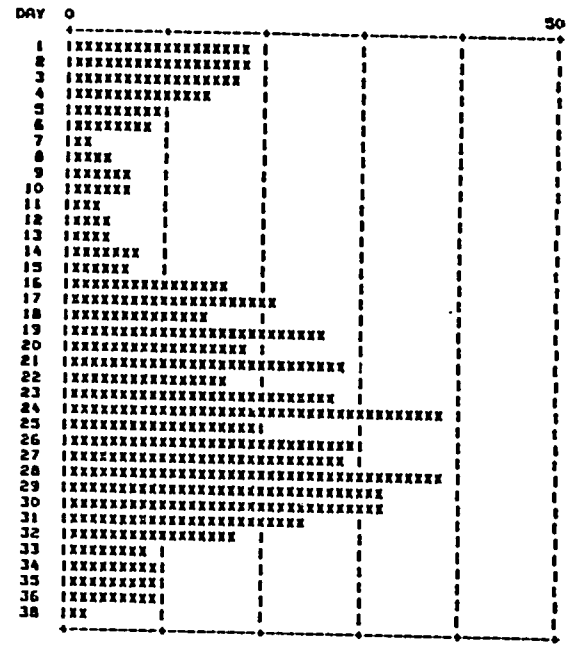
Live Recovery

NUMBER OF PEOPLE EXTRICATED ALIVE (TOTAL = 173)

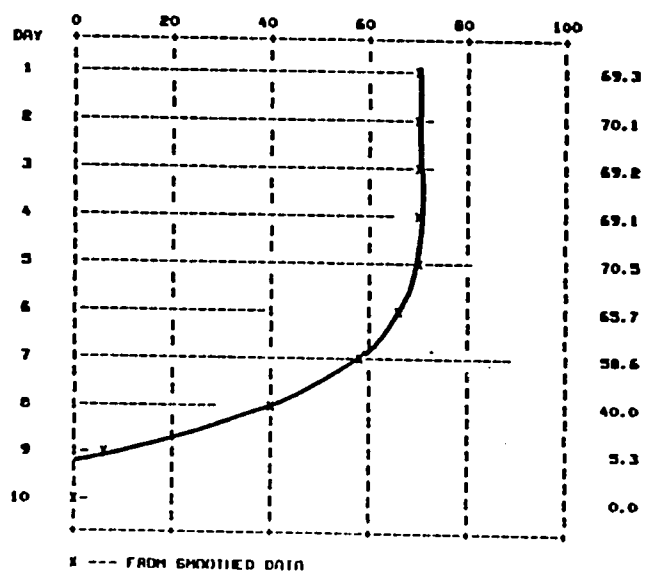


Dead Recovery

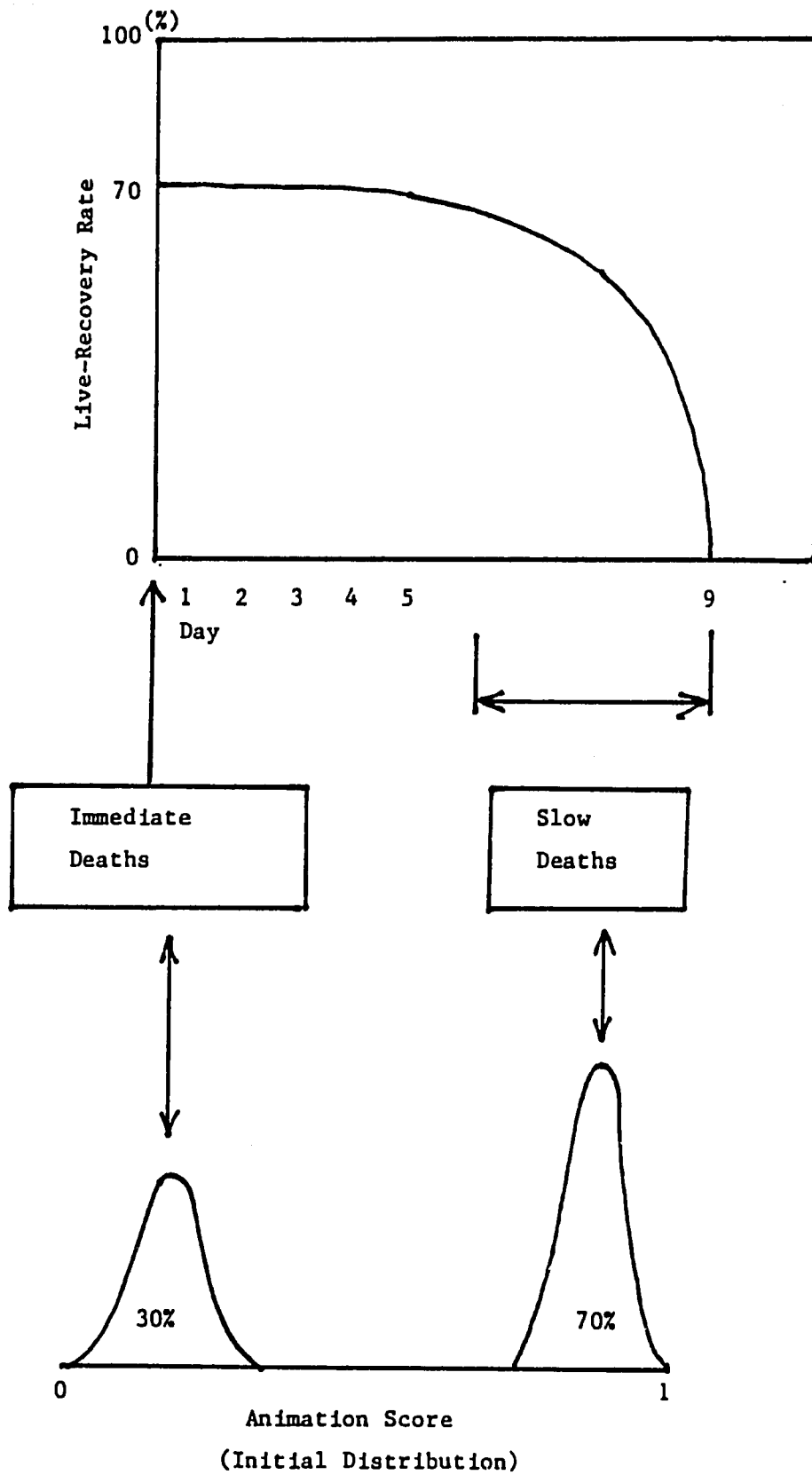
NUMBER OF PEOPLE EXTRICATED DEAD (TOTAL = 561)



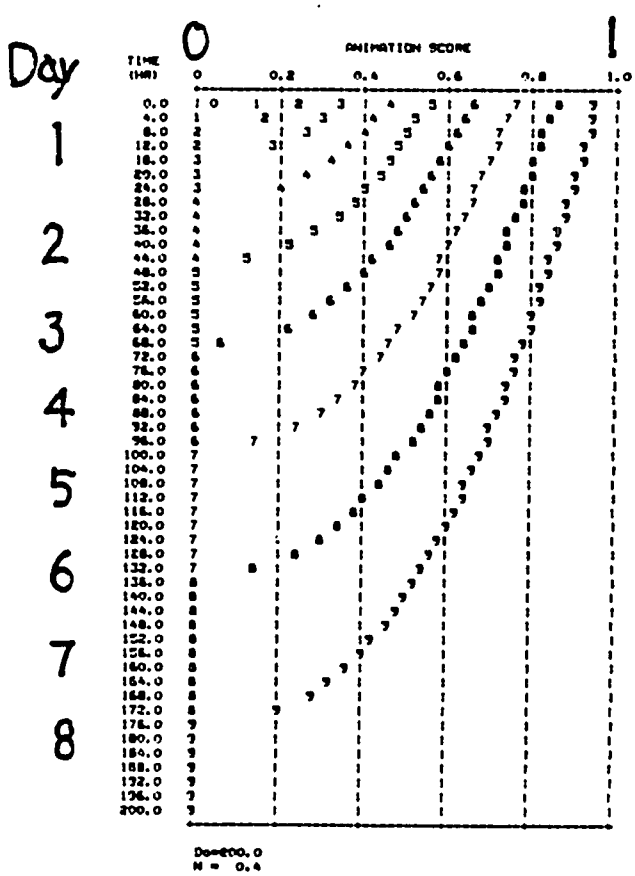
LIVE-RECOVERY RATE (%)



Live/(Live + Dead)

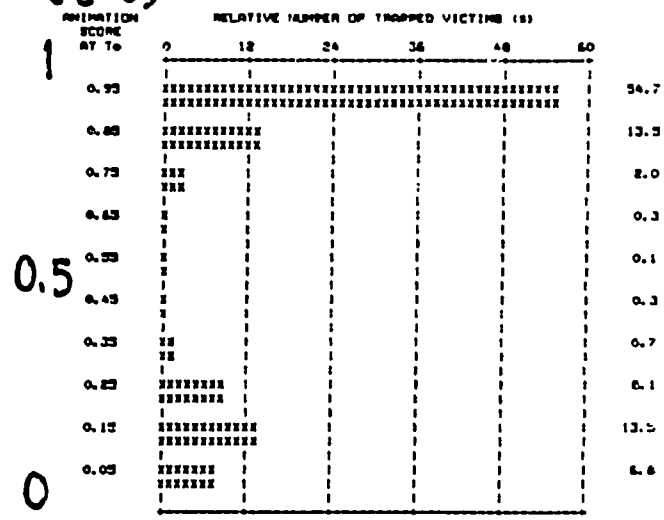

100 (%)
70
0
Live-Recovery Rate
1 2 3 4 5 9
Day
Immediate Deaths
Slow Deaths
30%
70%
0
1
Animation Score
(Initial Distribution)

Animation Score

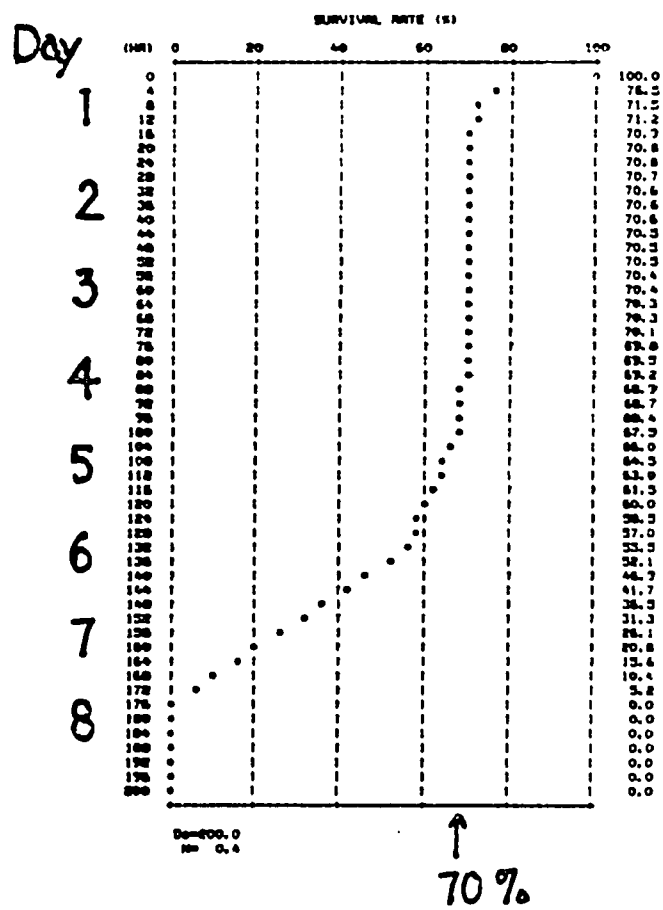


Animation Score (t=0)

Number of Trapped Victims

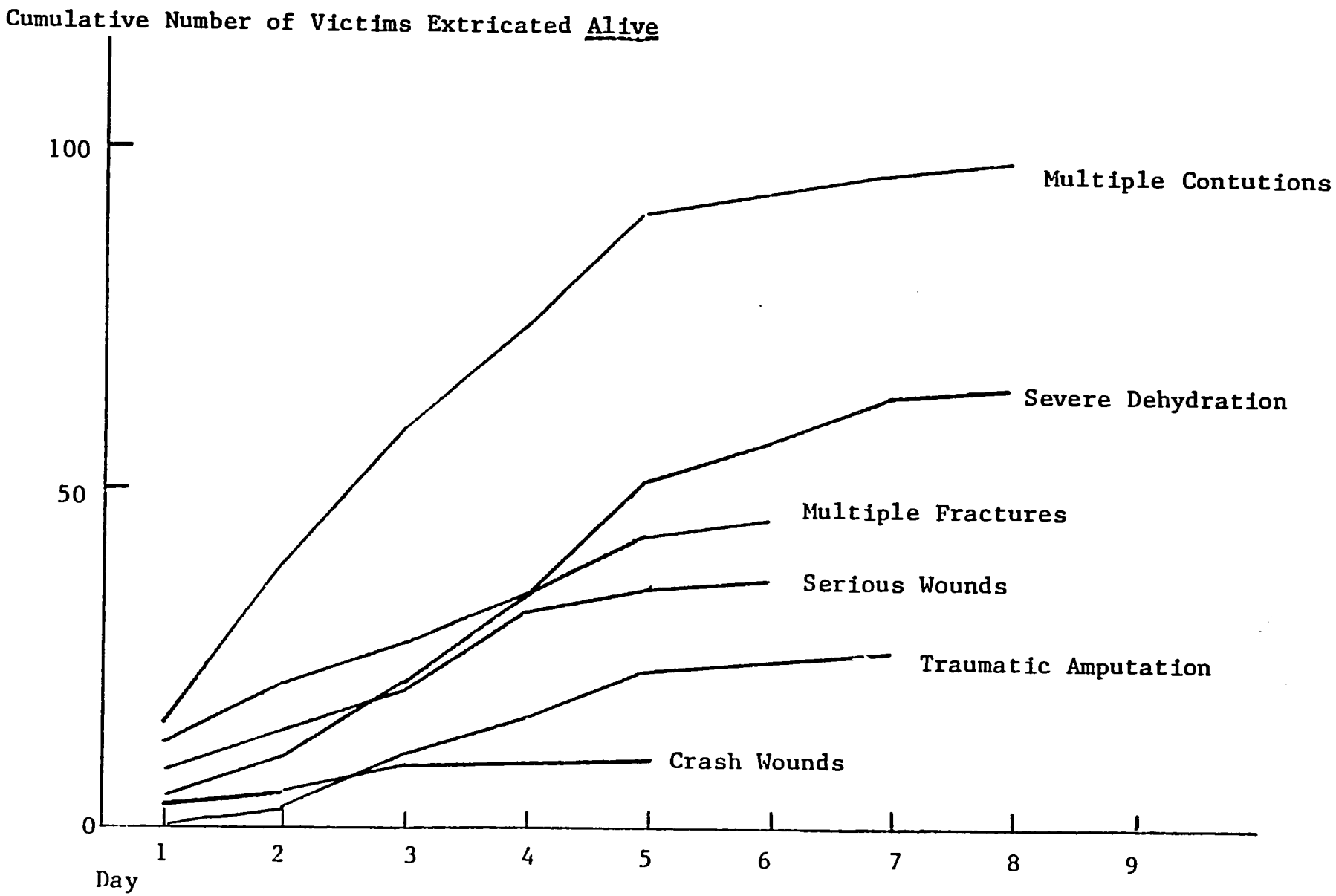


Survival Rate (%)



Juarez Hospital
1985
〈Simulated〉

Juarez Hospital, 1985

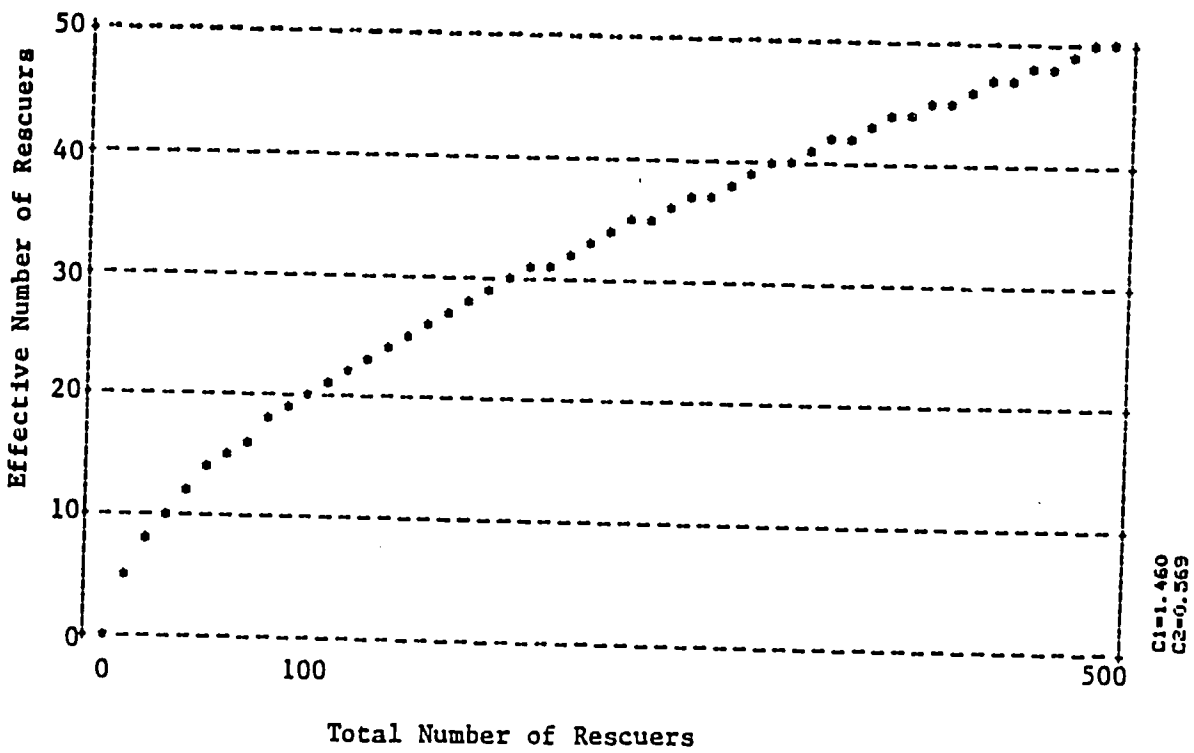


Juarez Hospital, 1985

EXTRICATION DIFFICULTY

LEVEL	MAN-HOUR
1	8
2	30
3	250

TIME (HR)	MAN-POWER ARRIVED	GROSS	EFFECTIVE
0.0	50	50	14
12.0	50	100	20
24.0	100	200	30
48.0	200	400	44
72.0	100	500	50



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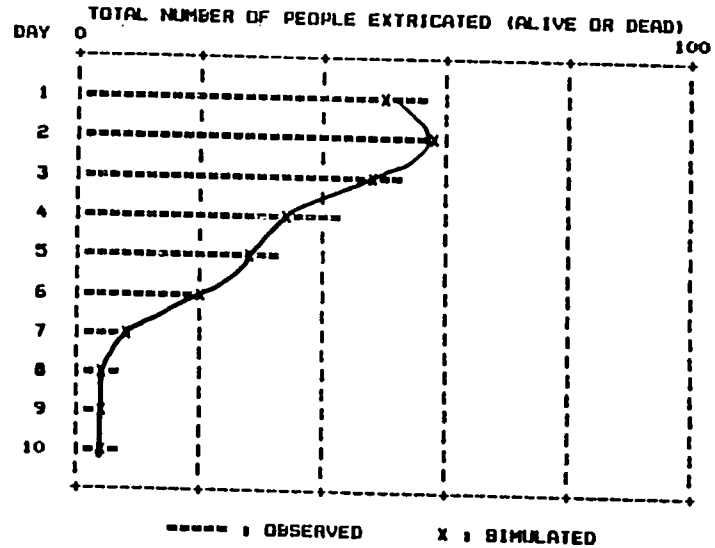
Juarez Hospital

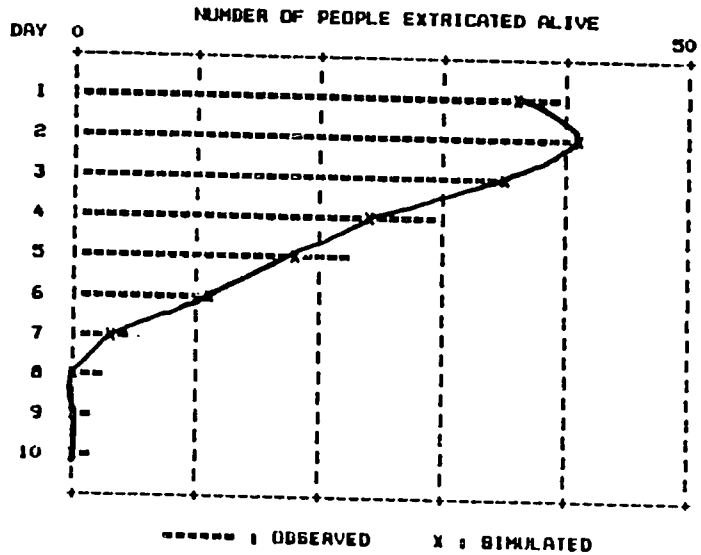
=== Observed

X Simulated

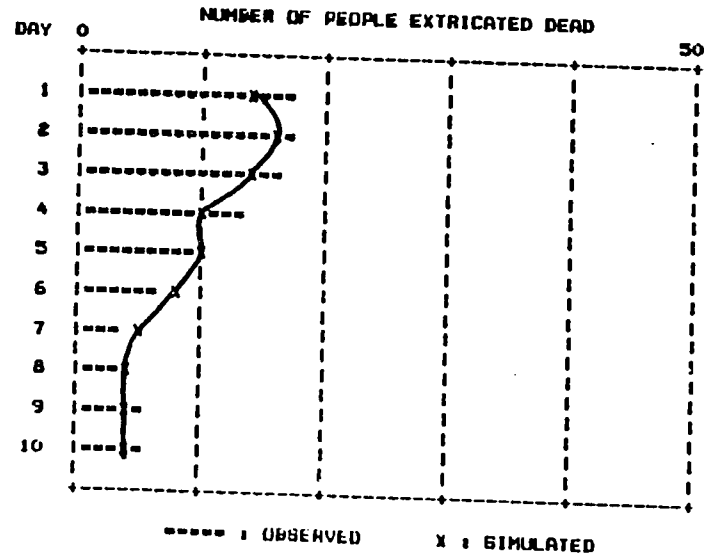
Alive + Dead



Alive



Dead



A Computer Model for the Recovery of Trapped People in a Collapsed Building: Development of a Theoretical Framework and Direction for Future Data Collection

We did:

(1) Identification of Affecting Factors

(2) Development of a Computer Model

(3) Test of Computer Model
Juarez Hospital, Mexico City, 1985

↓

(4) Direction for Future Data Collection

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Items to Be Investigated in Future Events

1. On-Site Data Collection

   (1) Extrication Time and Health Condition
         Each Extricated Victim, Alive or Dead
         Fade-Away Time and Injury Severity Score
         Detailed Description of Injuries
   (2) Arrival Time of Rescue Power
         Man-Power, Equipment
         Amount, Quality
   (3) Rescue Activities (Type of)
   (4) Extrication Difficulty
         Period between Search and Extrication

2. Application of Inversion Method
   (Recovery Model Developed Here)

   (1) Distribution of Trapped Victims by Animation Score
   (2) Extrication Difficulty
         Averaged and Categorizes

FEDERAL URBAN SEARCH AND RESCUE

CAPABILITIES AND ROLES IN THE UNITED STATES

THE INTERAGENCY COMMITTEE ON SEARCH AND RESCUE
(ICSAR)

AD HOC STUDY GROUP ON URBAN SEARCH AND RESCUE

Laurence W. Zensinger, Chairman

January, 1988

P-296

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ABSTRACT

The Federal Interagency Committee on Search and Rescue (ICSAR), until recently, has been concerned primarily with coordinating the activities of the federal government (U.S.) dealing with wilderness, air and sea search and rescue. In May of 1988, however, the committee created an Ad Hoc study group made up of representatives of member and non-member agencies for the purpose of assessing the current status of federal urban search and rescue capabilities and recomnmending steps that could be taken to improve these capabilities.

The report of the ICSAR Ad Hoc study group on urban search and rescue capabilities of the federal government was transmitted to the ICSAR in January of 1989. The report, in accordance with the assignment given the study group, identified the current capabilities of the federal government for supporting urban search and rescue requirements, assessed the strengths and weaknesses of these capabilities, and suggested roles that it would be appropriate for the federal government to undertake in the development of a national urban search and rescue system. The study group concluded, not surprisingly, that urban search and rescue capabilities, to the extent that they exist at all in the United States, reside primarily at the local level, but that these capabilities are not inventoried or easily accessible if needed in response to a catastrophic emergency. The report further concluded that, while it is probably not appropriate that a pool of federally owned or controlled teams or equipment resources be created, there is definitely a role for the federal government in organizing a process by which non-federal urban search and rescue resources in the U.S. could be identified, validated, standardized, trained and mobilized in response to rescue needs across the country. In addition, the study group felt that the federal government should play a leadership role in research and development activities.

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REPORT OF THE

AD HOC STUDY GROUP ON HEAVY URBAN SEARCH AND RESCUE
(INTERAGENCY COMMITTEE ON SEARCH AND RESCUE)

INTRODUCTION

This report was prepared by participants identified on the attached list (Attachment 1) in accordance with the Terms of Reference for the Ad Hoc Study Group on Heavy Urban Search and Rescue (Attachment 2). The report focuses on Federal Government activities and responsibilities, but also identifies State and local government and private sector officials with whom Federal Government officials have had some association as they explore development of search and rescue capabilities.

Sections of the report correspond with the five specific points the study group was tasked to address. They are:

Part A: Key organizations, offices, and persons which have responsibilities, capabilities or interests that may relate to heavy urban Search and Rescue (S&R) efforts. A brief list is supported by a broader synopsis that outlines the general interests and capabilities of the organization, office, or person.

Part B: A brief written summary of key laws, agreements, plans or other key documents that may relate to heavy urban S&R or to similar disaster response efforts.

Part C: A brief written opinion of the key strengths and weaknesses of existing plans as they may relate to federal coordination or federal response to heavy urban S&R.

Part D: Suggested Federal plans or efforts that should be made to improve planning and preparation for large scale urban S&R scenarios, with recommendations as to who should lead and be involved in these efforts, and suggested suitable target dates.

Part E: Recommendation as to the role The Interagency Committee on Search and Rescue (ICSAR) should play, if any, in furthering federal preparation for heavy urban S&R, and what alternatives exist, if any, to ICSAR involvement.

The Ad Hoc Study Group on Heavy Urban S&R also considered their role as an ongoing mechanism for coordinating Federal urban search and rescue activities.

PART A: RESOURCES/CAPABILITIES

SUMMARY OF KEY URBAN SEARCH AND RESCUE RESOURCES

Federal Resource/Plan/Capability	Organization/Point of Contact
Plan for Federal Response to a Catastrophic Earthquake	FEMA Larry Zensinger (202)646-3681
Emergency Support Function #9, Urban Search and Rescue, annex to the Plan for Federal Response to a Catastrophic Earthquake, primary and support agency responsibilities.	DOD/Department of Army Lt Col Don Willhouse (202)695-7045/695-2003 (primary); access to support agencies
Access to State/local government private sector resources; organized international response teams; foreign assistance.	Office of Foreign and Disaster Assistance Oliver Davidson (202)647-5916
Quick response teams experienced in mine rescue, building collapse, and earthquake response. Experience includes Mexico City earthquake, Joplin, Missouri building collapse, Bridgeport, Connecticut building collapse and Brownsville, Texas building collapse. Seismic listening devices, television and communications probes, on-site radio communications equipment, satellite radio equipment and mobile command centers.	Mine Safety and Health Administration (MSHA) Madison McCulloch (703)235-1580 Robert Peluso (412)621-4500, x256 Jeffery Kravitz (412)621-4500 x691
Expert knowledge of Search and Rescue Management, requirements and resources. Experience includes many mine emergency operations, Mexico City earthquake, Joplin, Missouri building collapse, Bridgeport, Connecticut building collapse and Brownsville, Texas building collapse.	Jeffery Kravitz (412)621-4500 x691

Following are other than Federal Government resources which may have applicability to Urban Search and Rescue. The availability

and applicability of these resources has not been confirmed.

Non-Federal Resource/Plan/ Capability	Organization/Point of Contact
Search dog teams; some experienced in earthquake/mudslide response	NASAR Dog Division Marian Hardy, (301)762-7217
Engineering services	Society of American Military Engineers Brigadier General W.O. Bachus, (703)549-3800
Expert knowledge of search and rescue requirements and resources	Fred Krimgold VPISU, (703)549-0099
Regional rescue teams	Firefighters and Ironworkers Unions Steve Cooper, Safety Officer, Ironworkers International (202) 383-4829

Other Unique Special Search and Rescue Capabilities

Special Medical Response Team: Experience includes mine emergency operations at the Brownsville, Texas, building collapse.

Access via MSHA (Refer to contacts on page 2)
Richard Kunkle, M.D. (800)482-2122; (412)349-1248

PART A: ACTIVITIES (Continued)

Federal Government Activities:

1. The Interagency Committee on Search and Rescue (ICSAR) is an interagency committee formed to coordinate Federal search and rescue activities. ICSAR is chaired by the Coast Guard, and members are representatives of Department of Transportation (DOT), Department of Defense (U.S. Air Force) (DOD), Department of Commerce (DOC), Department of Interior (DOI), National Aeronautics and Space Administration (NASA), Federal Communications Commission (FCC), and the Federal Emergency

Management Agency (FEMA). The National Search and Rescue Plan and National Search and Rescue Manual were updated in late 1986. Both documents outline responsibilities for coordination of search and rescue operations, other than urban search and rescue.

CONTACT: Dan Lemon, ICSAR Secretariat, U. S. Coast Guard, Chief, Search and Rescue Liaison, 2100 2nd street, S.W. Washington, D.C. 20593-0001, (202)267-1951.

2. In May 1988 ICSAR formed an Ad Hoc Study Group on Heavy Urban Search and Rescue, and set out terms of reference for the group. The group was to prepare a report to present at the October 4 meeting of the ICSAR. Participants and Terms of Reference are included as Attachments 1 and 2 to this report.

CONTACT: Larry Zensinger, Chairman, Ad hoc Study Group on Heavy Urban Search and Rescue, FEMA State and Local Programs and Support, Disaster Assistance Programs, SL-DA-PA-HM, Room 714, Washington, D.C. 20472, (202)646-3681, FAX 646-3077.

3. Planning and operational responsibilities are assigned to Federal agencies in the Urban Search and Rescue annex (Emergency Support Function #9), Plan for Federal Response to a Catastrophic Earthquake. Primary responsibility was assigned to DOD with support from USDA, HHS, DOI, DOL, DOT, FEMA, GSA, VA. Responsibility is for coordinating and managing application of Federal resources to support State and local governments upon Plan implementation.

CONTACT: Lt Col Don Willhouse, Department of the Army, Directorate of Military Support (DA/DOMS), The Pentagon, Washington, D.C. 20310-0440. (202)695-2003/3848, FAX 647-3147

4. The Comprehensive Response to Isolated Severe Events (CRISES) Subcommittee of the Federal Interagency Committee on Emergency Medical Services (FICEMS) was formed to study and make recommendations concerning shortfalls in Emergency Medical Services as they apply to various isolated and severe events. The first event chosen for study by the Subcommittee was the collapse of single reinforced concrete buildings, but has been expanded to include multiple-building collapse events, especially characterized by earthquakes in urban areas. Draft conclusions and recommendations concerning both events have been submitted to FICEMS, and deal with medical as well as related heavy urban search and rescue issues. The Subcommittee will continue to monitor progress on building collapse while examining other EMS situations.

CONTACT: Robert W. Curry, Chairman, CRISES, Central Intelligence Agency, Office of Medical Services, Washington, D.C. 20505, (202)351-2278.

5. The Office of Foreign Disaster Assistance (OFDA), Agency for International Development, has contacts with State and local governments, Federal agencies, and the private sector to identify and obtain search and rescue resources. An international quick response search and rescue team for collapsed structure rescue is being established. It will be fully equipped, trained, and prepared to depart within 2-6 hours after official notification.

CONTACT: Oliver Davidson, Assistant Director for Operations Support, Office of Foreign Disaster Assistance, Room 1262A, Washington, D.C. 20523, (202)647-5916, FAX (202)647-5269.

Non-governmental activities:

1. The American Society for Testing and Materials (ASTM is a not for profit management system for development of voluntary consensus standards) initiated work on a search and rescue standard. Per memo of October 27,1987, prospective members were invited to attend a meeting held in St. Louis March 4-5, 1988 and a meeting was held on July 31,1987 to plan for a new search and rescue activity.

The project will address standards in areas of:
- equipment and uses
- organization and management
- personnel training and education
- search operations and techniques
- rescue operations and techniques
- terminology

CONTACT: Wendy Dyer, Staff Manager, Developmental Operations, ASTM, (215)299-5400, 1916 Race Street, Philadelphia, PA 19103

2. The National Association For Search And Rescue (NASAR) is an active volunteer organization which places considerable emphasis on the special needs of urban search and rescue. Areas of interest are use of dog teams for search, and special equipment and expertise for rescue. An Urban Search and Rescue Working Group is chaired by Lois Clark McCoy, past president of NASAR and presently an emergency services official in Santa Barbara County, California. Extensive lobbying effort by this group to California legislature, DOD, FEMA, OFDA and NASAR is underway. A white paper on Heavy Rescue Operations was published June 10, 1987. The NASAR Search and Rescue Dog Division maintains a directory of more than 60 search dog groups nationwide; experience of dog teams is mostly in wilderness/isolated incident search. In early 1986 a National/International S&R Dog Response Coordination Project was initiated to address use of dogs in the urban collapsed building environment.

CONTACTS: NASAR President: Bill Pierce, National Park Service (Contact through NASAR headquarters), (703)352-1349, P.O. Box 3709, Fairfax, VA 22038.
NASAR Urban Search and Rescue Working Group: Chair, Lois Clark McCoy, (805)568-3417, ext. 7327 and (805)681-4200.
NASAR Dog Teams: Marian Hardy, (301)762-7217.

3. Society of American Military Engineers (SAME) works through 150 posts nationwide; about 50 of the posts have completed readiness plans. Members are willing and able to assist in search and rescue, but they need to know how to integrate their response capabilities with other organizations. Brigadier General Bachus presented information at a special meeting of the

Interagency Committee on Search and Rescue, March 21, 1988.

CONTACT: Brigadier General W. O. Bachus, USA, Retired, Executive Director, The Society of American Military Engineers, (703)549-3800, 607 Prince Street, P. O. Box 21289, Alexandria, VA 22320-2289

4. American Society of Civil Engineers (ASCE) met in Washington, D.C. in September 1987. One area of emphasis was urban search and rescue and what the ASCE should do to address the issue.

CONTACT: Edward Kippel, Manager, Technical Services, (212)705-7495, 345 E. 47th Street, New York, New York 10017.

5. American Public Works Association met in Chicago during 1987 where topic of urban search and rescue was considered.

CONTACT: Ron Sears, Council of Emergency Management, (312)667-2200, x534, 1313 E. 60th Street, Chicago, Illinois 60637.

6. Fred Krimgold, Virginia Polytechnic Institute and State University, under a grant from the National Science Foundation, has become a primary national expert on capabilities and issues related to urban search and rescue. A report is to be published.

CONTACT: Fred Krimgold, VPI College of Architecture and Urban Studies, The Washington Alexandria Center, 101 North Columbus Street, Alexandria VA 22314, (703)548-0099.

7. International Association of Fire Chiefs has organized a subcommittee on urban search and rescue.

CONTACT: Gary Briese, Executive Director, International Association of Fire Chiefs, (202)833-3420, FAX 452-0684.

8. Firefighters Union and Ironworkers Union have indicated they are establishing regional rescue teams in the United States to respond to building collapses like the Bridgeport, Connecticut incident. Newly elected officers are interested but will need several months before they address this issue.

CONTACT: Steve Cooper, Safety Officer, Ironworkers International, (202)383-4829.

9. Special Medical Response Team (S.M.R.T.) is a non-profit, volunteer medical rescue organization based out of Western Pennsylvania, in existence since 1982. The team provides a highly advanced level of medical care and support during mine disasters, industrial accidents, and other types of incidents involving prolonged entrapments to; have experience mobilizing the team and equipment (mobilize and respond within one hour or less from the time a call is received) to travel long distances;

be available for use upon official request-- depending on the nature of the incident, location, and availability of transportation--outside Pennsylvania; and to maintain a high level of training, modification of existing equipment, and research and development of equipment and methods of caring for seriously injured or ill patients while they are still entrapped. Primary source of funding for equipment and operational expenses comes from a Mine Safety and Health Administration grant (administered through the Department of Environmental Resources, Pennsylvania, Bureau of Deep Mine Safety).

CONTACT: Richard F. Kunkle, MD, President, (412)537-1187 (office). Emergency numbers: Indiana County 911, (412)349-1428, 1/800-482-2122. Within Pennsylvania 1/800-428-2121.

PART B: KEY FEDERAL DOCUMENTS

1. Disaster Relief Act of 1974 (P.L. 93-288), administered by FEMA, provides Federal assistance to supplement State and local government efforts upon Presidential declaration of an "emergency" or "major disaster" as a result of a natural disaster. Emergency assistance is provided to save lives and protect property, public health and safety or to avert or lessen the threat of a disaster. A major disaster declaration provides assistance above and beyond emergency services in alleviating the damage, loss, hardship, or suffering caused thereby.

2. The Plan for Federal Response to a Catastrophic Earthquake, dated April 15, 1987, describes the Federal response to any natural event as a result of a Presidential declaration (emergency or major disaster, under the authorities of the Disaster Relief Act) during life saving response operations. Delivery of assistance is organized through emergency support functions, with primary and support agency assignments to Federal agencies. The Department of Defense has primary responsibility to coordinate and manage the federal Urban Search and Rescue function as well as responsibility for coordination of all military support operations during a declared disaster, with support by USDA, HHS, DOI, DOL, DOT, FEMA, GSA, and VA. Officials of these and other Federal departments and agencies are signatories to the Plan.

3. Memorandum of Understanding between FEMA and the National Association of Search and Rescue, signed September 25, 1985, under the authority of the Federal Civil Defense Act of 1950, as amended. "Provides for mutual cooperation and establishes policy, procedures, and guidelines relative to the mutual concerns...in all facets of emergency response search and rescue."

4. Report by Applied Technology Council (ATC-21-2), April 1988, Earthquake Damaged Buildings: An Overview of Heavy Debris Removal and Rescue. Publication that presents information on rapid visual screening of seismically hazardous buildings and relationship to heavy urban rescue and victim extrication. It identifies types of buildings that might collapse, trap victims, and generate enough debris to require special or heavy equipment for extrication of victims; provides guidance on how to identify these types of buildings, based on major exterior features; and, provides information on types and capacities of equipment required to remove debris from collapse of such buildings.

5. Training course developed and pilot-tested by the California Fire Marshall, under a FEMA Civil Defense grant, for fire

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fighters and emergency workers on heavy rescue equipment techniques.

6. National Search and Rescue Plan, 1986. Signed by DOT, DOD, DOC, DOI, NASA, FCC, and FEMA. Plan provides internal guidance for signatory agencies for coordinating search and rescue services to meet domestic needs and international commitments. Does not specifically identify heavy urban search and rescue responsibilities or requirements.

7. National Search and Rescue Manual, 1 November 1986, adopted by Departments of Transportation (U.S. Coast Guard), Army, Navy, and Air Force. Outlines systems, procedures, techniques, and terminologies for coordination of search and rescue operations. Identifies international and national organizations and agencies that are concerned with search and rescue. Urban search and rescue is not included in the Manual.

8. Other documents:

"The Logistics of Deploying a United States Search and Rescue Team," OFDA.

Mine Safety and Health Administration, procedures for accessing and deploying response teams.

U.S. Air Force, Rescue and Recovery Center procedures.

Part:C

Strengths and Weaknesses of Key Federal Urban Search and Rescue Plans and Programs

This section will analyze some of the existing federal plans, programs and resources that have applicability to urban search and rescue in terms of their strengths and weaknesses for providing federal support to State and local government needs and capabilities.

Generally, what capabilities exist to undertake urban search and rescue, in response to the collapse of buildings in the United States, are concentrated at the State and local government level or in the private sector. Where resources do exist, at either the federal or nonfederal level there is no system for locating, accessing and paying for assistance in the face of a specific building collapse incident in the United States.

1. The Plan for Federal Response to a Catastrophic Earthquake,

(April, 1987), provides a mechanism for federal Urban Search and Rescue (US&R) assistance for catastrophic natural disaster. This plan would only be implemented, however, in the most rare instances of a catastrophic earthquake or other natural disaster. It does not provide for federal assistance for the majority of building collapse scenarios that can be anticipated. While the Department of Defense (DOD) has assumed responsibility for planning and managing federal US&R activities in response to a catastrophic earthquake or other catastrophic natural disaster, DOD is only now in the initial stages of determining how they will carry out the mission. In addition, DOD does not now contemplate establishing any specialized resources or expertise for US&R but rather applying existing manpower and logistical capabilities.

2. The Mine Safety and Health Administration (MSHA) has technical capabilities for handling some aspects of US&R operations. While MSHA has used its capabilities in building collapse rescue operations, and is an important resource to call during future emergencies, there are some limitations that must be recognized regarding their capabilities. First, MSHA's capabilities are designed for, and have as the priority mission, mine search and rescue and not building collapse search and rescue. While there are several similarities between the two emergency situations, there are undoubtedly some differences which have not been accounted for in the development of equipment, procedures and the training of personnel.

Second, the MSHA technical resources, consisting of seismic listening devices and other specialized capabilities, could probably deal with only one building site per hour. Finally, there is currently no mechanism to ensure after an incident that financing will be available to cover the costs of team deployments for US&R purposes. This limitation also applies to non-federal capabilities at MSHA's disposal.

There is, in addition, specialized equipment such as geophone listening devices in the possession of the U.S. Army Corps of Engineers and Borehole camera equipment owned by the Department of the Interior's Office of Surface Mining. Both of these capabilities have been used for rescue operations in Mexico City and can also be considered part of the limited list of federal technical rescue capabilities.

3. The quick response rescue teams currently being assembled by the Office of Foreign Disaster Assistance for mobilization to assist foreign countries offers a model that can be considered for application domestically. This capability, to be available within the U.S., would require a domestic agency Sponsor and the development of notification, deployment and financing mechanism.

Part D

Suggested Federal Efforts to Improve Capabilities in Urban Search and Rescue

The group felt that the majority of capability for urban search and rescue should continue to reside at the local government level. There was no suggestion that the federal government establish rescue teams and equipment separate and apart from capabilities of the kind which already exist. Nonetheless, there are substantial gaps in the nation's ability, in response to even a single building collapse incident, to call upon and mobilize the appropriate people and equipment, regardless of location and jurisdiction.

In debating whether there is a federal role in filling in some of these gaps, the group considered that:

a. In the area of emergency management and response, the federal government usually is called upon to provide assistance only when problems exceed the normal capability of local and State resources to deal with them (a collapsed building with one, two, or several people trapped is not a normal situation and would generally require outside assistance).

b. The occurrence of building collapse incidents in the U.S. is so infrequent that it is unlikely that local governments or even States are likely to be able to justify the development of specialized response capabilities. The likelihood of occurrence in any single jurisdiction is simply too low.

c. The limited response capabilities that currently exist are scattered geographically throughout the nation and at varying governmental levels and the private sector, creating a problem of coordination which the federal government may be best positioned to address.

d. The federal government typically provides a leadership role in the area of emergency management through guidance, training development of specialized techniques, funding, etc.

e. There is currently no specific legislative authorization or appropriation for any agency of the federal government to undertake initiatives in the area of domestic urban search and rescue programs. Short of such legislative authorization or funding, any initiatives would probably be limited to activities that could logically be subsumed under existing authorities and within existing budgetary considerations, subject to the support of agency leadership. One of the reasons for the lack of a

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federal focus for US&R efforts is the absence of legislative authority. Without legislative direction, federal US&R activities are likely to continue to be disjointed and incapable of filling the gaps in national capabilities.

The group identified four general areas in which it felt that immediate federal attention is both appropriate and necessary to meet the most serious needs relating to urban Search and Rescue today. The four areas, in their order of importance, are 1) A resources identification and referral system, 2) training, 3) planning guidance and, 4) research. A brief description follows of the committee's finding in these areas.

Resources Identification and Referral. The group felt that with minimal effort it would be possible to develop a checklist for insertion into State and local emergency response plans listing the name, telephone number, general capability and access requirements of search and rescue expertise and equipment currently known to experts in the field. This would provide a starting point for the State and local responders to get "into the system" and would serve an interim need until more sophisticated referral services were developed. It would also be available to Regional and Headquarters Offices of FEMA and other agencies to respond to inquiries or to suggest assistance to local government in response to incidents these offices become aware of even if no request has been made.

Training While the group did not undertake a comprehensive review of targeted training that may be available at the State level, consultation with experts in the field revealed that there is probably no training targeted for local fire and rescue personnel dealing specifically with on-scene management and command of building collapse incidents on a large scale. Furthermore, those local fire and rescue personnel that have some expertise in this area have not been identified in any systematic manner so they can serve as a cadre to be called upon to respond. The group suggests that experts be called together to develop a course curriculum primarily for State fire training institutions. Names of individuals receiving this specialized training, either at the national or state level, should be added to the referral system so that they can be mobilized through mutual aid agreements.

Planning Guidance There is currently no guidance available to State and Local governments on how to plan for and undertake urban search and rescue. For example FEMA, which provides extensive emergency planning guidance to State and local governments, does not suggest that building collapse is a potential problem and urban search and rescue is an area for which emergency response capabilities should be identified. This is understandable since local emergency managers would probably not perceive such an unlikely event to be an emergency

response need. The group believes that FEMA should include building collapse/entrapment as a potential hazard to be addressed by local emergency planners and develop appropriate guidance for urban search and rescue planning.

Research. There is agreement among members of the group and consulted experts that there is a need for research into the problems of and techniques and equipment necessary for accomplishing urban search and rescue. While some research has either been completed or is underway, there is no coordinated approach to identification and ranking of research needs and selection and funding of high priority projects. In addition, there is not a system for evaluating effectiveness of rescue operations that occur to document lessons learned and publish them for future application. None of the agencies represented on the group are essentially research oriented, but all saw the need for a research emphasis in this area. The National Science Foundation and non-governmental groups such as the Natural Hazards Center at the University of Colorado would probably have a role in any program of urban search and rescue.

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PART E

This section includes recommendations as to the role ICSAR should play, if any, in furthering Federal preparation for urban search and rescue, and what alternatives exist, if any, to ICSAR involvement. While urban search and rescue could be included under ICSAR's work, it appears to represent a significant departure from their current activities. Therefore, the group felt that FEMA or some other agency should sponsor an interagency committee which would meet a few times a year to exchange information about urban search and rescue activities, and serve as a forum to continue discussion of the appropriate Federal role. Furthermore, it was suggested that an Interagency Advisory Committee be established, with a rotating chairmanship between agencies, which would meet regularly to exchange information about urban search and rescue activities, serve as a forum to continue discussion of the appropriate federal role and disseminate information. The Interagency Committee should also establish an International Symposium and sponsor international research regarding US&R. The group recommends that FEMA consider providing Federal leadership in resource referral, planning guidance and training recommendations until more permanent arrangements can be made to meet these needs.

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12 May 1988

Terms of Reference for
Ad hoc Study Group on Heavy Urban SAR.

The Interagency Committee on Search and Rescue (ICSAR),

Recognizing the potential importance of federal resources in supporting heavy urban search and rescue (SAR),

Realizing the need for federal heavy urban SAR efforts to be closely coordinated with those of State and Local authorities and resources,

Noting that timely response is usually critical to the successful rescue of survivors from collapsed buildings, that a large number of lives could be at stake, and that multiple sites could be involved simultaneously,

Further noting the existence of such Plans as the National Search and Rescue Plan and the Plan for Federal Response to a Catastrophic Earthquake, and

Believing that current preparation for federal response to heavy urban SAR may be insufficient, and that the need for such response could occur at any time.

Tasks the Ad Hoc Study Group on Heavy Urban SAR to complete by October 1, 1988 the following work:

A. Identify key organizations, offices and persons which have responsibilities, capabilities or interests that may relate to heavy urban SAR efforts.

B. Prepare a brief written summary of key laws, agreements, plans or other key documents that may relate to heavy urban SAR or to similar disaster response efforts.

C. Prepare a brief written opinion of the key strengths and weaknesses of existing plans as they may relate to federal coordination or federal response to heavy urban SAR.

D. Suggest what appropriate federal plans or efforts should be made to improve planning and preparation for large scale urban SAR scenarios, recommending who should lead and be involved in these efforts, and suggesting suitable target dates.

E. Recommend to the Committee what role ICSAR should play, if any, in furthering federal preparation for heavy urban SAR, and what alternatives exist, if any, to ICSAR involvement.

PRESENTATIONS 4

THE MEDICAL SEVERITY INDEX OF DISASTERS

Bo Brismar

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From a medical point of view a disaster can be defined as a destructive event that causes so many casualties that extraordinary mobilisation of medical services is necessary. Considering this definition the parameters needed to quantify a disaster are the casualty load (number of casualties), the severity of incident (severity of injuries sustained), and the capacity of the medical services.

Casualty load

When the alarm center receives the first notification, it may be difficult to make anything but the most tentative guess at the number of casualties to expect. In minor to moderate disasters such as transport accidents the original estimate often made by a member of the public who reports tends to always be overestimated. While this figure often later has to be modified as casualties start being identified, sorted and transported, it is good enough for a first calculation, and can be designated as N.

In major disasters like earthquakes early reports describe a single fragment of a much larger situation and tend to be underestimated. Therefore it is necessary to send a mobile (preferably airborne) medical unit to survey the whole stricken area and assess the magnitude and nature of damage, the number of casualties and their location. Subsequent estimates made at intervals of 1 hour, 2 hours, 3 hours etc., are to be designated as N1, N2, N3, etc.

Severity of incident

The severity of the incident may be represented by the symbol S. Casualties can be divided, from a medico-organizational point of view, into 4 categories: 1 - dead and the dead-on-arrival (DOA); 2 - life threatening cases demanding immediate attention; 3 - non-life-threatening cases requiring hospital treatment; 4 - casualties not necessarily requiring hospitalization but rather less demanding single point care.

Since category 2 and 3 casualties are those, who need medical attention by professionals, those who have to be transported to hospitals by ambulances, and those who have to

be admitted into hospitals, they form the crucial group. Crucial, because any delay in treatment results in more dead and dead-on-arrival, while the condition of the remaining injured deteriorates.

It is known that in most earthquakes, railway accidents, fires, terrorist bombings and aircraft crashes category 1, 2 and 3 comprises more than 50% of the total number of casualties, while floods and volcanic eruptions cause many more killed than injured. Civil disturbances, on the other hand, usually result in many slightly wounded and a few heavily wounded. Therefore, it would seem that deviation to either side of seriousness occurs depending on the type of disaster and possibly some other factors, like population at risk, site where the disaster took place and the time of occurrence.

If many seriously wounded casualties (category 2 and 3) are to be expected S is scored as 1,5. If only many slightly injured are to be foreseen S is scored as 0,5. Car accidents usually result in a figure between these extremes and therefore S can be indicated as 1,0. This forms the basis for scoring the severity of the incident.

Capacity of medical services

Progressive medical care of disaster casualties is a concept of aid appropriate to the needs of the individual at any given time, beginning at the disaster site and continuing through the transportation and distribution phase to the period of definitive therapy in hospital. Thus, the capacity of medical services is divided into three phases. Medical care at the site, or medical rescue capacity (MRC), depends on the amount of professional medical help at the site. It is assumed that a team, comprising a surgeon, an anaesthesiologist and two nursing staff can deal with 10 casualties category 2 and 3 per hour, provided again they are afforded the support of personnel and equipment. Under abnormal conditions, say difficult terrain or bad weather this number will be fewer than 10.

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Medical tansport and distribution of casualties, category 2 and 3, to and among hospitals, or the medical transport capacity (MTC) depends on the number of ambulances with drivers, the ease of evacuation and a distribution scheme. This MTC can also be expressed in numbers. It is assumed that each ready-to-go ambulance is capable of transporting and distributing two casualties per hour. If however, the evacuation is hampered by difficult terrain, distance, or bad weather this figure will be fewer than 2.

Medical treatment in the hospital, or the hospital treatment capacity (HTC) depends on the total number of surgeons, anaesthesiologists, operating rooms, intensive care beds, residents and the like. The HTC refers to the number of casualties (category 2 and 3) that can be treated according to normal medical standards in one hour. If the disaster takes place at night or on the weekend, the HTC will be lower than the HTC during the morning of a weekday. As a rough figure, obtained empirically through many exercises held at hospitals of different sizes, an HTC for general hospitals can be estimated as 3% of the total number of beds.

Category 4 casualties frequently consult their local or private doctor or are spontaneously transported to the nearest hospital by private cars. Thus the nearest hospital to the disaster site is often overloaded with category 4 casualties and should preferably be excluded from category 2 and 3 casualties.

All the capacities mentioned are based on a "normal" situation of roads, weather and working hours. If the terrain is difficult, the weather is bad, or if the disaster takes place at night or on a holiday or weekend, then the capacities are lower than under "normal" condition. The capacities are expressed per unit of time i.e. per hour. Under disaster conditions, doctors, nurses, ambulance drivers, first aiders, etc. can probably work efficiently for 8 hours at the most. Again this is an assumption, because after 8 hours of hard work by all personnel, fatigue and lack of material most likely will decrease the HTC considerably.

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Therefore, the capacities should be multiplied by 8 in order to obtain the total capacity (TC) of the medical services for a realistic period of time.

In order to avoid stagnation during this chain of events, synchronization of MRC, MTC and HTC is imperative, which implies that these capacities should be equal to one another. Thus the lowest capacity determines the capacity of the whole chain.

Medical severity index

Once the casualty load (N), the severity of incident (S) and the total capacity (TC) of the medical services (MRC, MTC and HTC) are quantified, the medical severity index ($\frac{N \times S}{TC}$) can be defined. If N x S exceeds the local, total capacity of medical services (medical severity index >1) problems will arise, and the calamity is called a disaster.

Summary

By calculating the medical severity index, which is the product of the casualty load and the severity of the incident, and comparing this figure with the available total capacity of the medical services, which is the medical rescue capacity, the medical transport capacity and the hospital treatment capacity, it is possible to fairly quickly and precisely identify if a calamity is to be regarded as a disaster or not and if the region can cope with the situation. Moreover a calculation of the hospital treatment capacity in the region could serve as a guideline for estimation of the dimensions needed for the medical rescue capacity and medical transport capacity when planning how to deal with a disaster.

Effective Utilization of Victim Volunteers in the Emergency Response

Presented at:

A workshop on
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Effective Utilization of Victim Volunteers in the Emergency Response

Dramatic shots of earthquake victims being rescued from rubble piles make good stories and capture international attention. This type of rescue operation is the one the media and consequently the public will probably focus on, but it should not become the sole focus of emergency planners as they attempt to improve our ability to save lives following a catastrophic event.

This is not to suggest ignoring those victims who require such extraordinary efforts. Each life saved is important and worth the costs. But in the rush to expand the technology and increase our ability to make those dramatic rescues, we should not overlook the fact that the majority of victims who are rescued and survive are rescued in the initial hours following the event either through their own efforts or through the efforts of others in the area who are relatively uninjured.

Case studies and experienc show that victims of collapse have the best chances of survival when rescued in the first 24 hours following an event and that the chances of survival take a significant down turn after 72 hours. [Niu as reported in Olson, 1987:651] Unfortunately, the agencies which have the search and rescue expertise, usually fire and police departments, are likely to find their resources overextended in meeting the demands of their normal duties. In California, the fire services frequently tell communities to prepare to be on their own for 72 hours; by

this point much of the search and rescue process is limited to body retrieval.

One answer to this problem has been to assign search and rescue to outside agencies. We have been lucky not to have experienced a major quake in the United States for more than 20 years. But the U.S. expereince in other countries has been that search and heavy rescue resources, for reasons of bureaucratic red tape or transportation problems (including access to the stricken areas), have been unable to get into the disaster area until after that first 24-hour period has passed and frequently not until after the first 48 hours. In Armenia the U.S. team arrived in the fourth day of the response; the first trained search and rescue team in the area had arrived only one day prior to that.

Although the red tape should not be a major problem in bringing in U.S. resources from outside the stricken area in the event of a major earthquake in this country; the problem of debris and getting heavy equipment in and victims out of an impacted area still exist. In disaster training sessions in San Francisco it has been suggested that in the downtown area there could be as much as seven feet of glass and building debris filling the streets following a major earthquake. This is expected in a city with some of the strictest building codes in the world. What then can we expect in cities like St. Louis, Memphis or Boston, where the codes are much more relaxed and the number of dangerous buildings far greater, if struck by an earthquake in the near future?

This paper will not address what can be done to make heavy rescue more effective or possible means for clearing debris without hurting live victims who may be buried under that debris. However, it will address another search and rescue resource which has not been sufficiently utilized and which could provide help to trapped victims immediately. This is the volunteers, who are themselves victims, who converge on or are already present in the area.

Hurtles to Overcome, Advantages to be Gained

Until new solutions to the aforementioned heavy rescue hurtles are proposed, emergency planners would do well to consider how victim volunteers could be made part of the emergency response. Research on human response to disaster has shown that "a mood of altruism pervades during the emergency period." [Drabek, 1984, Fritz, 1961, Taylor, 1970, Raphael, 1987] Other work [Taylor, 1970, Kreps, 1984] has shown that encouraging victims to take part in the community's recovery can have a beneficial psychological effect for the victims involved.

Following a disaster victims frequently experience childhood feelings of powerlessness and inadequacy. They may also experience irrataional feelings of shame at being so helpless; with a rising sense of frustration and anger. [Raphael, 1986:59] However, it appears these feelings are to some degree ameliorated when victims are able to participate in the response and recovery. This action helps to give them some feeling of regaining control over their

environment. [Taylor, 1970, Oliver-Smith, 1982]

The problem with the volunteer response in its current form is that is very haphazard during the critical period before the emergency professionals arrive and when the chances for victim survival is greatest. Lacking direction these volunteers search and rescue in the areas they are familiar with, as they happen upon other victims, or for individuals with whom they have relationships. These volunteers might become an extremely valuable part of the response process if they could be directed to areas with probable concentrations of victims (such as hospitals, nursing homes, neighborhoods containing significant numbers of retired persons, schools, etc.) and/or given advice on how to locate victims and then remove those who are not deeply buried without injuring them further.

Using these individuals is not without problems and these will require some innovative thinking to overcome. First of all the agencies responsible for search and rescue activities are more familiar with controlling spectators and clearing emergency sites than they are with working with volunteers to effect emergency rescue. Secondly, these volunteers will for the most part be untrained and therefore will respond to the tasks given them according to the knowledge they have and could end up increasing the damage already done (e.g. moving victims without regard for possible spinal or neck injuries). Third, training citizens in earthquake prone areas in emergency response techniques prior to

an earthquake, although oneway of averting the other two problems, suffers from the problem of maintaining an ongoing group of people with a commitment to training and drilling for infrequent events with unpredictable recurrence rates. And fourth, but perhaps most difficult to overcome, communicatons. These are just a few of the factors which mitigate against the utilization of victim volunteers in urban search and rescue. There are others but this paper will focus on these four and try to suggest potential solutions to these dilemmas.

During routine response calls both fire and police departments are sensitive to spectators, at the emergency site, who could be injured or interfere with the response. Therefore, they make every attempt possible to restrain these individuals and keep them well clear of the site. This is also common practice in hands-on emergency drills.

However, a major urban earthquake requires a vastly different response from the routine of responding to the "average" emergency. Because such an event will quickly overwhelm the local and frequently the regional response capabilities as well, it requires a more flexible operating mode with provisions for inserting other resources, including volunteers, as they become available.

Perhaps the first caveat to working with volunteers is that they are exactly that and are neither aware of nor bound by the chain of command which is routinely accepted by the emergency

professional. Nor can they be expected to react in any specific manner to issued instructions. They may be suffering from shock; responding to their own agenda which does not include agency objectives; unsure of the terminology being used but unwilling to admit it; or any other numerous individual responses.

This is not to imply that volunteers cannot be utilized in the response system. Rather the implication is that agencies with responsibilities for managing disaster response need to consider and plan for inserting volunteers in "functional gaps" which may be created by overburdened resources. A functional gap is a task which needs to be done but for one reason or another is not being accomplished by the organizations responsible for it or those perceived as responsible for it.

It is useful to designate individuals within the agencies to work with volunteers in the event of a disaster. These individuals could receive training in working with volunteers, prior to an event, from organizations like the American Red Cross, which are in the business of effectively using volunteers in disasters.

Addressing the problem of lack of knowledge means considering, during disaster planning, things which volunteers could be told to do or instructed in doing in a couple of minutes time. These tasks should be relatively simple to accomplish and require nothing more than common household items, tools or debris. Then if volunteers are able to make contact with one of the responsible agencies

either by phone or in person there will be some guidance available to aid them in their response efforts. As one emergency doctor told a crowd of emergency managers at a meeting of the Southern California Emergency Services Association in Anaheim: "In an emergency people will do what they know how to do even if it's wrong." Therefore, it's important to be prepared to provide information if asked.

Another means of addressing the lack of knowledge in a more general framework, particularly with reference to medical response, is for groups like ours here today and associations of emergency response professionals to advocate increased emphasis on training communities and particularly our youth in basic first aid and self-protection steps to take in the event of an emergency. A recent paper by Dr. Eric Noji [1989:4] stated that it is estimated only 5% of Americans currently receive basic first aid training. It was not long ago that basic first aid was part of the physical education requirement in many schools and there is no reason for it not to be a part of that requirement. Basic first aid skills are not only useful in an earthquake but they are frequently needed in every day activities as well. Furthermore, this training would provide a base of knowledge amongst a significant proportion of our population which would allow them to make informed decisions about handling and treating victims in the case of a disaster.

The most desirable situation is to have trained people in the community who are not part of the formal response system but could

take immediate action in the post-event period. We cannot expect communities to spend limited resources on duplicating a capability which already exists, to some degree, amongst professional rescuers (i.e. heavy rescue). On the other hand individuals who were trained in some basic light search and rescue techniques requiring nothing more than common household items and yard tools could fill a "functional gap". These individuals could also receive training in basic first aid and means for recognizing signs of more deeply buried victims. This would enable them to provide not only better care for victims but also provide the professionals, when they arrive on the scene, with valuable information on where live victims might be buried.

Some organizations have sought to capitalize on the "good samaritan" feelings of individuals by recruiting community members who are concerned about a particular hazard to play some role in the emergency response. Many of these attempts, however, have been short-lived. Lacking a constant reminder that they are vulnerable to various hazards these individuals soon lose interest and return to the more pressing needs of their day-to-day lives. Even the neighborhood watch groups, which garnered great attention in the late 70's and early 80's and were formed to deal with a more common threat than disasters, crime, have seen a continual lessening of interest as the threat dissipates.

One possible means of creating a trained cadre of citizen responders is to recruit existing organizations rather than

individuals. If organizations make emergency response training a part of their emphasis the membership is more likely to accept it as a legitimate ongoing part of the organization's activities. This also provides the individuals involved with a common identification and thus it isn't necessary to create this in the training. It is also likely to come with an in-place leadership structure as organization members will already be aware of those who are leaders in other areas of the organization and turn naturally to them. Furthermore, involving pre-existing organizations automatically gives an ongoing existence to the training program as it becomes part of the ongoing activities of the organization. The organization also benefits by becoming involved in an activity which can have real benefits for the community and increase the organization's profile as a community resource. This means of citizen responder recruitment should be studied further.

Currently in Los Angeles an important experiment is occuring in disaster preparedness. The Disaster Preparedness Division of the Los Angeles City Fire Department was created in November, 1987. Amongst this division's activities are the training of both public and private employee response teams and community response teams. The employee response teams are housed within government divisions and within specific companies requesting training. The community response teams are housed within existing organizations. Eighty-six teams have been trained to date in skills ranging from team organization and management to search and rescue operations. The

training is broken down into seven classes lasting two and a half hours each with two sessions being dedicated to disaster medical operations. At the completion of the course there is a written exam and practical exercises which are critiqued by Division personnel. This experiment is in its early stages and it remains to be seen how effective this concept will be in the future as employee turnovers occur and individuals move out of their neighborhoods. This program was instituted right after the Whittier earthquake when preparedness was a very salient issue for much of the Los Angeles population but as time passes without the advent of an earthquake preparedness often loses its saliency and the new concerns displace that of earthquake vulnerability. We also do not know how effective the Division will be in maintaining its funding as the memories of the Whittier event dim in local government leaders' minds and Los Angeles goes without another earthquake of any size.

Finally, the fourth hurtle to effective use of volunteers is one which always ranks high on organizational lists of problems faced in an earthquake, communication. Even if telephone lines are not damaged by ground motion the system frequently becomes overtaxed by calls from concerned friends and relatives the result is the same. It has also been found that radio channels will frequently be overburdened by increased activity. This makes communication between victims willing to help and those who can direct their efforts extremely difficult.

One suggestion is to use radio and television stations if they are still functioning to send out information on how to care for victims and identifying areas where additional help is or may be needed in bringing victims to safety. In the Whittier event it was found that the public was searching for information and relied to an extent on both the television and radio as these remained on through the event. Standardized messages on basic first aid and safety precautions to be taken by victim populations should be prepared in advance and made available to the media for use in case of an event. Furthermore, in the case of an earthquake aftershocks are likely to follow and preparedness information should also be supplied to the public on a continuing basis. This was a recommendation to come out of some of the Whittier debriefings.

Finally, community fire stations should have well-stocked first aid kits on hand and be able to supply volunteers with information on what to look for as signs of serious injuries in victims. Local fire stations in the communities around Whittier were frequently overwhelmed by the numbers of victims who arrived looking for medical help.

Conclusions

We know from case studies and past experience that those victims who are not seriously injured in a catastrophic event are a willing resource to be used in the immediate emergency period. It is also quite clear that to date this resource has not been

effectively utilized. One of the reasons they have been underutilized is that emergency planning and emergency professionals have developed routines which do not have the flexibility to insert outside resources in the "functional gaps" which are created by a disaster's ability to overburden existing resources.

The first 24 hours following an earthquake has been called "the golden twenty-four". [Olson, 1987:651] This is the period of time following an earthquake when a victim of structural collapse has the greatest chances of surviving if rescued. It has also proven extremely difficult to bring in trained rescuers within this period of time. Many uninjured victims, however, are on the scene and able to engage in this rescue effort. The need then exists to provide these volunteers with information and guidance to enhance the success of their efforts. Not only will the community benefit from this additional resource but research shows us that the rescuers themselves also frequently benefit by regaining a feeling control and a diminishing of their feelings of powerlessnes.

Hurtles do exist to the effective utilization of these individuals and some forethought is necessary if they are to be overcome. Volunteers cannot be expected to accept orders or comprehend agency mandates the way trained emergency professionals would, nor are they likely to understand emergency terminology. Therefore, agencies need to appoint and train representatives to work with volunteers in a disaster.

Emergency responders must also take into consideration that volunteers will take action based on their perceived knowledge of what is needed even if that is wrong. The modus operandi in this situation is frequently better to do something wrong than to do nothing at all. Agencies should plan for frantic requests for information on how to treat victims or free trapped victims and have prepared information which can be delivered rapidly in simple terms and does not require either specialized knowledge or specialized tools. This information should be made available to the media and to local fire stations as well as agency operators.

Attempts to create a better educated public and pre-trained group of citizens should continue. Although the success record in this area has not been as high as we would like it, for each individual who retains part of the information that's one more available resource. One area where attempts at public education have met with better than average success is in the training of children. Both the efforts of the Children's Workshop and California public schools have shown that not only are children interested in knowing more about disasters and how to protect themselves but if the information is presented to them in a fun manner they tend to retain it. Children also share this information with their parents.

Volunteers in disaster response are as of yet largely an untapped resource but one which deserves greater consideration and

which can likely be used without considerable cost to the public. This makes them an attractive resource as well.

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Medical Care of Entrapped Patients in Confined Spaces

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In our technological age where structures, industry, inquisitiveness and failure to appreciate the power of geological and atmospheric forces push our capabilities to the very limits of technical knowledge, unforeseen combinations of events can result in structural failures and entrapped patients. These frequently present enormous challenges for the local responders when only a few to several patients are involved. Nevertheless, most of these can be managed with local resources. However, it is left to the disasters of much larger scale to truly challenge the organizational skills, mobilization capabilities and medical expertise of our society. Both natural and man-made, large scale disasters can result in large numbers of casualties, many of which are entrapped and require management of their medical problems prior to or during their extrication process if maximal salvage is to be achieved.

Statistics on which to base planning of the medical response to disasters, are frequently very difficult to find or are of a sketchy nature.(1,4,2,3) Most authors cite a much used ratio of three injured patients to every one dead patient(2),although the specific ratio may vary.(3) Locations, types of injuries and causes of death are helpful, but are frequently incomplete or not of sufficient detail to allow reliable use in guiding medical response and planning. Conclusions based on retrospective analysis are frequently gloomy and based on inability to deliver sophisticated field medical care on short notice. Retrospective data concluding that 80-90% of entrapped patients who survive are recovered in the first 24 to 48 hrs, by unsophisticated means have dampened enthusiasm to improve the recovery of the few percent who may indeed survive if provided with proper in situ medical care delivered early in their entrapment.(3,4) Unfortunately, when looking at numbers ranging from 100s to 100s of thousands, salvage of 10 to 100s of patients utilizing more sophisticated medical procedures, may pale before the scope of the situation. However, this paper reviews the proposition that entrapped patients, resulting from either natural or man-made calamities, may survive with timely delivery of in situ field medical care. It further supports the hypothesis that these patients may often be recovered in better physical shape and with a lower incidence of potentially fatal complications when stabilized before extrication.

In evaluating the potential applicability of the whole concept, one must review the literature to find what potentially salvageable patients occur during natural disasters such as earthquakes. In the 1978 Tang Shun earthquake many persons perished because of exsanguination and shock due to either external or internal hemorrhage.(3) If these individuals are located, stabilized and extricated early they may indeed survive. In addition, a smaller percentage of patients were entrapped for a prolonged period. These individuals require a more sophisticated level of medical care if they are to survive.

Many individuals in the Tang Shun and 1980 Italian earthquakes ultimately received crushing injuries.(3,4,5) Although much has been written over the years since crush injuries were first described in the German literature in 1909 (8) and later more comprehensively by Bywaters and Beal in 1941 (9) the mechanism of the injury is still poorly understood. However, crushing injury occurs when human tissue is exposed to a compressive force sufficient to interfere with the normal metabolic functions of the anatomy involved. We should

separate the injuries under discussion from the massive blunt force crush injury where destruction of vital organs occurs immediately and the patient succumbs to these direct force injuries.

Most often crushing injuries which are potentially survivable involve the extremities or lower torso. The medical literature is replete with case scenarios in which patients suffering from crush injury are found and initially appear well, only to deteriorate rapidly following their extrication and recovery.(7) In other cases where extrication is successful and patients are delivered to fixed medical care, acute renal and hepatic failure follows, placing huge technological demands on a medical system which has itself been severely disrupted during the disaster. If we as medical providers are to salvage the life of entrapped patients, it is insufficient to free a trapped patient only to have him/her die shortly after extrication or later as the result of a potentially preventable complication of his entrapment.

Although our understanding of crush syndrome is incomplete, some reasonable assumptions can be made which will allow us to care for our entrapped patients. Crush syndrome develops over time and as the time expands beyond the 4-6 hour(11) tolerance of muscle tissue for hypoxia, irreversible muscle tissue death occurs. Assuming resultant edema and vascular pressure is such that little or no return of fluid from the crushed extremity occurs, the patient will often remain stable for several days within the confines of other injury or illness. During this period, the ischemic limb has developed markedly compromised vascular integrity, disrupted membrane systems, and generalized loss of cellular architecture and structure. The extremity has further been exposed to destructive enzyme release.

When the patient is released from his/her entrapment, several detrimental processes occur simultaneously. Oxygen rich blood returns to the ischemic extremity with the first release of entrapment. With the markedly abnormal vascular integrity, third-spacing occurs almost instantaneously. This can result in a precipitous loss of intravascular volume and sudden onset of clinical shock. Failure to appreciate the potential problem alone represents a major loss of salvageable life in the confined spaces/crush injured patient.

Concomitant with the third spacing of intravascular volume in the affected injury, oxygen rich blood provides the source to develop superoxides and extremely active free radicals which attack already damaged lipid membranes. Arachadonic acid and other toxic products are created as the oxygen rich blood enters the damaged tissue.

These newly created oxadative by-products as well as toxic breakdown products of the injured tissue enter the blood stream and return to the systemic circulation. Massive amounts of lactic acid and other acidic products, developed as a result of anaerobic metabolism, rapidly enter the systemic circulation causing a systemic acidosis. High levels of K+ return from the extremity as the result of cellular breakdown and release of high levels of intracellular K+. Myoglobin and hemoglobin molecules flush quickly into the systemic circulation. Other not well identified toxins also are flushed from the extremity and enter the circulation, exposing the remainder of the body to their effects.(6) The sudden systemic exposure to these toxins can be rapidly fatal. Acidosis (which by itself can result in rapid release of further intracellular K+ from healthy cells) along with the high serum K+ from the damaged extremity can result in sudden cardiac arrest, usually in asystole. This is probably the second of the two major modes of sudden death following extrication in the entrapped patient.

Many of the cellular breakdown products of the injured extremity are filtered by either the kidney or liver. This is responsible for

one of the most readily recognized signs of "crush injury", the presence of dark reddish brown urine which is positive for "heme" on the urine dipstick, but which contains no RBC's on urinalysis. Laboratory analysis will reveal myoglobinuria. Although deposition of myoglobin in the renal tubules has been largely implicated as the mechanism of renal failure, newer information indicates that this is not the sole etiology.(13)

Unless very rapid steps are taken to reverse this process, acute renal failure ensues and the patient now requires massive technological support for prolonged periods if he is to survive. This is problematical in the best of settings, requiring massive technical and clinical support. However, in the setting of a disrupted medical system, the "saved" patient who is delivered from the pre-hospital care setting, well on the way to developing renal failure, is a patient doomed to die.

What can be done and what should be done in an effort to prevent these unnecessary deaths? In the narrow scope, each entrapped patient should be evaluated medically while still entrapped. This should be accomplished by trained professional medical personnel who are familiar with confined spaces rescue and who can work easily with the confined spaces rescue team. Timing of release from entrapment should be jointly decided, and medical treatment to prevent hypovolemic shock and/or systemic crush syndrome instituted, while evacuation route, egress plans, shoring, and other rescue considerations are being accomplished.

Within the limitations of the rescue situation, all patients so entrapped should be fully and adequately hydrated prior to release from entrapment.(12) Intravenous access should be such that rapid crystalloid resuscitation at flow rates of at least 6-10,000 /hr can be maintained based on the individual's response. An alkaline diuresis should be established prior to release, if possible, exceeding a rate of 3-5 cc/hr with a urine PH > 6.5. This may require significant bicarbonate loading before and after release from extrication. Use of mannitol and/or lasix to promote an effective diuresis may also be useful. Catheterization either before or early after extrication will obviously greatly facilitate this therapy. Serum K+ will need to be followed/monitored/estimated utilizing some guess work as well as serial changes in T-wave morphology when available. Control of K+ influx with sodium bicarbonate, calcium chloride and insulin/glucose infusion may be necessary immediately following release.

With attention to these variables, it has been shown that patients, who have been extricated from building collapse with crush injury, have been able to avoid the onset of systemic crush syndrome complications, including acute renal and hepatic failure.(14)

Other procedures have also been utilized to prevent onset of the systemic complications of crushing. The French national team, as well as other agencies, have very successfully used application of an arterial tourniquet above the injured extremity.(7,10) Although this has reportedly been successful, it does not resolve the problem when a severely overstressed medical community must still deal with either the release of the tourniquet or amputation of the extremity. Potential for damager to still viable proximal tissue is also an area of concern. However, this procedure may still be the procedure of choice in certain situations. Amputation of the entrapped extremity in situ is still a further option.(10) However, the potential for infection is high in the situation where devitalized muscle is present. This therapy should most likely be limited to those situations where extrication cannot be affected by other means.

Other problems encountered in entrapped victims include the

spectrum of trauma related illness and injury. Many of those suffering major injury will have self triaged within the first 12-48 hours. Those individuals with more serious, but not fatal thoracic, abdominal, head and respiratory problems may need to be addressed in the confined spaces setting. Their management must be adapted to the situation that exists. Management of potentially hazardous environments such as ruptured gas lines, compressed cooking gas, or other toxic or explosive industrial agents must be considered. Management of environmental extremes of hypo or hyperthermia need to be considered.

One of the more practical considerations is how to bring these medical therapies to the entrapped patient. This in turn deals with both a micro and and macro scale. One must consider the specific delivery of the care to the patient, as well as the larger scale delivery of the "system" to the disaster site, and the intermediate scale of getting the care givers from some central staging area to the specific area of entrapment.

On the micro scale, paramedics and physicians must practice delivery of medical care in confined spaces on a regular basis if proficiency is to be gained and maintained. Equipment modification, care delivery techniques and team cooperation must be refined and utilized regularly if the team is to function smoothly in these situations. Such simple procedures as IV access from unusual positions, volume expansion in low heights via air-purged, pressure infused bags and monitoring via automatic equipment are all techniques that must be well practiced so they can be efficiently instituted.

On the intermediate scale, equipment and materials must be packaged and staged so that they can be dispatched rapidly from a central clearing area in support of multiple rescue teams. Efficient communications between the central medical staging area, the operational medical teams and the incident command/dispatch center are key to this operation. Communications capabilities brought with the team that are field programmable are the most useful devices in this situation. This also allows centralized, computerized data recording via radio from the scene. This frees care-givers from time-intensive data recording, and facilitates secondary resource acquisition and information transmission. Incident command access to medical data without interrupting direct patient care, is a further asset.

On the macro scale much work remains to be done. Whether we are considering a national system such as NDMS, or an international response, the direct needs of the patient for rapid delivery of acute medical care cannot be diminished. If we are to reduce the death and disability of entrapped victims we must seek ways to bring the available assets to bear in the most timely manner. DMATS teams designed to come into play at 12-48 hours should be augmented with Quick Medical Assistance Teams (QMAT), with prepackaged equipment, highly trained members and immediate availability (1-2 hours from notification to launch). These teams should be highly adaptable to a wide range of situations and should be dispatched with minimal pre-knowledge, other than that a disaster with medical casualties has occurred and their assistance has been requested.

Evaluation teams should accompany these quick response teams in an effort to better direct the follow-up medical support effort. However, the ability to directly affect patient outcome is so dependent upon timely delivery of care that these quick response teams should be utilized as early as possible.

Likewise, in the international setting, delays of days awaiting clarification of needs when the acute delivery of care to the entrapped is critical is not justifiable. As soon as services are requested, the quick response teams should be dispatched as an

integral part of the evaluation/response operation. In those situations where the assistance of these teams is minimal they can be held at central staging areas and/or returned to the providing country as the situation dictates. If one looks at the successful rescue teams such as the Swiss and French operations, prepackaging, rapidity of response and early deployment to staging areas have allowed more timely utilization of their assets.

In an effort to provide these services on a regional basis,the Special Medical Response Team, Inc. was developed in 1983. The team was originally organized and trained to provide medical care in the underground environment of the deep mining industry. The team is composed of three residency trained, board certified emergency physicians and 14 highly trained paramedics. The team has expanded its areas of interest to include building collapse, medical treatment in toxic environments, and medical care delivery in other confined spaces such as nuclear and conventional power facilities, etc. The team has been involved in various responses on both a state and national level, including individual entrapments, mine fires and explosions,and building collapses.(15,16,17,18)

In summary, patients who are entrapped during building collapse frequently need sophisticated and specific medical care. Although their extrication may require hours to days, access to portions of the person may allow initiation of medical care early in the process. Those individuals receiving medical care in situ will be better stabilized for the extrication process. In certain situations such as hypovolemia and crush injury, specific care may ,in fact, prevent early demise following the release of entrapment, or later demise as the result of organ failure. This type of medical care can best be delivered by well trained, rescue oriented physicians and paramedics, working in conjunction with rescue professionals. These teams must be well equipped, totally self-sufficient, highly mobile, and immediately available to respond to local, national and international situations. These teams should be pre-certified as to competence, totally self sufficient and oriented to the disaster response situation so that they become an asset to the patients in need and not a further liability to the local, already struggling government. The Special Medical Response Team, Inc. is such a team; organized to respond immediately to disasters in which patients are entrapped in confined spaces.

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PUBLIC POLICY NEEDS IN EARTHQUAKE INJURY MEASUREMENT

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I'm here today not as a research scientist, but rather as a representative of the government agencies that use scientific research in the formulation of public policy. I intend to give you my views about governmental needs for epidemiologic research on earthquakes.

In preparing my remarks, I reviewed the recent report of the National Research Council Panel on Earthquake Loss Estimation Methodology [5]. In it I found the name of Bob Rigney of Redlands, California, who passed away about a year ago. Bob was a public administrator, but if he had a profession, today you would call him an an urban planner. He had been the administrator of the Environmental Services Agency of San Bernardino County, and later the Chief Administrative Officer of the county. Bob was a member of the California Seismic Safety Commission, a leader in Governor Brown's Task Force on Earthquake Preparedness, and one of the prime movers of the Southern California Earthquake Preparedness Project. It was his dream to develop a structural hazard model to identify hazardous buildings through county assessors' data banks, and then abate the hazards through code enforcement. From the structural hazard model, we could develop a human injury model predicting the consequences of a future earthquake, and prepare local government agencies and the community itself to respond properly. Bob's dream was quite relevant to what we are trying to accomplish today.

Bob's dream involves a two-stage process. Earthquakes don't hurt many people directly. Their shaking breaks <u>things</u>, and the things (or pieces of them) then hurt people as they fall. So engineers must first produce a reasonably reliable method for measuring structural damage in relation to ground shaking, and a method of forecasting it for future events. Then, epidemiologists must develop a reasonably reliable method for measuring human injury and forecasting it in relation to structural damage.

Earthquake engineers have made great strides in measuring damage, in relating that damage to ground shaking, and in constructing probabilistic models to predict damage in future events. We can now predict with some degree of confidence the damage an earthquake may do to structures, to industrial plant, and to

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lifeline services. We epidemiologists now need to match the engineers' progress with respect to human injury.

We need two kinds of epidemiologic information. Those of us in the hazard mitigation business need information on risk factors for death and injury in earthquakes, so we can plan proper hazard mitigation measures. Those of us responsible for planning medical and health responses need information on numbers and types of injuries, because these determine the amount and kind of medical care needed. From the governmental viewpoint, those two kinds of epidemiologic information are the most important products of this new field of "earthquake epidemiology".

What information do we need for mitigation of earthquake deaths and injuries? First, we need to estimate the risk of death or injury in different earthquake situations. We need to relate this to causative factors -- to identify those engineering or social elements that increase morbidity and mortality. If possible, too, we would like to assess the effects of hazard abatement. To do this properly we need <u>incidence rates</u> for death and injury in different events. These have seldom been available in past disaster studies. Without them, it is virtually impossible to make any precise estimates of risk, and rather difficult to identify any but the most obvious risk factors. Failing a measure of absolute risk, we should try to obtain some idea of relative risk for the suspected risk factors that we wish to mitigate.

What information do we need for response planning? We need estimates of the gross amounts of death and injury to be expected from different kinds of events, in order to predict the gross medical care demand. Our quantitative estimates are presently quite poor. If your future studies of actual events produce the incidence rates that we want, then we in government can predict demand more accurately for planning purposes. We also need information on severity and diagnostic distribution of injured survivors; these determine the kind of medical care needed, and to a great extent they also determine the kinds of equipment and medical supplies required. Much of this qualitative information is readily available for serious injuries requiring hospital care; it's lacking for minor injuries or "walking wounded". We need these data to create the planning model that was Bob Rigney's dream.

Many fine epidemiologic studies have been carried out in the past. In the medical field we are indebted to Professor Lechat for his pioneering development of the field of disaster epidemiology. We are indebted also to his students (de Bruycker, de Ville de Goyet, Glass, and Western, to name a few) for a large fraction of the disaster studies that have been carried out in the last fifteen years, most notably on the Guatemalan [3,4,6] and Italian [2] earthquakes. We are indebted also to a number of others, some of them geologists or architects or statisticians rather than medical professionals. Some of these have studied

the relationship of structures and furnishings to earthquake injury; others have proposed deterministic models that predict death and injury rates from projections of structural damage. I unreservedly admire the fine work that has been done in these separate but excellent studies.

However, I have to observe that much of this fine work has not received the broad circulation and discussion that is necessary to reach all the people active in studying or controlling earthquake injury. These people may be doctors, engineers, architects, geologists, statisticians, sociologists, or public administrators. As we would expect, most of the writers are accomplished in their own field, but naive in other professional fields. It isn't unnatural for an epidemiologist to define structural risk factors in his own idiosyncratic way, rather than to use the definitions of an engineer expert in that specific structural feature. It isn't unnatural for an engineer to use an unconventional measure of death or injury in his own study of structural hazard. The resulting findings are usually incomparable, and sometimes curious. As a result of these accidents of specialization, many fine studies have not been as useful as they could be. Many have been isolated in obscure journals, concealed from other workers in the field of disaster research. Worse yet, because of inadequate inter-disciplinary understanding, some studies may have promulgated erroneous ideas that diminished their usefulness for public policy determinations.

These problems should be attacked in the same way that the problem of highway trauma was attacked - through formation of a multi-disciplinary interest group that links the medical, social science, and engineering professions to define the problems, and includes public policy leaders to implement solutions. We are doing exactly that in this meeting.

Now let me suggest some specific areas where I think this inter-professional approach would be especially productive.

1. Community surveys. Community surveys such as Glass's and de Bruycker's provide the means for reliable assessment of death and injury rates, and also provide panels for historical-prospective studies of various risk factors. Such surveys should be carried out after small, moderate, and large incidents, to allow appreciation of gradients of risk. The Glass and de Bruycker studies are excellent examples that might be followed. It would be useful to stratify the sampling frames for such surveys on the environments that we consider especially worthy of study, for this would facilitate secondary use of the data in historic prospective analyses.

2. Comparability of data. Most descriptive studies of earthquake injury are of limited utility, because they don't use standard diagnostic categories. At the least, I recommend that investigators use standardized disease classifications, such as

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the International Classification of Diseases. To describe environments and structural risk factors, we should share the classifications and definitions used by engineers and architects for their structural risk models (ATC-13, for example [1]).

3. Standardized instruments. Few existing studies are comparable, because they don't ask the same questions. Standardized questionnaires have been recommended. These questionnaires should speak to the needs of clinical, epidemiologic, engineering, and public policy researchers. In particular, they must ascertain the amount and type of human injury, and the amount and type of structural damage which was associated with it. I believe that Louvain has promulgated such a model, which might be modified to bring the damage questions in line with the damage measures of the 1985 Applied Technology Council models [1].

4. Development of an "Injury Probability Matrix". Rates determined from studies of different events are difficult to compare because of the complex multivariate nature of the forces and environments of each incident. Epidemiologists should consider development of a multi-dimensional model conceptually similar to the "Damage Probability Matrix" used by the Applied Technology Council.

5. Injury studies. Most clinical studies are not useful for planning purposes, because they do not assess risk. I strongly suggest that descriptive injury studies, wherever possible, should be carried out in conjunction with community surveys or appropriate case-control studies to enable risk assessment. I strongly suggest that minor injuries be assessed, so that the demand for non-hospital medical care can be measured.

I earnestly hope that some of these technical issues can be discussed in greater detail as this conference progresses.

We in the Health Resources and Services Agency wish you every success in establishment of a strong working group in earthquake injury epidemiology. We look forward to using your products in our own disaster mitigation and medical relief programs.

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THE STUDY OF VOLUNTEER AND EMERGENT ORGANIZATIONAL RESPONSE: APPROACHES AND ISSUES FOR FUTURE RESEARCH

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INTRODUCTION

The study of death and injury during disasters is complex along a number of dimensions. First, it involves a rather elaborate linkage of a variety of interacting variables and activities. For example, a complete understanding of the issue requires disentangling the labyrinth of relationships between such variables as the characteristics of the disaster agent, the nature of destruction to the built and natural environment, the etiology of casualties in relationship to that environment, the contextual effect of ecological and cultural variables, the structure, pattern of activities and efficacy of search and rescue efforts, and the influence of emergency medical and treatment activities. Second, due to the variety of elements involved in the problem, the study is inherently interdisciplinary. The knowledge from such varied disciplines as architecture, civil engineering, emergency medicine, epidemiology, sociology and social psychology has relevance. Third, because of the complexity of variables and disciplines, the area of investigation tends to lack theoretical integration. As a result, much of the work is heavily empirical and somewhat atheoretical. Finally, the topic presents some rather complex and significant methodological problems.

This paper will only address this last issue. Actually the discussion will be even more limited, because consideration will only be given to methodological approaches to the study of one subtopic. Specifically, approaches to the study of volunteer and emergent organizational response in search and rescue activity will be examined. A few observations and themes on the nature of the problem will be presented. Subsequently, some suggestions for future research questions will be offered. However, before turning

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to these issues, a brief overview of prior and contemporary research on the topic may prove helpful to determining what we have been and are doing.

A BRIEF OVERVIEW OF PREVIOUS STUDIES

Although there were no comparative, systematic studies of search and rescue activity undertaken until the 1970's, disaster researchers in the prior two decades had made a number of observations on the nature of search and rescue in the course of examining community and organizatinal response patterns. For example, Fritz and Marks (1954) discussed the nature of emergent activity as found in the NORC studies. Form and Nosow (1958) noted and documented the important role of volunteers, particularly family units, in the rescue activities at the Flint-Beecher tornado. Fritz (1961) summarized what was known in the field at that time and emphasized the continuity between search and rescue activity and normal social relationships. During the 1960's a number of observations on search and rescue were made by the Disaster Research Center in their studies of organizational response to disaster (Anderson, 1970; Kennedy, 1970, Wenger and Parr, 1970).

Although the observations were rather limited, a number of important findings were presented in these early studies that have been reaffirmed over the decades. Among the most important for purposes of this discussion are the following: 1) the initial search and rescue activity is undertaken by victims and volunteers, 2) the magnitude of the volunteer response is extensive, 3) most of the victims are rescued by volunteer and emergent organizational activity, 4) formal, professional search and rescue activity is subsequent and supplemental to the intial volunteer actions, 5) there is considerable difficulty in integrating and coordinating volunteeer and formal, organizational actions, and 6) search and rescue, even among formal, established organizations, presents serious problems of coordination and management.

By 1970 these findings had become codified by Dynes (1970: 114-119) in his overview of organizational adaptations to disaster. In addition, the extensive volunteer and emergent organizational

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activity had been given a label (the "mass assault") and an explanatory scheme of 35 bivariate hypotheses by Barton (1969). Furthermore, the scope of the problem was conceptually broadened by including the study of search and rescue within the purview of examining "emegent groups." Forrest (1972) reviewed existent studies and delineated the social forces that influence the development and characteristics of emergent groups. Empirically, Taylor et al. (1970) undertook a qualitative analysis of the formation and role structure of an emergent, disaster work group.

Without question, however, the most extensive and comparative study of search and rescue activity was undertaken during the late 1970's by Drabek et al (1981); it remains unsurpassed in its scope and magnitude to this day. The study involved the emergent organizational and volunteer search and rescue activity that took place in six disasters and one remote area operation. In addition, a survey of rescue officials in two states was conducted. The research involved a variety of techniques, including block-modelling. In addition, it conceptually recast the study of search and rescue into an emergent, interorganizational, systemic approach. While reaffirming a number of the previous observations, the study highlighted the interorganizational or management difficulties inherent in search and rescue. For example, four common operational problems were observed: 1) difficulties in interagency communications, 2) ambiguity of authority, 3) poor utilization of special resources, and 4) unplanned media relations.

During this same period, work on other topics was also providing insights that were relevant to search and rescue. Quarantelli (1983) in a broad-based, extensive study of emergency medical services during disasters provided important insights into the problem of acquiring victims and integrating their entrance into the emergency medical system. Furthermore, work by Glass et al. (1977 and 1979) was providing epidemiological evidence on the etiology of injuries and deaths that had obvious implications for search and rescue behavior.

Currently, there has been an increasing interest in the problems of search and rescue, particularly in collapsed buildings, both

in the United States and other countries. (For an indication of the rather extensive research undertaken in Japan and elsewhere, see Murakami and Durkin, 1988), Durkin (1987, 1989) and Durkin and Murakami (1988) have examined the patterns of rescue from the perspective of victims in collapsed structures in Mexico City and San Salvadore. Krimgold (1988; 1989) has studied the problems of heavy rescue in Mexico City and other sites. In addition, the study of volunteer and organizational response during the 1985 Mexico City earthquake has been undertaken by the Disaster Research Center (Wenger, 1987; Dynes and Wenger, 1988; and Dynes et al. 1989).

For purposes of our limited discussion, it is not possible to do justice to all of the findings produced by these recent efforts. However, it can observed that all of these studies are in general agreement that 1) volunteer and emergent group response is massive in these settings, 2) the initial search and rescue activity is accomplished by volunteers and emergent groups, 3) since most survivors were rescued within the first two days, this emergent and volunteer activity is critically important to the rescue effort, 4) although professional search and rescue teams provide a valuable service, they often arrive too late to undertake other than highly specialized rescue activities requiring sophisticated skills or equipment, 5) the integration of volunteer and established organizational activities is seldom efficiently achieved, and 6) problems of management of rescue activities are serious and include difficulties in coordinating activities across independent, autonomous organizations, disagreement over rescue strategy, and ambiguous authority relationships.

Therefore, this brief review of some social science studies has shown that not only is volunteer and emergent organizational activity critically important in the search and rescue process, but that it is a topic that empirically has been found to be problematic and in need of future research. What suggestions and observations can be offered with regard to approaching the study of volunteers and emergent organizations? How might future studies benefit from the previous work? A few observations are offered in the following section.

SOME OBSERVATIONS ON METHODOLOGICAL APPROACHES

The manner in which one approaches or frames the study of any phenomenon determines not only what specific research techniques are utilized, but also what specific questions are posed, and to some extent, what answers are obtained. The previous investigations of volunteer and emergent organizational search and rescue activity indicate that our studies in this area may benefit by rethinking how we approach the topic at the broadest level. As such we must begin with a consideration of conceptual and theoretical reframing of the topic. In addition, this reframing of our approach will have direct influence upon the specific methodological techniques we implement. The following observations regarding approaches to the study of the volunteer and emergent organizational activity will begin with the broader conceptual issues and then consider specific methodological implications.

General, Conceptual Observations

All search and rescue activity must be conceptualized as being primarily emergent and collective in nature.

There is a tendency to differentiate search and rescue behavior along two dimensions. First, a distinction often is made between the activities of established, traditional search and rescue organizations and that of emergent, volunteer groups. Second, another distinction is often made between individual and group behavior. These conceptual distinctions have significant methodological implications For example, if one is interested in studying formal, established, professional search and rescue groups, the former distinction leads to a focus upon intraorganizational established patterns of authority, task allocation, resource utilization, and activities, often at the exclusion of examining interorganizational issues, let alone the activities of emergent groups. The second distinction tends to lead to the conceptualization of all volunteers as individual actors and thus

directs research along the lines of survey analysis focusing upon individualistic personal, psychological, and behavioral elements.

It can be argued that these two traditional distinctions are unfortunate, and that it may be advantageous to view all search and rescue activities in disasters as emergent and collective in nature. Drabek et al. (1981) clearly illustrate that in all but the smallest, most focalized and traditional search and rescue operations (e.g. small accidents and other emergencies) the response -- even among established, professional organizations -- is emergent in nature. New "multiorganizational networks" develop among the responding units.that take of the form of "supraorganizational entities" that mesh the activities of both established and nascient groups. Many of the management problems observed for established search and rescue groups result from their inability to effectively integrate their normal structure and authority relationships into this broader, emergent pattern of organized activities. Earlier disaster researchers also noted the emergent, ad-hoc nature of the response of even established organizations (Dynes, 1970). Recent research from Mexico City also reaffirms these prior observations (Dynes et al. , 1989).

In addition, it is known that individual volunteers only very rarely function as isolated, individual actors. The magnitude and nature of the tasks necessitate collective action, and individual volunteers provide it by forming new, emergent groups (Taylor, 1970; Forrest, 1972), Truly individual behavior is very rare in disaster search and rescue. The activities of these emergent groups must be approached at the collective level, not the individual level.

By approaching all search and rescue activity as collective and emergent, including the actions of established, professional organizations, we are led to examine a variety of issues that have been found in recent studies to be problematical (Durkin, 1987; Krimgold, 1989). Among these are interorganizational communication, coordination, authority relations, task allocations, and resource acquisition. Furthermore, we are sensitized to view the process of search and rescue as a whole, i.e., as a system with new, but interrelated parts, involving both traditional and emergent groups.

The study of search and rescue activity must be conceptually viewed as only one part of a broader process of victim assistance and thus linked to both preceding and subsequent activities.

There is an unfortunate tendency to view search and rescue as an isolated process. Studies often begin at the point after impact when victim search commences and end at the point of victim acquisition. Empirically, however, search and rescue is influenced by numerous preimpact and impact contextual factors and itself has effects upon subsequent activities. For example, the nature and effectiveness of search and rescue is influenced by such prior variables as the size and resources of the community, the level and quality of emergency and disaster planning, the nature of local building codes and construction practices, the predictability, forewarning, destructive capacity and scope of impact of the agent, the time of impact, the cultural and work patterns of the community, and many others. Furthermore, the nature of search and rescue activity is inherently related to the process of providing emergency medical services to the victims (Quarantelli, 1983). Current work at the Disaster Research Center on emergency medical services is taking this approach. Also, Durkin (1987) has examined the linkage between victim behavior, the etiology of injuries, search and rescue activity, and emergency medical care, and such studies are strongly recommended.

This placement of search and rescue within a broader process-oriented conceptualization will focus our studies on examining related factors that at first glance may appear to be only tangential to search and rescue behavior, but in fact can strongly influence what occurs during the search and rescue process. Also, it will require a broader definition and utilization of research techniques. Finally, as will be noted later, this conceptualization moves us in the direction of truly interdisciplinary research.

Studies of search and rescue must take an all-hazards approach

There is a tendency to view search and rescue activities as agent-specific in nature. Studies may focus upon such "different" topics as search and rescue in collapsed buildings (both light and heavy varieties), in remote areas, in floods, in tornadoes, in water, in winter storms, and mines. This framing of the problem is natural and somewhat justified because these different kinds of settings do provide some differences in such dimensions as appropriate search strategy and needed equipment and expertise.

However, previous research indicates that many of the serious problems associated with search and rescue activity are not specific to any one type of agent or disaster. It must be remembered that search and rescue is a behavioral process, and the behavioral problems inherent in that process exist in most disaster settings. Thus, the problems of effectively planning for search and rescue activity, integrating emergent group and established organizations into a new emergent system, impact assessment, communications, and coordination can be observed and studied, regardless of the nature of the specific disaster.

This conceptualization forces us to undertake comparative studies across a variety of hazards and types of disasters. Only then can we truly determine what dimensions of the activity are agent-specific. Also, by focusing upon an all-hazards approach we do not severely narrow the universe of events that are available for study.

Some Specific Methodological Implications of These Conceptual Observations

These three conceptual observations basically orient our studies in two ways. First, they refute the notion that volunteer and emergent organizational behavior is somehow different from established organizational action. Instead, it is offered that all search and rescue activity be viewed as emergent and collective. Second, they broaden our focus of study by examining processual linkages of search and rescue activity across a variety of hazards. Given this orientation, a number of specific research methodologies are indi-

cated. Among the many implications, the following would appear to be quite significant.

Since search and rescue activity is emergent, the data are often of an ephemeral nature and requires the development of quick-response research techniques.

Rapid entre into the research site is of significant value in undertaking studies of search and rescue because much of the data is short-lived or ephemeral in nature. Some of the data is of a physical nature, such as patterns of structural and nonstructural damage and the location of victims to that damage. The rescue process itself often alters or "contaminates" this type of information. Also, important information regarding such social and organizational issues as victim actions, the process of formation of emergent groups, the mobilization of personnel, and the interaction between emergent and professional groups may be lost if access to the research site is delayed.

This type of quick-response capability exists within the social sciences. It is best exemplified by the research of the Disaster Research Center (DRC). In studying more than 500 disasters over 25 years the DRC has developed elaborate and sophisticated techniques for sending teams of trained researchers within four hours to the site of a disaster. Researchers are trained to gather data through a variety of techniques, including observation, interviewing and the analysis of documents. Successful "research protocals" have been established for such issues as gaining entre to organizational personnel and informants and handling confidential and anonymous data. Although the DRC has developed the most sophisticated quick-response capability in the world, the actual research techniques and procedures are established social science tools and can be utilized by any researcher. What is required is considerable pre-event preparation, training and design.

Future research should consider development of this quick-response capability. It may be argued that the techniques are not the problem, instead, the difficulties are in obtaining requisite travel

funds.and having a limited number of events to study. However, those funds can be obtained, and if an all-hazards approach is utilized the universe of research sites will be expanded.

A variety of research techniques may be appropriately applied to the study of search and rescue activity

There is no one, singularly appropriate data gathering or analysis technique for studying search and rescue activity; a variety of techniques may be appropriate. For example, random population surveys that treat subjects as respondents (i.e., they are queried about their own personel behavior) are appropriate for gathering individual-level data. Such issues as the magnitude of participation by volunteers, the characteristics of volunteers versus nonvolunteers, and the patterns of tasks and activities that individuals undertake can be fruitfully studied. For example, the DRC (Dynes et al. 1989) recently conducted a random survey of the population of Mexico City that addressed these types of issues.

The previous proposal to conceptualize search and rescue activity as emergent, collective (i.e., group) behavior, however, also lends itself to the utilization of purposive samples of informants, (Informants are not queried about their own activities or perspectives. Instead, they are asked about the activities and structure of the groups and organizations with whom they participated or interacted.) Informants are selected based upon their positions in the emergent search and rescue system. Those in key decision-making, communication, liason, operations, and emergent leadership positions are selected. Some informants in established organizations can be preselected by design. Those involved in emergent groups can also be identified through "reputational" or snowball techniques. Their identification is facilitated, because participation in volunteer activity is often undertaken by established groups, such as family units, work groups, and voluntary associations; rarely is it a purely isolated, individualistic form of behavior.

It can be observed that treating subjects as informants, rather than respondents, is one solution to the complex problem of obtain-

ing a random sample of volunteers. (Since the behavior is emergent and ephemeral, the exact nature of the universe is unknown and traditional sampling strategies are difficult to apply.) By selecting informants based upon their knowledge of group and organizational action, information on collective and emergent phenomena can be obtained. It must be remembered that the old sociological adage that "the group is more than the sum of its parts" has validity; one cannot gather collective or group level data by simply summing the responses of individual respondents.

With regard to data manipulation, both qualitative and quantitative techniques may be used. Probably most of our knowledge in the area has come from qualitative analysis. However, some quantification has been undertaken in recent surveys of participants. In addition, Drabek et al. (1981) use of "block modelling" and similar forms of network analysis are very appropriate for examining supraorganizational or "multiorganizational networks" that are the essence of the conceptualization previously presented.

This approach to the study of search and rescue activity requires interdisciplinary research.

By broadening the study of search and rescue and linking it to antecedent and subsequent factors and activities, one is lead in the direction of interdisciplinary research. Sociologists have traditionally studied search and rescue activity, and recently architects have undertaken major research However, most of these studies have been disciplinary-bound. What is required is truly collaborative efforts across such disciplines as architecture, planning, emergency medicine, sociology, and civil engineering.

One must not be naive in calling for interdisciplinary efforts. This type of research is extremely difficult, and many projects end in the dissolution of the interdisciplinary team.with each team member vowing "never to do that again." However, the nature of the problem exceeds disciplinary boundaries. Most of the specific research techniques we have discussed are amendable to the various disciplines.

In sum, there is no "magic methodological solution" to the problems inherent in studying emergent search and rescue activity. What has been offered are a few suggestions that are consistent with the conceptual approaches presented earlier. In particular, the utilization of quick-response methodologies and purposive samples of informants appear to hold the most promise.

A FEW BRIEF SUGGESTIONS FOR FUTURE RESEARCH ISSUES

Research questions ideally should be driven by theory. This deductive approach has limited application in the study of search and rescue, because of the sparse theoretical development in the field. Instead, the following brief list of research issues is organized around certain key topics. It is also based upon previous studies, because there is considerable need for further verification and replication on prior findings. Thus, it may be profitable for future research to study:

the nature of volunteer behavior in search and rescue, focusing upon such issues as their social characteristics, skills and abilities, and tasks undertaken.

the role of existing community, nonemergency-oriented organizations in emergent search and rescue activity.

the process and structure of group emergence among volunteers.

the interface and coordination of emergent group activity with the specialized, professional search and rescue actions.

the problems of managment of multiorganizational group networks, including an examination of such issues as interorganizational communication, authority relationships, coordination, and task allocation.

the relationship between emergent group activities during the initial 48 hours of rescue with subsequent rescue and emergency medical provisions.

the inclusion of volunteer activity into the search and rescue planning of established, professional organizations.

the efficacy of alternatiive educational and training strategies in preparing volunteers for engaging in search and rescue.

the appropriateness of different search strategies and technologies in different types of disaster situations.

A CONCLUDING NOTE

This discussion intentionally has been focused upon only one aspect of the study of the epidemiology of death and injuries in disaster. Our comments only address issues involving the study of emergent organizational search and rescue activity. Many important methodological issues and problems inherent in such studies as determining the etiology of casualties, the patterns of destruction, and the provision of medical care have not been addressed. For example, no consideration has been given to the serious problem of simply defining who is injured and developing a valid sampling design to locate them. Furthermore, we have not considered specific rescue practices and strategies. However it is hoped that some of the suggested approaches may have applicability to these other areas of investigation.

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PRESENTATIONS 5

MODES OF FAILURE OF BUILDINGS UNDER SEISMIC ACTIONS

By Roberto Meli*

The consequences of the collapse of a building are directly dependent on the mode of failure and on the characteristics of the structure that constitutes the main force-resisting system of the building. The understanding of the way the forces induced by the ground motion are transmitted through the structural members and of the type of failure they can produce, will help to explain the different patterns of damage that can occur and their consequences in terms of the injuries to the occupants.

The ground shaking that constitutes an earthquake produces the vibration of the building and generates inertia forces that are proportional to the mass (weight) of each part of the building and to the acceleration it suffers. In a simplistic explanation, the inertia forces are mainly dependent on the weight of the floors and of the loads they support. The forces are transmitted through the floor system to the vertical structural elements (columns or walls) and by them conveyed to the foundation and again to the ground. A schematic representation of the flow of lateral forces is shown in Fig 1.

The flow of forces through the structure is much more complex than the simplistic model described above, and many different modes of failure can occur. The transmission of forces through the floor system can produce failures in the slabs, particularly when large openings in the plan of the building generate concentrations of forces in a small area or when the slab is constituted by prefabricated units that are not properly connected. The transmission of forces from the slabs to the columns can cause failure in the beams or in the beam-column connections.

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The above mentioned modes of failure generally are of a local nature and do not involve a complete collapse; nevertheless they can weaken the rest of the structure and modify the flow of forces in such a way to produce in some critical member, large concentrations that were not accounted for in the design, thus triggering the failure of a major part of the building. The continuity between the members that constitute the floor system and between these and the vertical members is the key to a proper transmission of forces.

The failure of the vertical members is much more severe than that of the horizontal members, because it affects the main source of support of the building and it can bring about its total collapse. Furthermore the members that are subject to high compressive forces, as those induced by gravity loads in the columns, are prone to brittle or degrading modes of failure that are particularly dangerous for earthquake effects, as it will be explained later. Thus the preservation of the integrity of the main vertical load-resisting elements is essential in order to avoid a catastrophic collapse. One solution is the separation of the function of resisting the lateral loads from that of resisting the vertical ones, as can be attained by using bracing or structural walls for resisting lateral loads and giving to the columns the task of supporting the vertical forces only.

In terms of the consequences of the failure is essential to avoid any possible mode of failure that could be of a brittle nature; by a brittle failure is meant one that gives rise to a total and sudden loss of strength once the capacity of the members is exceeded. In Fig 2 the different behavior of a brittle and a ductile member is schematically shown. In the latter, the capacity of the member is maintained for large deformations before collapse, thus allowing important redistributions of loads. Furthermore, the ability of a structure to sustain seismic actions depends more than on its strength, on its capacity for dissipating the energy introduced by the ground motion through different types of damping. The most important source of damping is the inelastic deformation that can take place under the repetition of cycles of loading. Therefore is essential to provide a structural systems that is able to sustain a large number of cycles of large alternating deformation withouth loosing its integrity. In Fig 3 the difference is shown between the behavior under cycles of alternating loads of a system that has a stable response with large energy dissipation capacity and one that has a degrading behavior.

The ductility of the sections and members is an essential parameter to obtain a favorable behavior, as well as the

redundancy of the structural system; that means the number of section that must attain their maximum capacity before the structures becames unstable and collapses. In Fig 4 examples are given of a structural system with low redundancy and of a highly redundant system whose governing mode of failure involves the inelastic deformations in a large number of sections.

The collapse of the building can be also related to lateral instability, either due to the excessive flexibility of the structural system or to large deformations of the subsoil. The collapse can be finally caused by the failure of the columns under the effect of the flexural moments generated by the axial forces acting over the large lateral displacements of the structure, or by the complete overturning of the building through a foundation failure. The latter case is usually much less catastrophic than a column failure, because the integrity of the main structure is frequently preserved and the building falls almost as a rigid body.

Several mid-height buildings that overturned in Niigata (Fig 5) and one eleven-story building that overturned in Mexico City are good examples of this kind of failure.

Different kinds of irregularities in the structural system can give rise to a local weakness or to large concentrations of seismic forces in a well defined part of the building where the failure is generated. A weak story or the abrupt change of lateral stiffness are found rather frequently in existing buildings and are often the cause of a collapse that can be transmitted to the rest of the building. Fig 6 illustrates schematically the two situations.

Large torsional vibrations caused by a severe lack of in plan symmetry of the structural system, produce concentrations of forces in some columns that can bring on their failure. The problem is shown in Fig 7.

When the collapse of the vertical structural members occurs, the rate of injuries is directly related to the area of collapse that is involved, to the weight of the floor systems and to the amount of fragmentation they undergo. Even with relatively heavy floors some occupants can save their lives if the floors collapse in large units that can be supported by some elements of the building content, as heavy pieces of furniture, leaving some room for the protection of the occupants. This situation is typical of monolithic floors, as cast in place concrete slabs. When heavy floors can separate in small pieces, the consequences are much more severe, as can happen in prefabricated concrete slabs.

Failure of the non-structural elements of the building, as heavy partitions, ceilings and cladding can be also very harmful. The damage in these elements is mainly related to the lateral flexibility of the buildings; the interstory drift is a measure of this flexibility. To limit this kind of damage either the building must be provided with substantial lateral stiffness, or the non structural members must be connected to the structure in a way they are not affected by its lateral displacements.

Hammering between adjacent building can weaken the vertical supporting members (columns) to the point of causing the collapse of an entire floor. The situation is critical when, as often occurs, the floors of the adjacent buildings are at different heights thus the slab of one building hammers the columns of the other near to their mid-height.

SPECIFIC PROBLEMS OF CONCRETE BUILDINGS

The most appalling building failures during earthquakes have been related to concrete or masonry structures. Specific problems of structures of the first of these two materials will be given some attention in what follows.

In concrete structures, column failure has been by far the critical reason of collapse. The evaluation of the structural damage caused by the 1985 Mexico earthquake revealed that at least in 70% of the severely damaged buildings, column failure was involved.

In defining the mode of failure of concrete columns, confinement is a key factor. When its compressive strength is exceeded, the concrete of a column crushes and loosens, the vertical reinforcing bars are not restricted from buckling anymore, and the column suffers a sudden brittle failure. When the concrete is enclosed in a cage of closely spaced longitudinal and transverse reinforcement, the confinement provided greatly delays the crushing of the concrete, thus allowing the preservation of the capacity of the column to supporting the weight of the building, even after a large number of repetitions of lateral loads. The behavior of the two columns of Fig 8 clearly illustrates the difference.

The behavior of columns is critical in frame structures where the columns constitute the only vertical resistant members and they are subjected to large seismic actions that can lend to their failure and to a pancake type of collapse, if the strength is not sufficient and the requirements for providing ductility are not followed. In most cases the collapse of concrete buildings is due

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to failure of the columns by shear forces or by eccentric compression, as shown in the example of Fig 9.

Frames are inherently flexible systems that are prone to lateral instability with a final failure by column crushing, as in the case of Fig 10. The collapse and its consequences are not significantly different from those of the previous case (pancake).

A particular version of a concrete frame building is the flat-plate system, where the absence or proper beams gives rise to very flexible structures and the problems of frames buildings are enhanced. An additional critical mode of failure in this type of building is the punching of the slab by the columns (Fig 11) that can generate the complete collapse of the floors. The total collapse by this mode of failure is avoided when proper longitudinal and transverse reinforcement is provided in the slab around the columns.

A mixed system with structural walls and columns gives a much greater protection against collapse, because the task of resisting the major part of the lateral load is taken by the walls, thus releiving the columns from large moments and shear forces. Failures of structures with a reasonable amount of shear walls have been scarce and tend to be of a more local nature.

Some specific problems that occur in concrete structure are the failure of short columns where large concentrations of shear forces are induced, producing a brittle kind of failure that is normally limited to a local collapse, but sometimes triggers a more general floor failure (Fig 12).

A modality of concrete buildings that has been particularly prone to total collapse, is that of prefabricated buildings where the connections between resisting members have not been properly designed. In prefabricated frame buildings the critical zone is commonly the beam-column connection. The recent 1988 Armenian earthquake has shown many examples of the catastrophic character of the failure of this type of building, where the fragmentation of the structure is very high because of the separation of the poorly connected prefabricated units during the collapse (Fig 13).

Another type of prefabricated concrete system is the panel building, where the critical aspect is the connection between the floor panels needed to form a horizontal diaphragm. When a proper diaphragm action is not achieved, the floor panels will transmit their inertia forces to the

walls perpendicular to the direction of the seismic action, inducing out-of-plane moments and the overturning of these wall (Fig 14). A highly catastrophic house-of-card type of failure can occur where the prefabricated panels fall separately.

CONCLUDING REMARKS

Many different modes of failure can produce the partial or total collapse of buildings. Nevertheless it can be stated that independently of the material and structural system adopted, if proper earthquake resistant design criteria are followed as well as adequate detailing and construction practices, damage can be limited to a local distress not involving collapse.

The continuity between structural members, through proper connections, the redundancy of the structural system to ensure large energy dissipation, and the regularity of factors to avoid a brittle failure.

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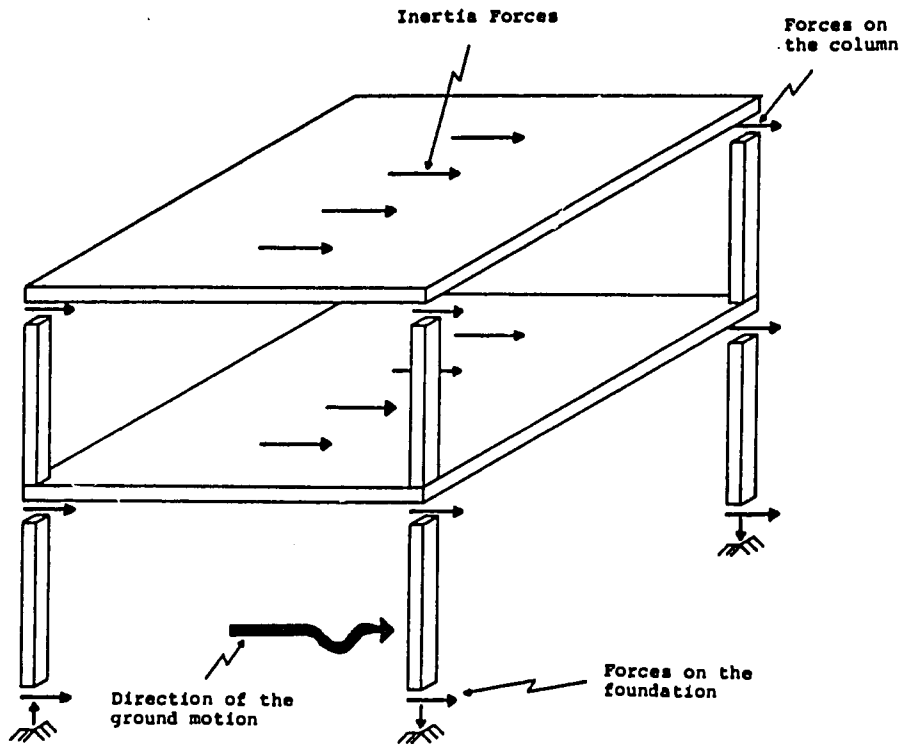

Fig 1. Schematic representation of the flow of forces induced by the ground motion in a structure

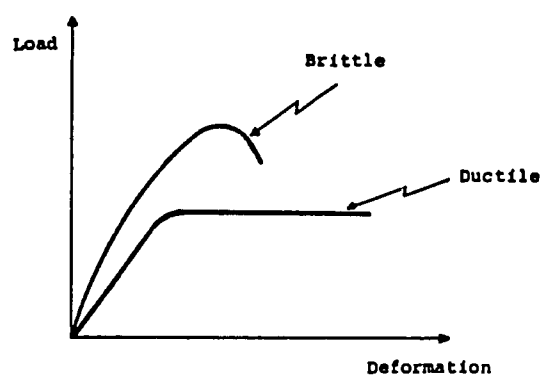

Fig 2. Load-displacement relationships for structures with brittle and ductile failure

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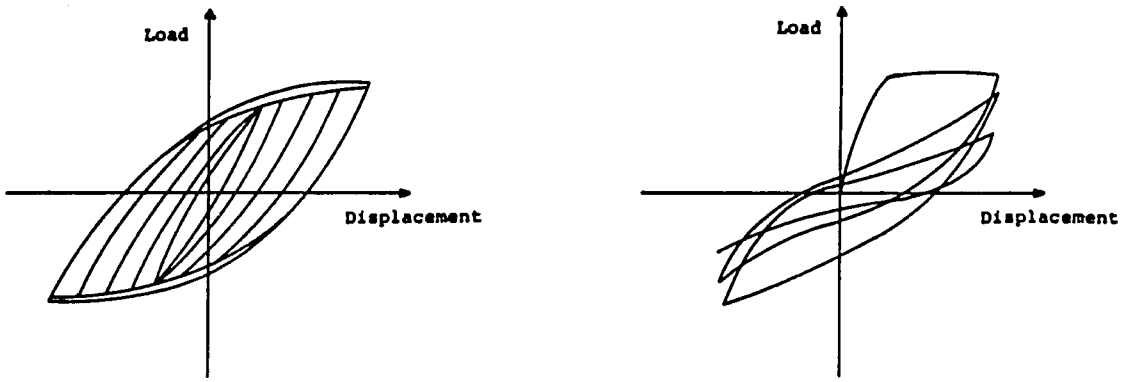
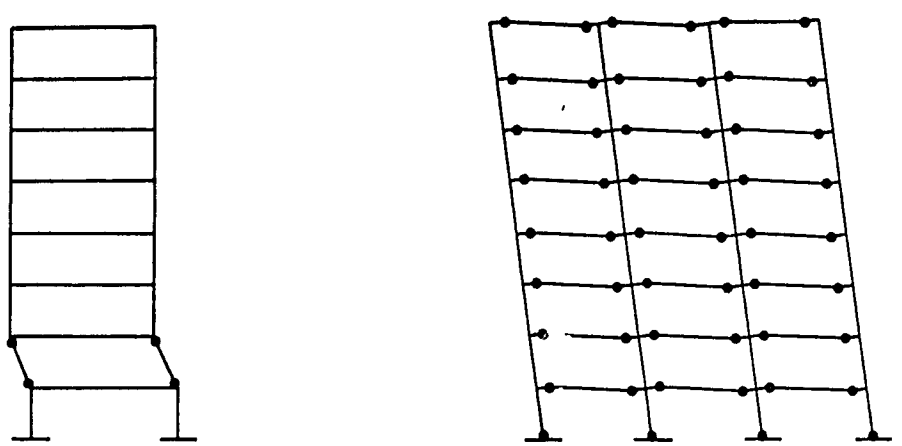


a) Structure with large capacity of energy dissipation and with a stable behavior under load repetitions

b) Structure with a low capacity of energy dissipation and with a degrading behavior

Fig 3. Cycles of load-displacement relationships for structures with different behavior



a) Low redundancy

b) High redundancy

Fig 4. Systems with modes of failure involving low and high redundancy

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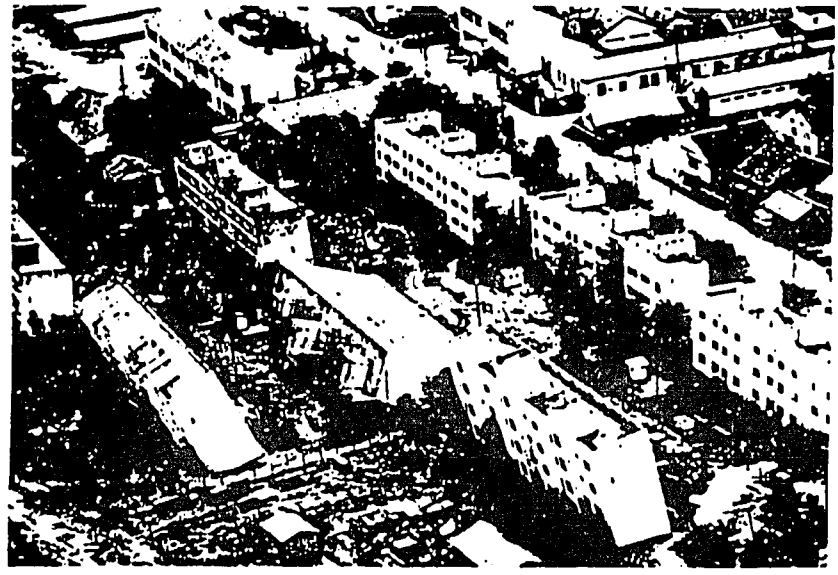
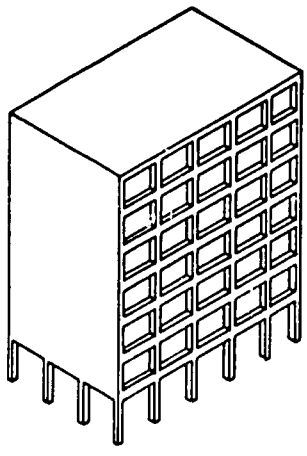
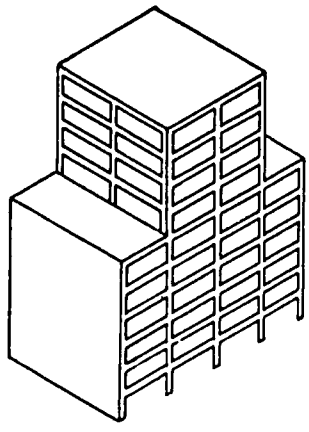


Fig 5. Overturning of buildings due to liquefaction of the soil



a) Weak Ground Story



b) Abrupt Change of Stiffness and Strength

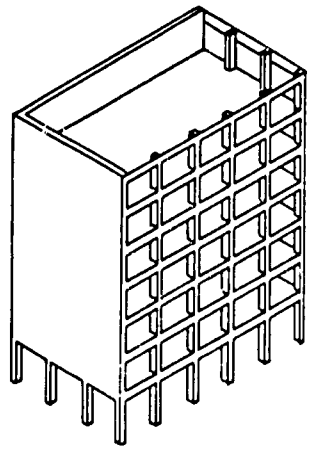


Fig 7. Structure with large in plan eccentricity

Fig 6. Structures with irregularities in elevation

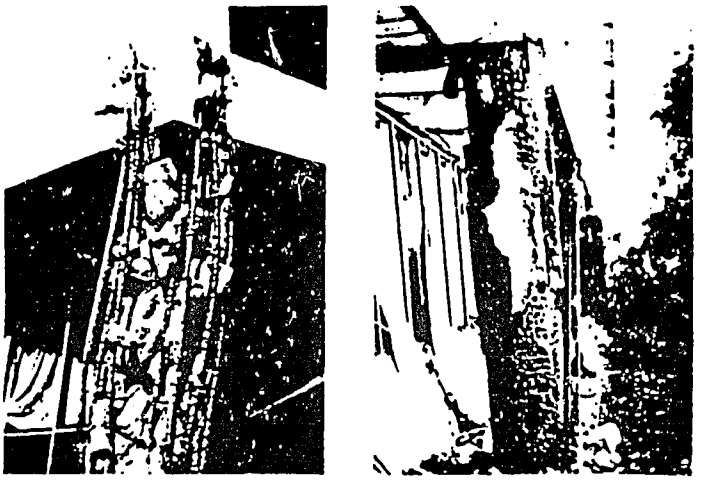


Fig 8. Failure of a poorly confined column (left) and of a column confined with spiral reinforcement (right), in the same building

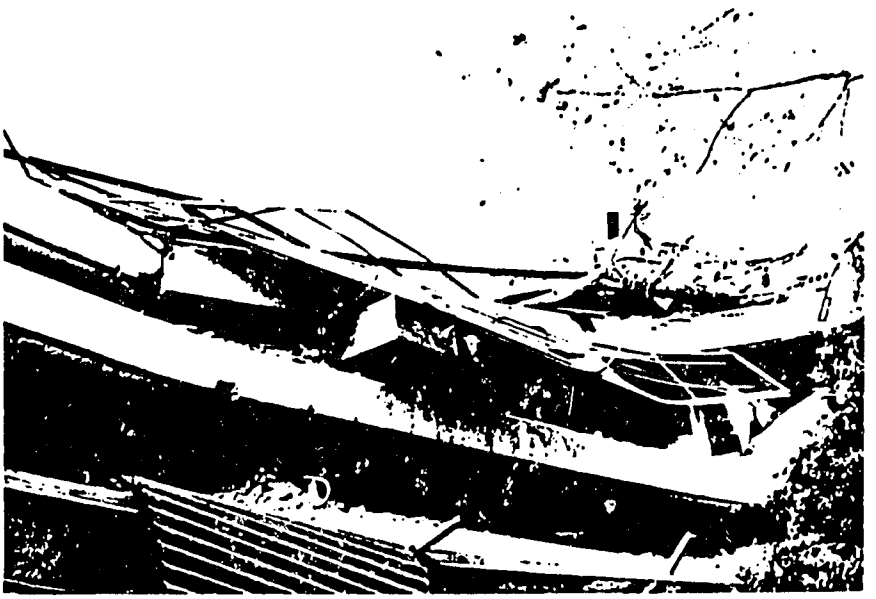


Fig 9. Collapse due to column failure

Fig 10. Collapse due to column failure, involving lateral instability

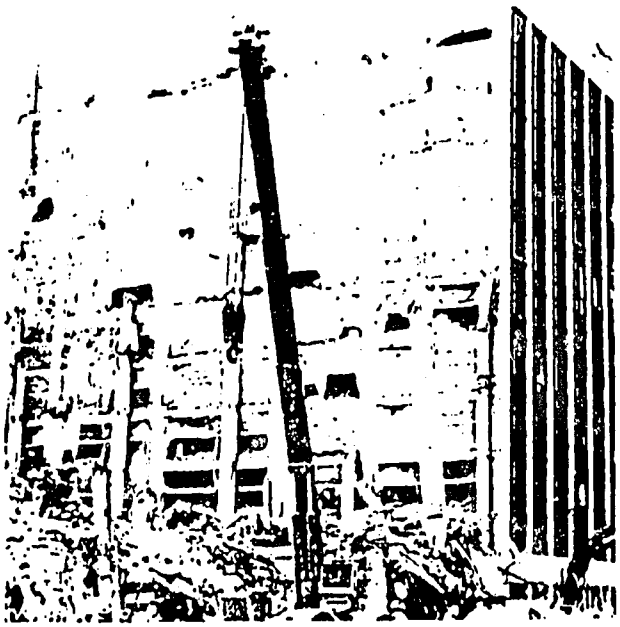


Fig 11. Collapse of a building by punching shear of flat plate slabs

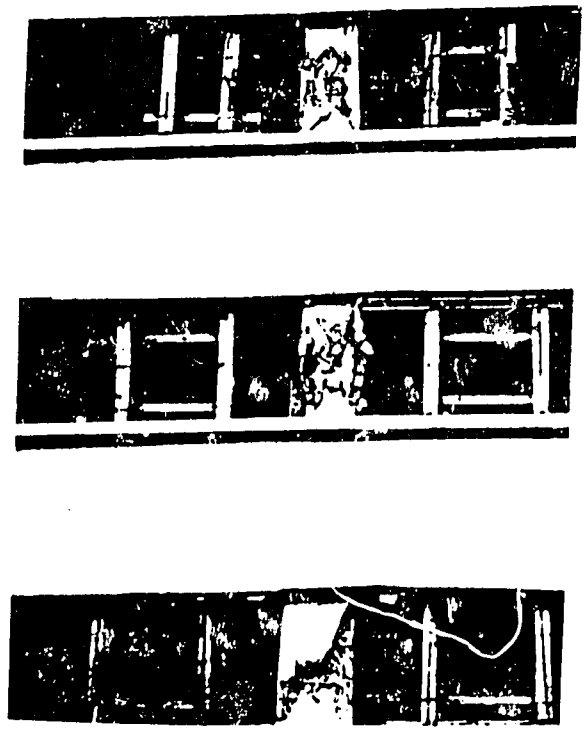


Fig 12. Shear Failure of Short Columns

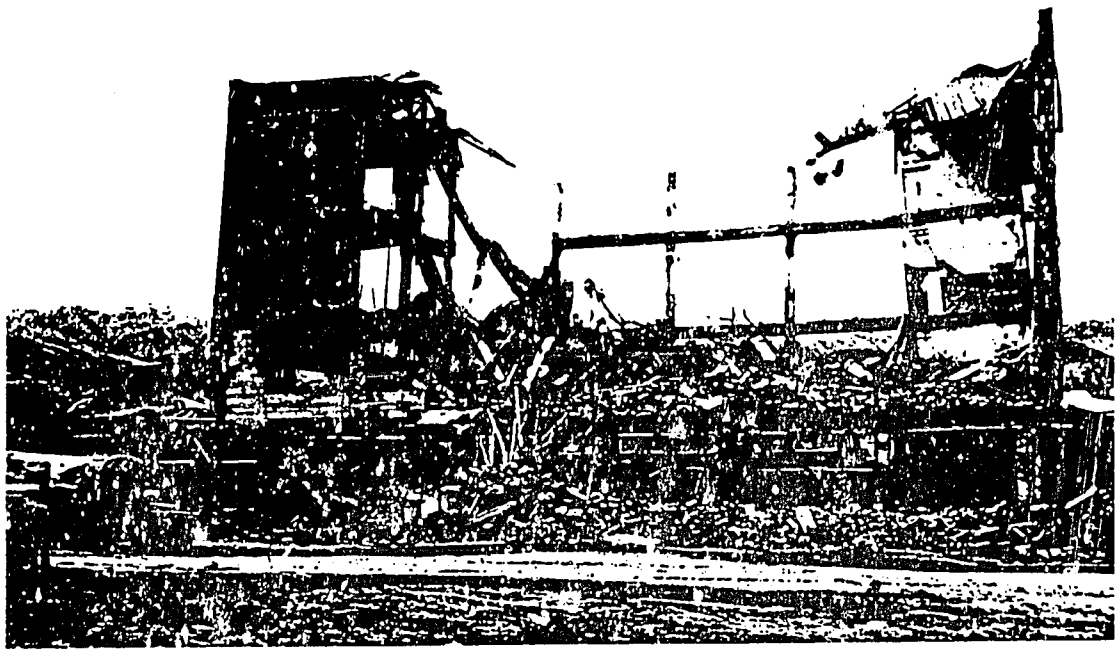


Fig 13. Failure of a Building with Prefabricated Frames

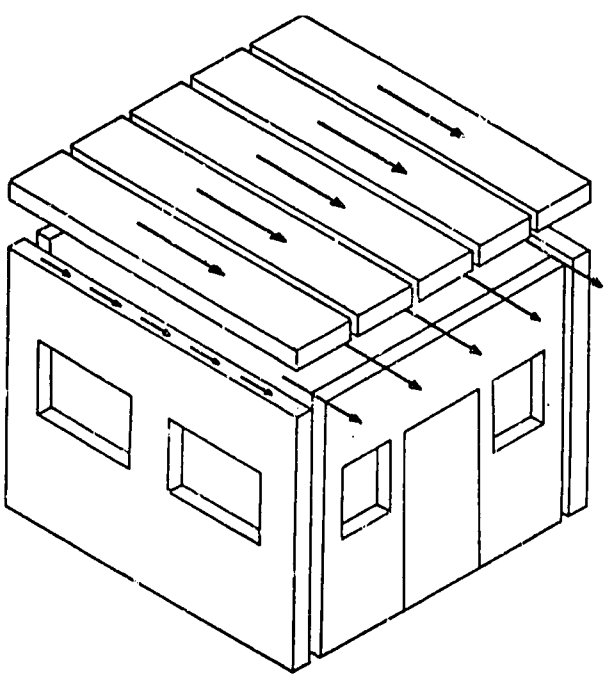


Fig 14. Transmission of inertia forces when floor slabs do not form a horizontal diaphragm

INTERPRETATION OF DAMAGE TO HOUSES AND CASUALTIES RELIED ON A PRECISE EVALUATION OF EARTHQUAKE GROUND MOTIONS IN THE EPICENTRAL REGION

—THE 1945 MIKAWA EARTHQUAKE—

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ABSTRACT

Although about two thousand people were killed by the 1945 Mikawa earthquake, a clear description of the entire event has yet to be given because the earthquake took place just before the end of World War II. In order to describe what happened in the epicentral region during this earthquake, the authors estimated the ground motion and investigated the damage done to houses the casualties caused by the earthquake.

The ground motion was estimated by a nonlinear finite element method, in which modified joint elements were adopted to model the fault plane. The seismic intensity in the area near the fault was estimated from the calculated maximum velocity. The damage done to houses and the casualties caused were investigated by questionnaire. The destruction of houses was compared in detail to the number of casualties. The type of damage is discussed in relation to the estimated ground motion.

1. INTRODUCTION

The Mikawa area in eastern Aichi Prefecture was struck by a strong earthquake at 3:38 A.M. January 13, 1945. About two thousand people were killed, more than fifteen hundred dwelling wooden houses completely collapsed, and more than eleven thousand non-dwellings partially destroyed [1]. Moreover, a considerable number of people were injured during the partial and total destruction of wooden houses by the earthquake. Although this was a major disaster, no clear description of the entire event was made because it took place at the end of World War II and its scale was hidden from the public. There has been an investigative report made that describes the damaged houses, ground destruction, casualties, etc. [2]; but, it contains ambiguous statements concerning where there were liquefied sites and the causes of casualties.

KEY WORDS: Mikawa earthquake, Nonlinear dynamic analysis, Rupture mechanism, Liquefaction, Damage of wooden houses

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To determine what actually happened in the epicentral region during the earthquake, the authors first estimated the ground motion near the fault, investigated the characteristics of the disaster, then evaluated the relation between ground motion and the number and types of damaged houses and casualties. Ground motion was estimated by analyzing the fault model, the damage and casualties by questionnaire.

In the past two decades, the investigation of fault rupture mechanisms has been progressed remarkably. One commonly used theoretical approach by which the generation of seismic waves from a fault is analyzed is the "dislocation" theory. Most methods of this type are based on the elastic wave transmission theory in a half space. Various fault parameters such as rupture velocity, magnitude of final dislocation and source-time function, that are needed in this method are assumed in advance of numerical calculation, as are the geometrical parameters needed to describe the fault rupture process.

In an actual fault plane rupture begins, however, at some point on the plane then is transmitted. This produces successive ruptures in adjacent regions because the area of the rupture zone is governed by the stress field and the strength of the fault plane. Furthermore, the fault parameters mentioned above are not the source but the result of rupture.

Because of this, Toki and Miura [3] proposed a new technique with which to simulate the fault rupture process. It is based on the nonlinear finite element method in which a modified joint element is used to model the fault plane. In their method only two parameters are necessary; the distributions of the yield stress and the stress drop on the fault plane.

The authors investigated the rupture mechanism and the strong ground motion produced by the 1945 Mikawa earthquake in the Mikawa area using Toki and Miura's method. To simulate the rupture mechanism, we used the fault model proposed by Ando [4]. The crust-fault structure was determined from data gathered from explosion tests made in the Mikawa region [5,6].

As more than forty years have passed since the Mikawa earthquake, it is impossible to directly investigate the disaster that it caused. Therefore, a questionnaire was sent out to gather information on the extent of the disaster. Sixteen hundred and sixteen replies were collected, from which the distributions of liquefied places and the ratio of destroyed houses to the loss of life were obtained. These distributions are discussed in the relation to the estimated ground motion.

2. METHOD OF ANALYSIS

A flow chart showing how the authors estimated the near field ground motion and investigated the extent of the disaster caused by that motion is given in Fig. 1. The procedure had three main steps: (1) modeling of the crust-fault system with the finite element model; (2) calculation by static analysis of the initial stress field caused by the tectonic force and simulation of the fault rupture process by the nonlinear dynamic finite element method; and (3) discussion of the relation between ground motion and the extent of the disaster caused by the Mikawa earthquake. In the second step, the resultant dislocation at ground surface was compared with the recorded value, iteration of the calculation being continued until the difference between the calculated and observed dislocations became very small. As the method of analysis used is the same as that proposed in an earlier study [3], the process is given briefly.

2.1. *Modeling the fault*

The fault was modeled by arrangement of the modified joint element shown in Fig. 2. The relation between shearing stress and deformation is shown in Fig. 3. It is linear for a stress lower than τ_y, the yield stress. When τ reaches τ_y, the element yields and the shear stress decreases instantaneously to the residual strength, τ_r, because of the dynamic stress drop, $\Delta\tau_d$. Hereafter, the stress drop, $\Delta\tau$, is defined by $\Delta\tau=\tau_0-\tau_r$, in which, $\Delta\tau_0$ is the initial stress. The crust was modeled with two dimensional isoparametric elements.

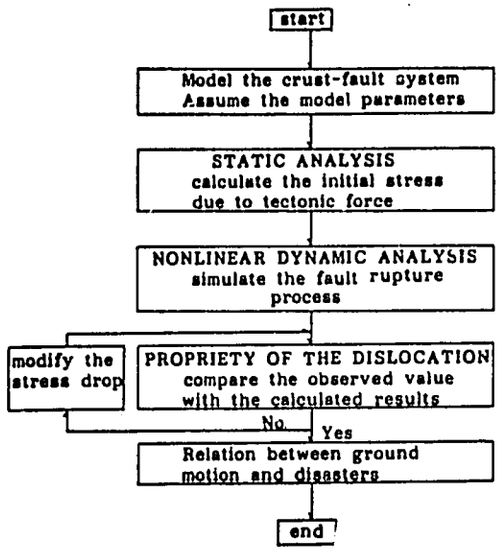

Fig. 1 Flow chart of the study.

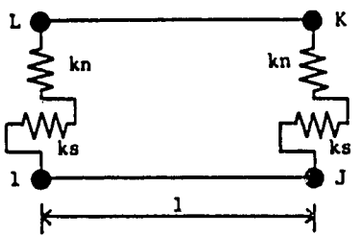

Fig. 2 Schematic representation of a modified joint element.

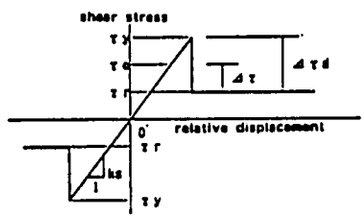

Fig. 3 Constitutive relation of the joint element.

2.2. *Procedure for analysis of fault rupture*

A static analysis was made to obtain the initial shear stress produced by the tectonic force along the fault. Lateral force was applied to both sides of the model as the tectonic force. This lateral force was increased until the induced shear stress reached the yield shear stress at some point on the fault; that was the origin of rupture. A dynamic analysis then was made in which the stress field determined in the previous step was used as the initial stress condition. The external force, in the first iteration in integrating the governing equation of motion, was the nodal forces equivalent to the dynamic stress drop of the joint element that corresponds to the original rupture. Strain energy was released by the first rupture as an elastic wave, and stress in the neighboring field was increased causing successive ruptures in those elements. In this way, rupture continued serially satisfying the governing equation of the crust-fault system. The only parameters that needed to be assigned to the fault were the shear strength and the stress drop. Therefore, the method does not assume other fault parameters such as fault rupture velocity, source-time function, final dislocation, etc. These values were obtained from the results of the simulation.

Integrating the equation of motion, the authors adopted Newmark's β method and assigned a value of 1/4 to β. The load transfer method was the scheme of numerical integration.

3. MODELING THE FAULT OF THE 1945 MIKAWA EARTHQUAKE

The fault of the 1945 Mikawa earthquake and the structure of the crust near this fault are shown in Fig. 4. The structure below ground was determined from explosion tests [5, 6]. The geometrical figure of the fault determined by Ando [4] was adopted. The width was 11 km, the length 12 km, and the dip angle about 30 degrees. The final dislocation of the fault was recorded as about 2.2 m at ground surface. Therefore, the authors repeated the dynamic analysis until the calculated final dislocation became nearly equal to the recorded value (Fig. 1). The finite element mesh used for the crust-fault system is shown in Fig. 5, and the model constants summarized in Table 1. The number of elements are 430 and the number of freedoms 936. Ten joint elements are arranged along the fault.

The average stress drop, $\Delta\tau$, one of the assigned parameters, was calculated as 20 bar from the following equation [7,8];

$$\Delta\tau = 0.74 \cdot \mu \cdot U/W \qquad \cdots\cdots(1)$$

in which, μ is the shear modulus, U is the average final dislocation and W the width of the fault. The distributions of the yield stress, τ_y, the other assigned parameter, and of the stress drop,

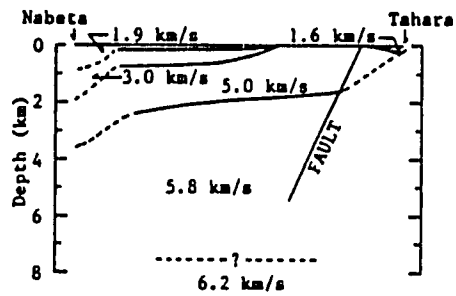

Fig. 4 Fault model and ground structure in the Mikawa area.

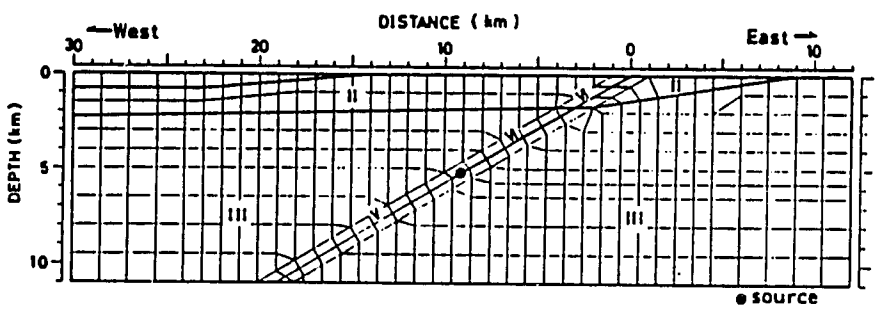

Fig. 5 Finite element mesh for calculation of the initial stress distribution and, analysis of the fault-rupture process.

Table 1 Parameters of the ground structure and the fault.

Crust	Unit weight (tf/m³)	Vp (km/s)	Vs (km/s)	Damping factor
I	2.0	2.0	1.0	0.0100
II	2.3	5.0	2.8	0.0033
III	2.5	5.8	3.4	0.0025

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$\Delta\tau$, are assumed from the distribution of the initial stress as shown later (see Fig. 6).

4. RESULTS OF THE ANALYSIS AND THE ESTIMATION OF SEISMIC INTENSITY

4.1. *Results of static and dynamic analyses*

The distribution of the initial shear stress along the fault obtained from the static analysis is shown in Fig. 6. The distribution of the shear strength (yield stress) also is shown. The origin and position of the fault rupture in the lower layer where the initial stress exceeds the shear strength is designated by symbol ● in the figure.

The source-time function that denotes the time trace of the development of dislocation at ground surface is shown in Fig. 7. After the rupture front reached ground surface, the dislocation increased sharply to about 1.8 m within 3 seconds. Thereafter, dislocation was gradual and was complete by 40 sec. The final dislocation at ground surface was 2.08 m. This value approximates the recorded value of 2.2 m. The discussions in the following sections are based on the results of this analysis.

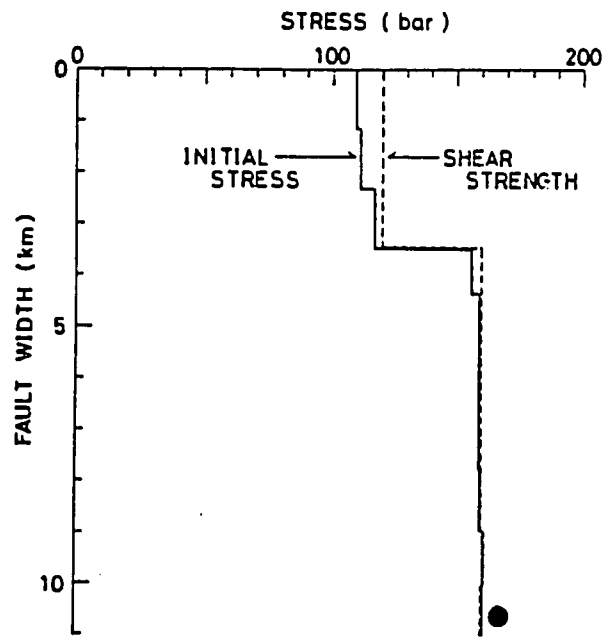

Fig. 6 Initial shear stress and shear strength distribution along the fault plane.

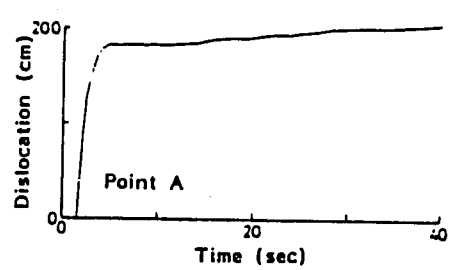

Fig. 7 Calculated source-time function at ground surface.

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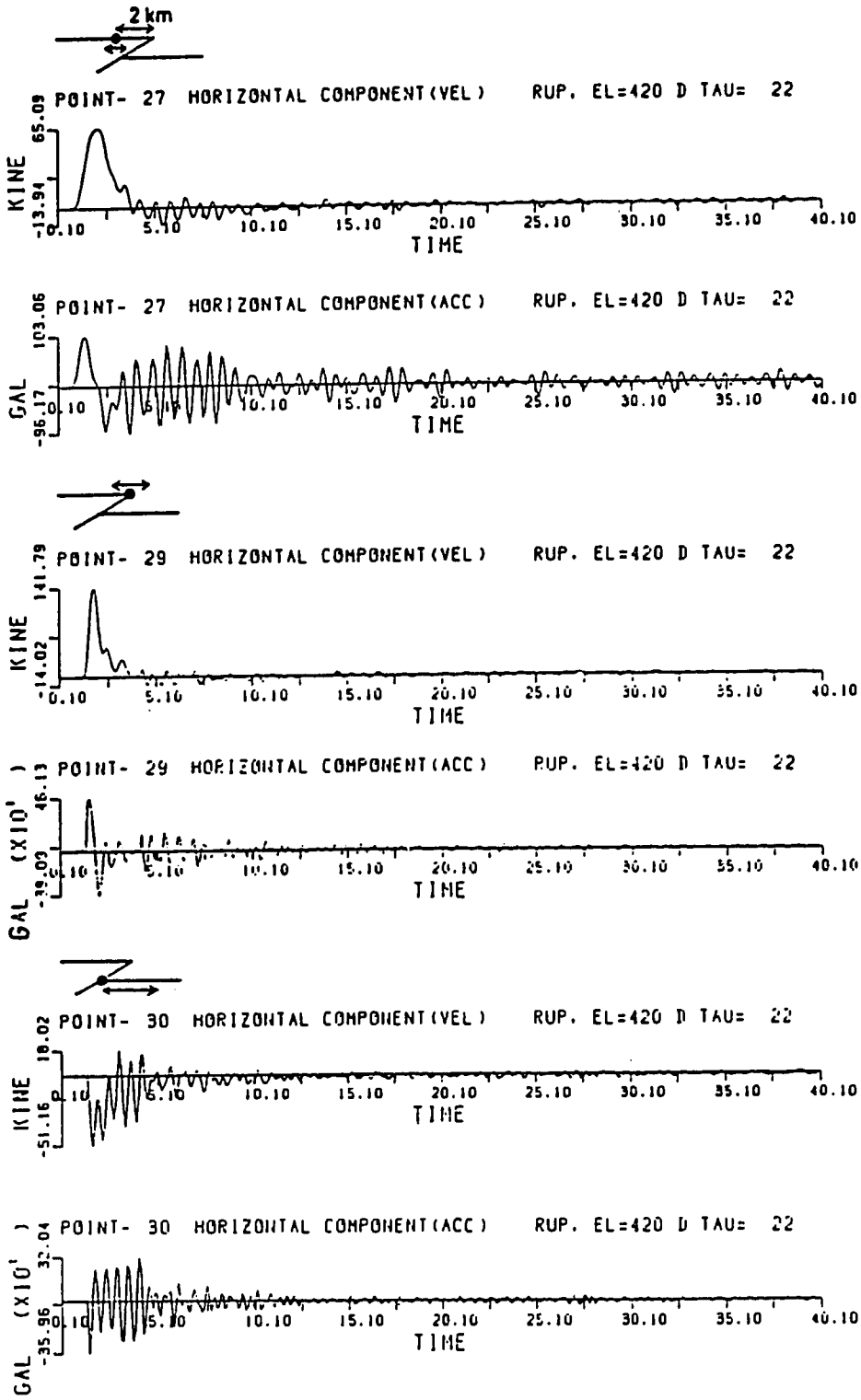

Fig. 8 Deformation curves for the horizontal component.

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4.2. *Estimation of seismic intensity*

Time history curves obtained from the analysis made at and near the outcropping of the fault are shown in Fig. 8. The main shocks of acceleration continue for 10 seconds and those of the velocity only for 3 seconds. Moreover, the shape of the velocity curve during the main shock is almost single in terms of pulse. This is very important when considering the relation between ground motion and the disasters it causes.

In general, the JMA (Japan Meteorological Agency) intensity is related to maximum ground acceleration; but, this relation is valid only for ground motion with a predominant period of less than 1 second. When the predominant period is longer than that, there is a better correspondence between the intensity and the maximum velocity [9]. This relation is shown in Table 2. Fig. 8 shows that the predominant periods of these accelrograms are longer than 1 second; therefore, the authors could use the relation between the intensity and maximum velocity.

The attenuation curve of the maximum velocity at ground surface is given in Fig. 9. The region for each of the intensities determined from Table 2 is also given in this figure. For the upper block (the left side of the fault in the figure) the JMA intensity is VII within 1 km of the outcropping of the fault, VI from 1 to 10 km, and V beyond 10 km. In contrast, for the lower block, the JMA intensity is VI within 3 km and V beyond 3 km. The intensity on the upper block is higher than on the lower one, which agrees with the general tendency for damage done by an earthquake to be more severe on the upper than on the lower block.

The authors next compared the above results and the recorded intensity shown in Fig. 10. This figure was mapped by Iida [2] from a field survey of the Mikawa seismic disaster that included destroyed houses and is based on the JMA intensity. According to this figure, for the upper

Table 2 Relation between the seismic intensity and the maximum acceleration and maximum velocity.

Seismic intensity (JMA)	Maximum acceleration (Gal)	Maximum velocity (kine)
I	0.8–2.5	0.1 –0.32
II	2.5–8.0	0.32–1.0
III	8.0–25	1.0 –3.2
IV	25–80	3.2 –10
V	80–250	10–32
VI	250–400	32–100
VII	400–	100–

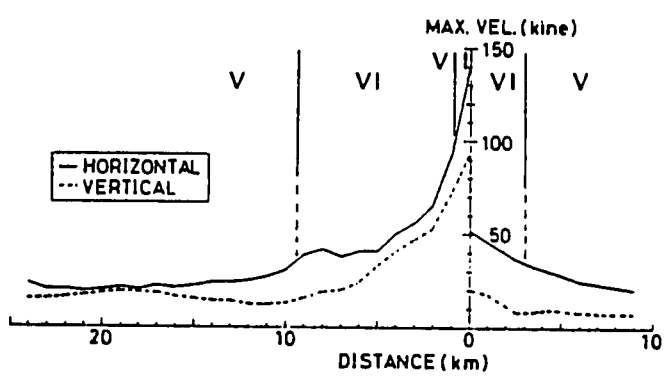

Fig. 9 Attenuation of peak velocity.

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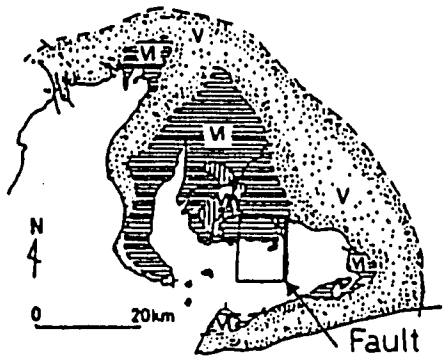

Fig. 10 Distribution of the recorded seismic intensity.

block, the intensity is VII on the fault and in other regions VI, except near the Yahagifuru River where the intensity is VII. For the lower block, the intensity is VI within of the outcropping of the fault. The analysis and the records for the region agree well within 10 km of the fault outcropping on the upper block and within 3 km on the lower block. For regions beyond those distances, the calculated seismic intensity is smaller than the recorded value. This discrepancy is attributable to lack of the amplification effect because of the soft surface ground use in the calculations. Accordingly, the authors took this effect into account in our calculations of seismic intensity First, we calculated the amplification factor of the surface ground by the multiple reflection theory, then multiplied this factor by the maximum velocity shown in Fig. 9. The resulting intensities are plotted in Figure 11, in which each city and town has been divided into 3 to 9 small zones and an intensity assigned to each zone. The general features of the distribution of the intensity in this figure closely resembles that in Fig. 10. This shows the validity of our fault model and the method used to analyze ground motion.

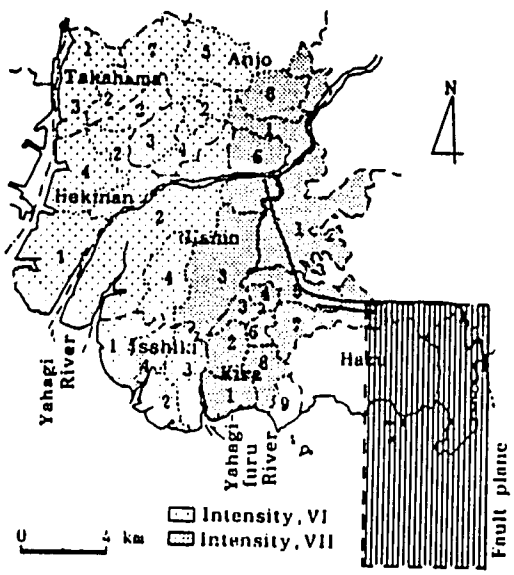

Fig. 11 Distribution of seismic intensity evaluated on the basis of the calculated maximum velocity (see Fig. 9).

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5. INVESTIGATION OF THE MIKAWA DISASTER BY QUESTIONNAIRE

5.1. *Outline of the questionnaire*

In order to determine the extent of liquefaction, the damage done to houses and the number and types of casualties, the authors distributed 2840 questionnaires to inhabitants of the West Mikawa area (shown by hatching in Fig. 12). Six cities and towns are included in the area. The survey was made on those who actually lived in the area and were more than twenty years old at the time of the 1945 Mikawa earthquake. Sixteen hundred and sixteen answers were collected (56.9% recovery).

5.2. *Liquefied sites*

According to the 1977 report [2], there were only a few liquefied sites. This is unnatural because the seismic intensity was very high near the fault and a soft alluvium deposit extended widely over the area; therefore, the potential for liquefaction is thought to have been very high. In fact, we found from our questionnaire that there were many liquefied sites. Figs. 13, 14 and 15 show liquefied sites in Kira Town (Kira-cho), Isshiki Town (Isshiki-cho) and Nishio City.

The solid circles in all these figures and the hatched zones in Figs. 14 and 15 denote liquefied points and zones. Solid squares show site where wells overflowed. These points and zones were determined from positions directly marked by answerers on maps which were distributed with the questionnaires. The large circles show liquefied points marked by more than three answerers, the small circles liquefied points marked by one or two answerers. In these figures, equi-depth contour line for the base of the alluvium deposit and the terrace (shadowed zone) also are given. Many liquefied points show up in the alluvium deposit plane in this city and the towns. In particular, liquefaction occurred over the entire alluvium deposit plane in Nishio City. In Isshiki Town, many liquefied points are located along the Yahagifuru River and in the west coastal zone.

5.3. *Damaged houses*

As examples, the damage done to wooden houses in Kira Town and in Nishio City is shown in Figs. 16 and 17. The damage ratio in percentage is given for each small zone shown in Fig. 11. Numbers allocated to the small zones are written at the left of the chart; from 1 to 9, Kira Town and from 1 to 4, Nishio City. The decimals at the right of the chart show the ratio of the rapidly demolished houses to the total number of destroyed (rapidly plus slowly demolished houses). This ratio hereafter called Wd.

In Kira Town, the rate of completely collapsed houses (rapidly plus slowly demolished houses)

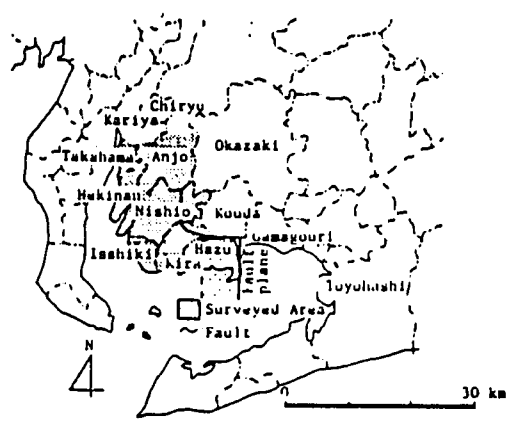

Fig. 12 Surveyed areas and the earthquake fault model.

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Fig. 13 Distribution of liquefied sites in Kira Town.

is highest in zone 4, about 65%. The value decreases in the order of zones 3, 2 and 1. The high percents in these zones are attributed to both strong ground motion and liquefaction. Zone 4 and 7 are located next to the fault. The Wd values in these zones are very high, 0.69 in zone 4 and 0.75 in zone 7. Although the ratio is higher in zone 7 than 4, the percent of completely collapsed houses is lower than in zone 4 because there was no liquefaction (see Fig. 13).

In Nishio City, the average rate of completely collapsed houses is a high 53.3%. In zone 3, the percent is highest, 69.3%, followed by zone 1, with 52.8%. These zones are close to the fault and liquefaction took place at many sites in them (see Fig. 15), which are the reason's for the high values. In contrast, zone 2 is closer to the fault than zone 4; but, the percent of destroyed houses is lowest in the city because there was little liquefaction in this zone. The Wd values are very high in zones 3 and 1, 0.86 and 0.73; whereas, in zone 4 and 2 they are relatively low, 0.68 and 0.64. These values are considered high in comparison to those for Kira Town. On the basis of Figs 16 and 17 and the above discussion, the number of completely collapsed houses is shown to be strongly affected by liquefaction and for the ratio of rapidly demolished houses (Wd) to increases suddenly when the completely collapsed houses exceed 10%, the Wd becoming

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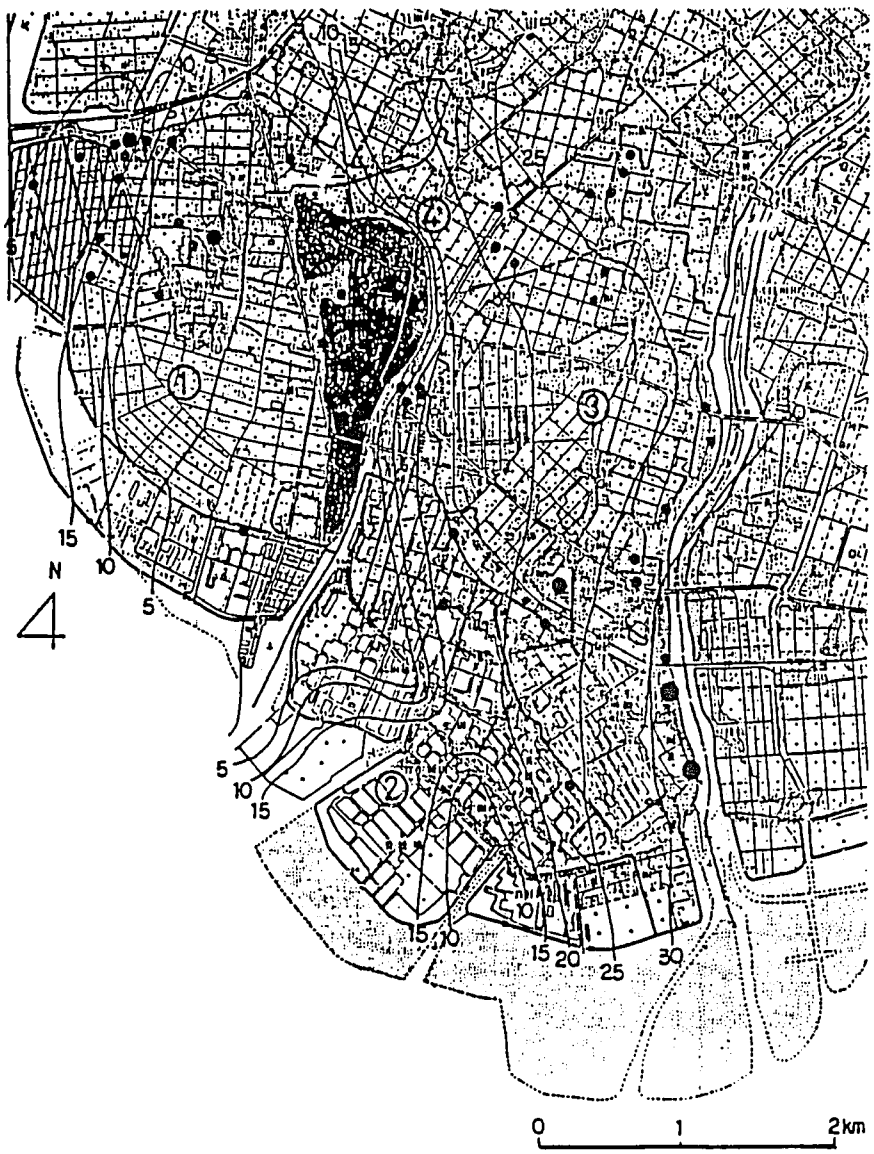

Fig. 14 Distribution of liquefied sites in Isshiki Town.

more than 70–80% when at value exceeds 50%.

The relation between the maximum velocity and the percent of completely collapsed houses is shown in Fig. 18. A house is completely ocllapsed above 40 kines. In general, the ratio increases with the maximum velocity, there being two groups, A and B, in the relation. Zones belonging to group A are those in which liquefaction occurred are near the fault, or both. Zones belonging to B are in Hekinan City, Takahama City and mountainous area of Kira Town where liquefaction was rare.

5.4. *Casualties*

The number of answerers was 5464; men 46.3% and woman 51.7%. Table 3 lists the percent

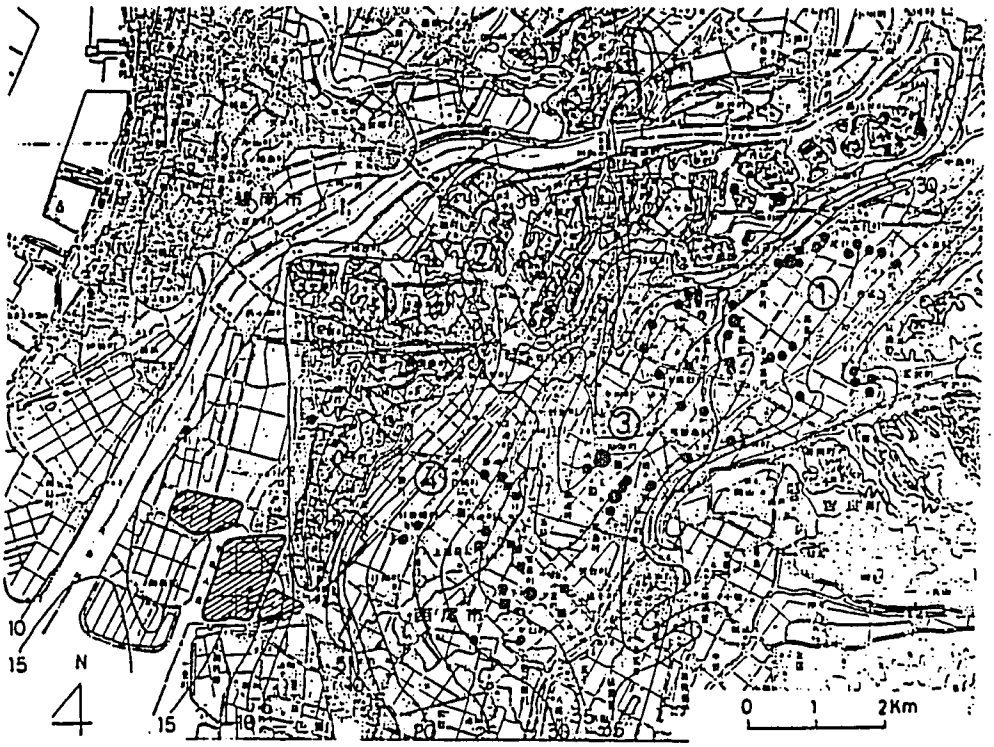

Fig. 15 Distribution of liquefied sites in Nishio City.

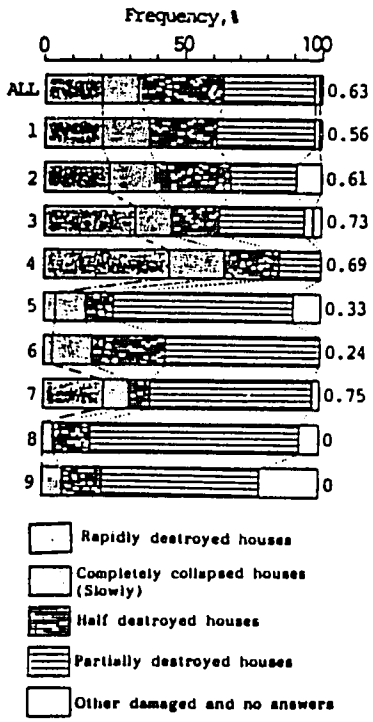

Fig. 16 Damaged wooden houses in Kira Town.

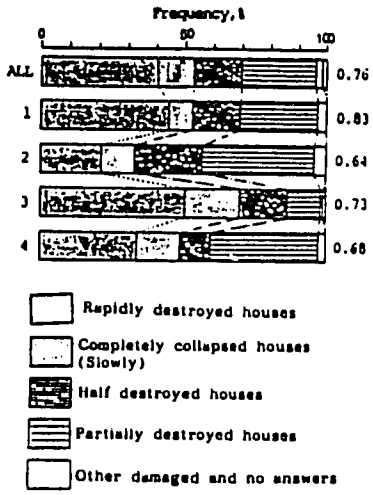

Fig. 17 Damaged wooden houses in Nishio City.

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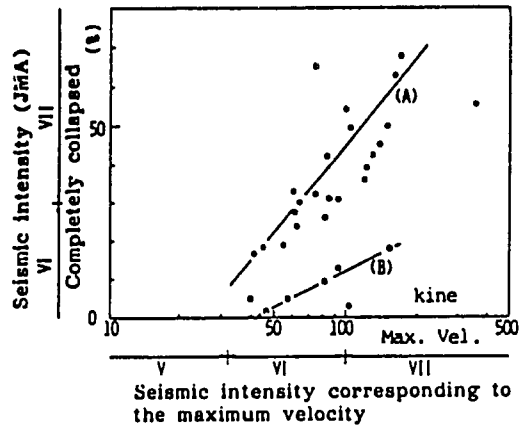

Fig. 18 Relation between maximum velocity and completely collapsed houses.

Table 3 Persons injured in each area by the 1945 Mikawa earthquake.

Surveyed area	Loss of life in percent	Percent of Injured	
		serious	slight
Kira	4.0	1.4	4.7
Nishio	6.0	2.9	8.4
Anjo	5.4	2.5	7.9
Isshiki	2.1	1.3	5.8
Takahama	0.2	0.7	3.3
Hekinan	0.2	0.1	1.8

of dead, seriously and slightly injured persons in each area affected by the Mikawa earthquake. The values for Nishio City are the highest; 6.0%, 2.9% and 8.4%. The values for Anjo City are the next highest.

The figures for the dead and injured in each area are compared with those for other earthquakes (Fig. 19). The value for the Mikawa earthquake is extremely high in comparison to

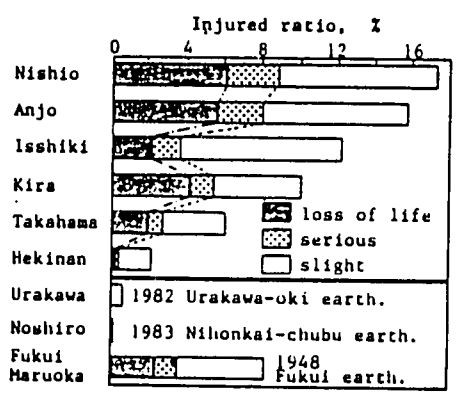

Fig. 19 Injured ratio from the Mikawa earthquake, and its comparison with other earthquake.

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values found for recent earthquakes. For example, the value for casualties from the 1982 Urakawa-Oki earthquake is 0.7% in Urakawa Town where the JMA intensity was VI. It is 0.08% in Noshiro City where the JMA intensity was V for the 1983 Nihonkai-Chubu earthquake. Taking into account that the maximum JMA intensity is VII for the Mikawa earthquake, there is a tendency for the casualties value to increase by an order of one as the intensity increases on rank.

The JMA intensity in Fukui City and Maruoka Town in the 1948 Fukui earthquake was VII. Figure 11 shows intensity VII zones in Nishio City, Anjo City and Kira Town, in which the loss of life was more than 4%. In contrast, the figure was 2.4% for the Fukui earthquake. These values for the Mikawa earthquake are two to three fold the value for the Fukui earthquake. As casualties in the Mikawa earthquake mainly were caused by the destruction of houses, the difference in values can be attributed to the time the earthquake took place; the Mikawa earthquake took place at midnight, whereas the Fukui earthquake took place in the afternoon.

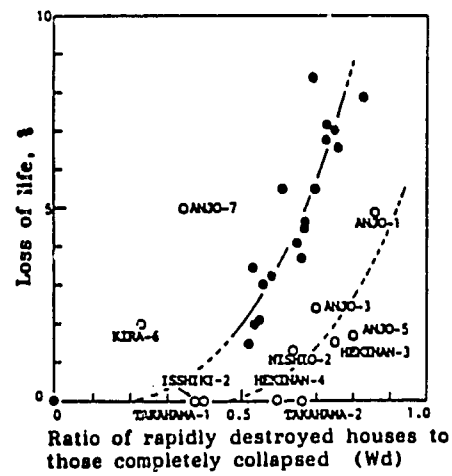

Fig. 20 Relation between the Wd (rapidly demolished house to the number of completely collapsed houses) and the loss of life.

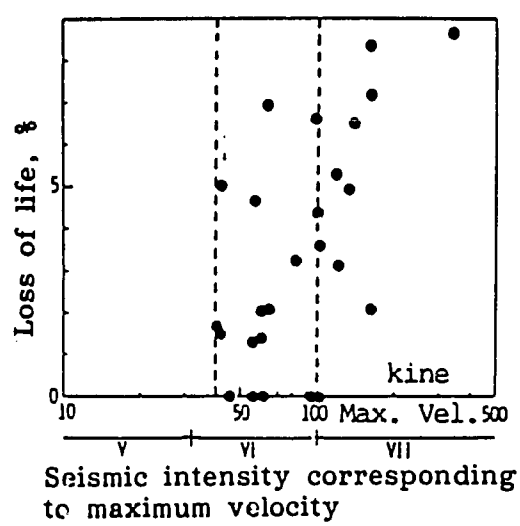

Fig. 21 Relation between the maximum velocity and loss of life.

The relation between the loss of life and rapidly demolished houses to the total number of destroyed houses is shown in Fig. 20. There are two groups as in Fig. 18. Zones belonging to the group of solid circles in Kira Town, Nishio City and Anjo City are located near the fault. In general, people were killed at more than 0.5 of Wd in the near and/or liquefied zones and loss of life increased sharply as the Wd increased.

On the other hand, people were killed at more than 0.6 of Wd in the regions belonging to the group of open circles, excepting zones Kira-6 and Anjo-7. In areas designated by open circles, there might be only a short time from the first excitation to the main shock because the sites are farther than the sites designated by solid circles. This made it possible for the inhabitants to take action quickly after the main shock and resulted in a lower loss of life in the open circle area for the same Wd value.

The authors have summarized the relation between the maximum velocity and the loss of life in Fig. 21. There is a tendency for the value denoting loss of life to increase as the maximum velocity increases. People would be killed at intensity VI, the loss of life being 0–7% for a seismic intensity of VI, and about 2–9% at intensity VII.

6. CONCLUSIONS

The authors have estimated the ground motion during the 1945 Mikawa earthquake and investigated the disaster caused by it. The ground motion was simulated by the nonlinear finite element method, and the disaster investigated by questionnaire. The relation between the intensity of the ground motion and the disaster was discussed. The main results were as follows.

(1) The distribution of seismic intensity in the Mikawa region estimated from the calculated maximum velocity gave a maximum intensity of VII near the earthquake fault and in the soft ground area in the south of the Mikawa region.

(2) The authors found many liquefied sites in Nishio City, Kira Town and Isshiki Town. The percent of damage to wooden houses and casualties in liquefied areas were greater than in nonliquefied areas.

(3) The relation between the loss of life and the JMA intensity, which is related to the maximum velocity, showed that people would be killed above intensity VI. Loss of life was 0–7% for intensity VI, but ranged from 2–9% for intensity VII. The value was higher than that for the Fukui earthquake which also had a maximum intensity of VII.

ACKNOWLEDGMENTS

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ESTIMATION OF POST-EARTHQUAKE SEARCH AND RESCUE PERSONNEL AND EQUIPMENT NEEDS

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INTRODUCTION

Urban earthquakes have recently and repeatedly resulted in tens of thousands of deaths, due primarily to the entrapment and crushing of victims in collapsed masonry and reinforced concrete buildings. Mexico in 1985 and Armenia in 1988 have vividly demonstrated the need for immediate massive expert search and rescue (SAR) operations.

Immediate SAR capability in the U.S. generally resides in the local fire departments, who generally are very ill-equipped for urban heavy rescue (heavy rescue is that involving the penetration and/or removal of heavy and bulky materials or major building components such as floors or wall elements, and is distinguished from light rescue, involving extrication from automobile accidents, victims fallen into shafts etc). SAR capability beyond this is generally of a similar nature, consisting of additional fire service personnel responding in mutual aid, with relatively little additional to offer in improved equipment or expertise. In order to improve SAR response, critical examination is required of the SAR task following a major U.S. earthquake, and present capabilities for accomplishing this task.

The nature and magnitude of SAR personnel and equipment requirements following a catastrophic earthquake in the United States have received little or no attention. FEMA[1] and NOAA[2] estimates of the effects of major earthquakes were primarily intended for estimation of medical caseload and generally provide only summary information on the number and distribution of dead and injured Numbers and geographical distribution of building collapses and associated trapped victims is information vital to rational planning on the part of the fire service and emergency preparedness agencies. Equipment needs for extrication of victims from earthquake damaged buildings has received only preliminary examination to date[3].

In order to provide some insight into the nature and magnitude of SAR personnel and equipment requirements following a catastrophic earthquake in the United States, this paper first briefly overview prevailing U.S. building types and associated earthquake collapse patterns. We next discuss the general problem of the

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estimation of building collapse due to earthquake, and provide some preliminary estimates of building collapses, by building type, for a major earthquake in the San Francisco Bay Area, similar to a repeat of the 1906 event. We then briefly discuss post-earthquake search and rescue needs in light of these estimates, and conclude with a review of the important questions and "critical variables" which need to be addressed.

BUILDING COLLAPSE PATTERNS AND SOURCES OF HEAVY DEBRIS

Buildings come in all shapes and sizes, but as a first cut may be generally categorized according to their primary material of construction (wood, concrete, steel etc), basic structural system (box, shear wall, moment frame, etc) and perhaps occupancy[4]. For the purposes of earthquake damage estimation and based on this simple categorization, U.S. buildings can be assigned to one of a dozen types, Table 1. In this table, each building type has been generally rated as to their average risk of major damage and/or collapse, for three seismic areas of the U.S. (low, moderate and high seismicity areas). In this, high ratings or "scores" are "good" (i.e., have low potential for major damage) and low scores are "bad", which 2 being a generally accepted minimum. Naturally, a particular building's rating will depend on the conditions and aspects specific to that building.

These general building types tend to differ in their earthquake response and collapse patterns. Figures 1 to 6 illustrate structural systems and typical collapse patterns for four of the most common and/or hazardous building types: wood frame (low hazard but very common), unreinforced masonry (URM), reinforced concrete (RC) frame, and tilt-up (TU). The collapse and debris patterns differ significantly among these four types, with generally:

- Wood Frame (Figure 1): complete collapse is rare for this building type, although partial wall or roof collapse is possible. Location of trapped victims is rapidly and easily accomplished, and debris can be easily removed and/or penetrated, often with only hand tools.

- URM (Figures 2 and 3): complete collapse is not common for this high hazard building type, although loss of facades is very likely. Debris is heavy but can often be moved by hand and with simple tools.

- RC (Figures 4 and 5): this type encompasses several subclasses, of which the older non-ductile RC frame is the highest hazard, being the mass killer in US and foreign earthquakes. Complete "pancake" collapses are non uncommon, resulting in major SAR requirements.

- TU (Figure 6): complete pancake collapse of these low-rise buildings has not been observed to date, although experience has been limited to only moderate size and duration earthquakes[5]. Partial roof collapse and loss of wall panels is common, in which tend victims to be more easily located and extricated, relative to the typical RC pancake collapse.

	Building Identifier	Seismic Area (NEHRP MAP AREAS) low (1,2)	moderate (3,4)	high (5,6,7)
W	WOOD FRAME	8.5	6.0	4.5
S1	STEEL MRF	3.5	4.0	4.5
S2	BRACED STEEL FRAME	2.5	3.0	3.0
S3	LIGHT METAL	6.5	6.0	5.5
S4	STEEL FRAME W/ CONCRETE SW	4.5	4.0	3.5
C1	RC MRF	4.0	3.0	2.0
C2	RCSW NO MRF	4.0	3.5	3.0
C3/S5	URM INFILL	3.0	2.0	1.5
PC1	TILT UP	3.5	3.5	2.0
PC2	PC FRAME	2.5	2.0	1.5
RM	REINFORCED MASONRY	4.0	3.5	3.0
URM	UNREINFORCED MASONRY	2.5	2.0	1.0

Table 1: Building Types and Basic Seismic Hazard. (After FEMA, 1988)

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Building Type	Collapse Potential	General Collapse/Debris Patterns	Human Injury Potential	Search & Rescue Needs Search	Rescue
Wood	Low	Complete collapse is rare. Partial Coll. pse. Debris is easily penet ated.	Low - Moderate. Broken limbs usually worst injury.	Low	Low
URM	High	Typically, wall collapse causing loss of vertical support to roof/floors. Interior partitions often prevent pancake collapse. Debris is broken masonry and is easily handled.	Moderate - High. Head injuries due to falling masonry.	Low - Mod.	Moderate
R.M. R.C. Precast	Moderate Mod. - High Mod. - High	Collapse usually pancake. Large concrete floors cannot be lifted and are difficult to penetrate, requiring tunnelling and burrowing.	High. Dust inhalation and/or crushing in pancaked floors leading to immediate death. Extrication requiring many hours, leading to dehydration, crush syndrome, etc.	Moderate High Moderate	High High Moderate
Tilt-up	Mod. - High	Complete collapse is rare. Partial collapse usually due to wall panels falling away from roof/floors, causing loss of vertical support. Debris from collapsed wood roof/floors is handled with some effort.	Moderate. Broken limbs usually worst injury, but fall of heavy framing members can cause crushing.	Moderate	Moderate
Steel	Low	Collapse usually pancake. Large concrete floors cannot be lifted and are difficult to penetrate, requiring tunnelling and burrowing. However, steel frame buildings are more easily penetrated than RC buildings.	High. Dust inhalation and/or crushing in pancaked floors leading to immediate death. Extrication requiring many hours, leading to dehydration, crush syndrome, etc.	Moderate	High

Table 2: Building Types: Collapse, Injury and SAR Aspects

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These and other aspects for the more common building types are summarized in Table 2.

Sources of heavy debris resulting in the majority of the SAR burden are thus seen to result from URM, TU and RC/RM collapses. The primary source, and most difficult to deal with, is the "pancake" collapse of multi-story buildings, in which the floor slabs, nearly intact, fall on top of one another and become closely stacked (see Figure 5). These large floor slabs prevent access or extrication, and thus pose significant problems, especially when the victim location and condition are unknown. Because of their expanse and mass, these floor slabs cannot be lifted, and require skilled experts to engage in difficult, dangerous and time-consuming tunneling and burrowing[3].

ESTIMATION OF BUILDING COLLAPSE DUE TO EARTHQUAKE

This section briefly discusses the general problem of the estimation of building collapse due to earthquake, and presents some preliminary estimates of building collapses, by building type, for a major earthquake in the San Francisco Bay Area, similar to a repeat of the 1906 event.

Method

The general method for estimation of building collapse is relatively straightforward:

$$E[C] = \sum_{N,i} E[C|I]\, I \qquad \text{...(1)}$$

where $E[C]$ = expected number of collapses

i = the number of building types to be examined

N = the number of buildings of a particular type

$E[C|I]$ = the expectation of collapse for a given seismic intensity, termed seismic collapse vulnerability function.

I = seismic intensity, in terms of Modified Mercalli Intensity (MMI), peak ground acceleration (PGA), or other parameters.

Two aspects of this methodology present difficult problems at present :

Building Inventory: detailed information on numbers and locations of building types, let alone more detailed information specific to individual buildings within a type, is generally not available in summary or easily usable form. The State of California for example is just now in the process of inventorying its remaining URM buildings, by sidewalk survey, more than 50 years after they were legally banned.

Seismic Vulnerability Functions: Relatively little information is available for the estimation of the earthquake response of buildings, as a type, due to the general lack of systematic data collection following U.S. earthquakes. The best general

information presently available is the ATC-13[6] document, which is based on expert opinion rather than being statistically or analytically based. Further, the seismic vulnerability functions in ATC-13 are intended for estimation of mean or average damage, for use in studies of the economic impact of earthquakes, rather for the estimation of building collapses.

It is generally acknowledged that a major earthquake in the US will generate numerous building collapses and a major SAR task. Official estimates of casualties for a repeat of the 1906 event in the San Francisco Bay Area range as high as 11,000 dead and 44,000 injured[1], although little or no detail is available. Numbers and geographical distribution of building collapses and associated trapped victims is a necessary item of data for rational planning on the part of emergency planners.

Case Study: San Francisco

In order to address this need, the author is presently engaged in a study to estimate building collapses in the San Francisco Bay Area. The major emphases of the study are the two aspects outlined above: building inventory and development of seismic collapse vulnerability functions. Seismic intensity for the scenario earthquake is less of an issue, and the estimates developed by Evernden are employed[7]. We next briefly discuss our efforts to date, and then present some preliminary findings.

Building Inventory: Building inventories for purposes of earthquake damage estimation are generally not available. For the San Francisco Bay Area, we have developed estimates of square footage of floor area for several building types for each postal zipcode in the Bay Area. The building types are:

Residential: Wood (three sub-categories), URM, Mobile Home and CSM (an aggregate of concrete steel and masonry, with three sub-categories).

Industrial/Commercial: 15 sub-categories, comprised of the following basic types: URM, TU, RC, RM, Steel, Light Metal and Wood.

Briefly put, the inventory has been developed starting with estimates of insured values[8], disaggregating these to the zipcode level based on demographic and business patterns data, sub-categorizing these based on data from ABAG[9] and then further disaggregating them for quality based on patterns of historical development. Examples of the results, for San Francisco and San Mateo Counties only, are given in Figures 7 and 8.

Seismic Vulnerability Functions: At present, no relations appear to available in the literature for the estimation of building collapse. As mentioned above, the seismic vulnerability functions in ATC-13 are for estimation of mean damage for use in studies of the economic impact of earthquakes, rather for the estimation of building collapse. In order to develop seismic collapse vulnerability functions, the author has examined the "tails" of probabilistic distributions provided in the ATC-13 document, to determine probabilities of exceeding various levels of damage. Three levels have been examined: 60%, 80% and 100% damage. Sixty percent damage has been previously employed[4] as a measure of major damage. One hundred percent would logically be a measure of collapse, but the results obtained

using this measure appear to be too low, calling into question the feasibility of using the ATC-13 data for a purpose for which it was not intended. Eighty percent was also employed in our calculations, as an intermediate value. Seismic collapse vulnerability functions were developed in this manner, based the ATC-13 data, for the above 21 sub-categories of building types, with one exception. That exception was the relations for URM collapse. The results from ATC-13, in the author's opinion, were clearly too low, so that the seismic collapse vulnerability functions employed in this study for URM are based on the author's own judgement, and are considerably higher than what was derived from ATC-13. Example seismic collapse vulnerability functions for three building types, RC, TU and URM, are presented in Figure 9.

These functions are still under examination. Irrespective of the bases for these functions however, rates of collapse are presumably *somewhere* in the vicinity of the 60th, 80th or 100th percentile, so that our preliminary results, using these tentative functions, are also *somewhere* in the neighborhood of what will actually occur. Further, the geographic distribution of collapses provides some insight.

Preliminary Results: Based on the foregoing, preliminary estimates of numbers of building collapses, and persons occupying the buildings at time of collapse, have been developed for the San Francisco Bay Area. Table 3 presents a summary for the more heavily affected counties.

TABLE 3
PRELIMINARY ESTIMATES OF BUILDING COLLAPSE
San Francisco Bay Area, Repeat of 1906 Event

COUNTY	DMG %	TOT COLLAPSED BUILDINGS	PERSONS TRAPPED RESID.	I/C
Alameda	60	595	3556	10162
	80	130	600	4686
	100	40	122	2186
Sta Clara	60	1772	10027	44319
	80	464	2092	19937
	100	147	508	8497
San Mateo	60	877	5563	11252
	80	183	1091	4037
	100	46	247	1578
San Franc	60	615	9791	31202
	80	310	5271	18972
	100	180	3568	11107
TOTAL	60	3859	28937	96935
	80	1087	9054	47632
	100	413	4445	23368

Table 3 indicates for example that if 80% damage is taken as the uniform average measure of collapse for all building types, approximately 1,087 buildings are expected to collapse in the four counties indicated. Were the earthquake to occur at night, when most people are at home, in wood frame buildings, approximately 9,000 persons would be occupying buildings which would have collapsed. If the earthquake were to occur during the day, when many persons are occupying buildings of an industrial/commerical (I/C) nature, then approximately 48,000 persons would be in collapsed buildings. This is not to say that 48,000 persons would be killed or even injured in a daytime repeat of 1906, since some fraction of these persons would flee the buildings prior to collapse, and others would be relatively lightly injured and immediately extricated. Some fraction of these 48,000 persons would be badly injured and/or trapped however, requiring major medical and or SAR resources. Note that FEMA estimates for the same event are:

TABLE 4
ESTIMATES OF CASUALTIES
Northern San Andreas Event
(after FEMA, 1980[1])

TIME	DEAD	INJURED
2:30 AM	3,000	12,000
4:40 PM	11,000	44,000

Some detail of the results by building type, for I/C collapses, are presented in Table 5 and Figures 10 and 11.

TABLE 5
INDUSTRIAL/COMMERCIAL COLLAPSES BY BUILDING TYPE
(Collapse = 80% Damage)

County	<...URM...>		<....RC...>		<....TU...>	
	Bldgs	Pers.	Bldgs	Pers.	Bldgs	Pers.
Alameda	44	3668	1	100	5	910
Sta Clara	176	14613	4	585	26	4687
San Mateo	30	2518	2	354	6	1152
San Franc	225	18777	1	190		
TOTAL	475	39576	8	1229	37	6749

POST-EARTHQUAKE SEARCH AND RESCUE NEEDS

The author has previously discussed post-earthquake search and rescue needs[3], and will not dwell on this topic. In summary, the present state of the art of heavy rescue from collapsed buildings, especially pancaked RC-type buildings, involves tunneling and burrowing techniques and equipment rather than the commonly assumed large truck cranes. An important point to briefly discuss however is the SAR personnel and equipment needs that might be required if the foregoing numbers are even approximately correct.

For the daytime event, the 475 URM buildings involve approximately 12 million square feet of floor area, each collapse of which might require perhaps a dozen rescue workers per shift, two shifts per day. This translates into 11,000 workers (and 11,000 pairs of heavy gloves, etc). The 37 tilt-up collapses, each building being larger, would add about 2,000 workers to this, while the eight RC buildings (an estimate the author feels is too low) might each require perhaps twice as much effort and resources, adding another 1,000 workers. We thus see that perhaps 15,000 rescue workers might be required. Associated with these workers would be jackhammers, airbags, "jaws of life" etc.

In making these estimates of person-hours required for SAR, it is important to note that the effort is only partially driven by the unknown number of entrapped victims. The required effort is perhaps equally well driven by the size of the rubble, independent of the number of victims, since the rubble has to be searched to determine that all surviving victims have been removed. This is not to say that the same effort would be devoted to SAR in a collapsed factory during an off-shift collapse as during the workday, but simply that rescue effort cannot be precisely correlated with trapped victims.

CONCLUDING REMARKS

The above discussion has attempted to outline some aspects of the nature and magnitude of SAR personnel and equipment requirements following a catastrophic earthquake in the United States. Of the prevailing U.S. building types and associated earthquake collapse patterns, we find that the pancaking large concrete floored building present the major SAR problem, but that preliminary estimates of numbers of collapsed buildings indicates that URM will constitute the majority of collapsed buildings. These estimates hinge to some extent around the building inventory but primarily around the seismic collapse vulnerability functions, which are presently based on very little data. These are a critical variable for the estimation of SAR requirements following a major earthquake. Preliminary estimates of building collapses, by building type, for a major earthquake in the San Francisco Bay Area similar to a repeat of the 1906 event indicate several hundred to several thousand building collapses. While these estimates vary by an order of magnitude, they indicate one to several tens of thousands of required rescue workers.

ACKNOWLEDGEMENTS

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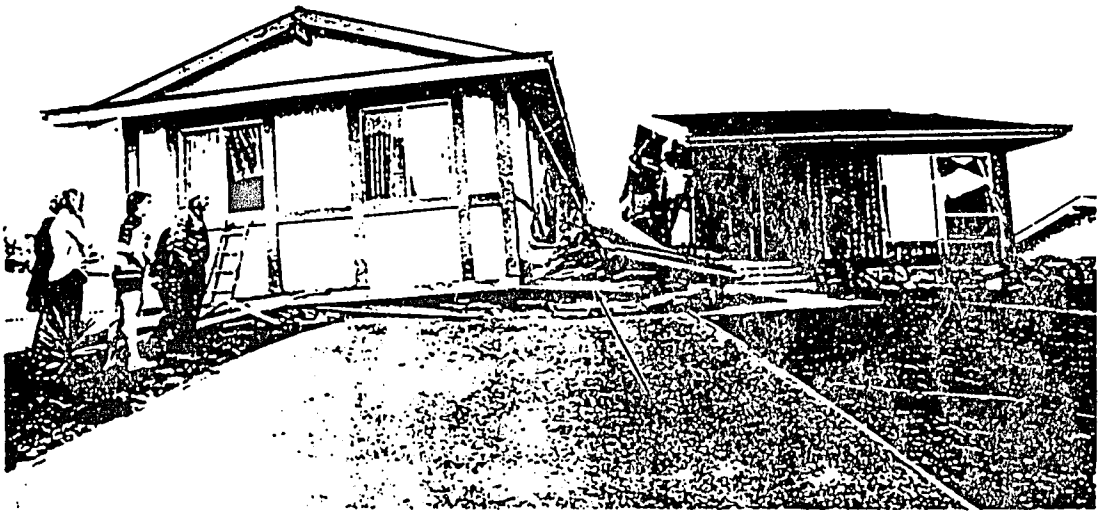
Single-family house, Sylmar. Note crushed car (arrow). For location, see Map 3. (Los Angeles Times Photo).



Destroyed wood-frame house on 8th Street near Fernmont Street, San Fernando.

Figure 1: Typical Wood Building Collapse Patterns

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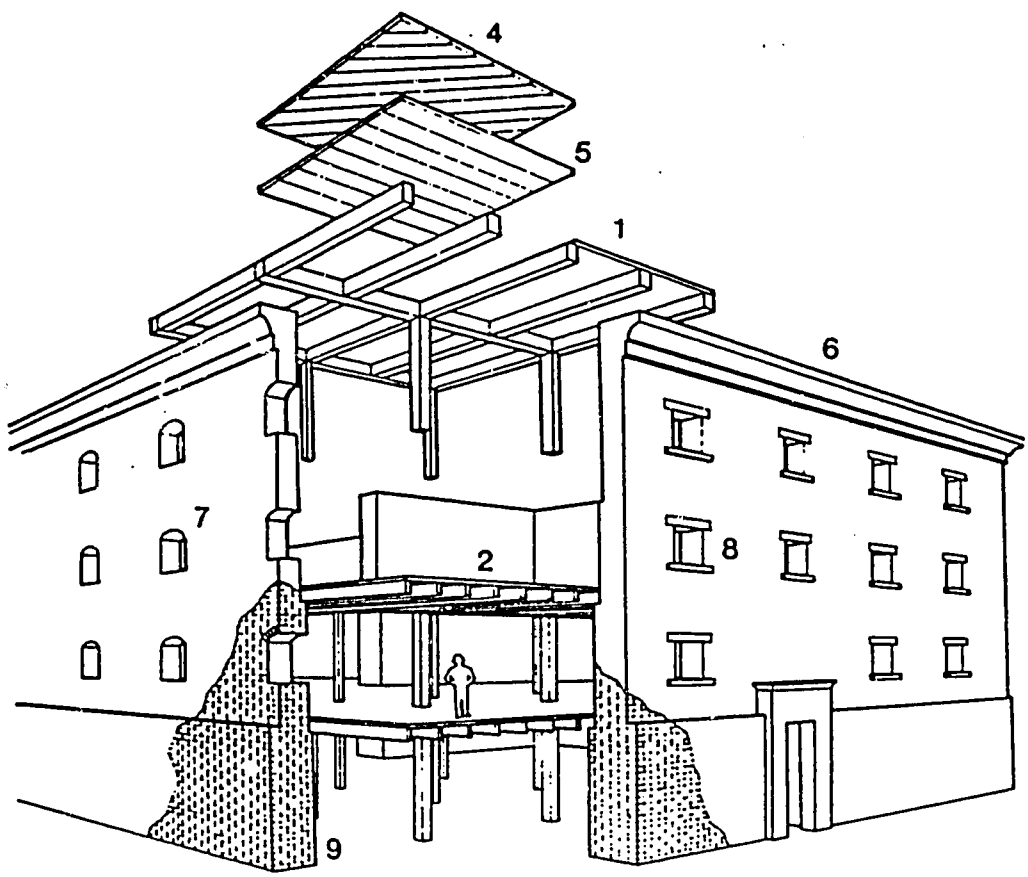
Roof/floor span systems:
1. wood post and beam (heavy timber)
2. wood post, beam, and joist (mill construction)
3. wood truss-- pitch and curve

Roof/floor diaphragms:
4. diagonal sheathing
5. straight sheathing



Details:
6. typical unbraced parapet and cornice
7. flat arch window openings
8. small window penetrations (if bldg is originally a warehouse)

Wall systems:
9. bearing wall-- four to eight wythes of brick

Figure 2 Unreinforced masonry bearing wall

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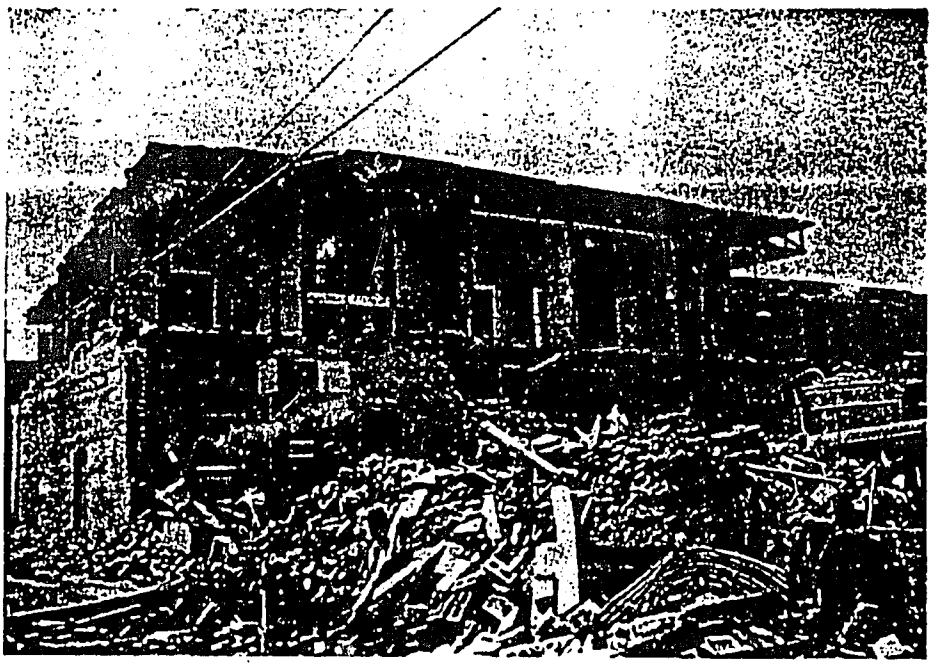
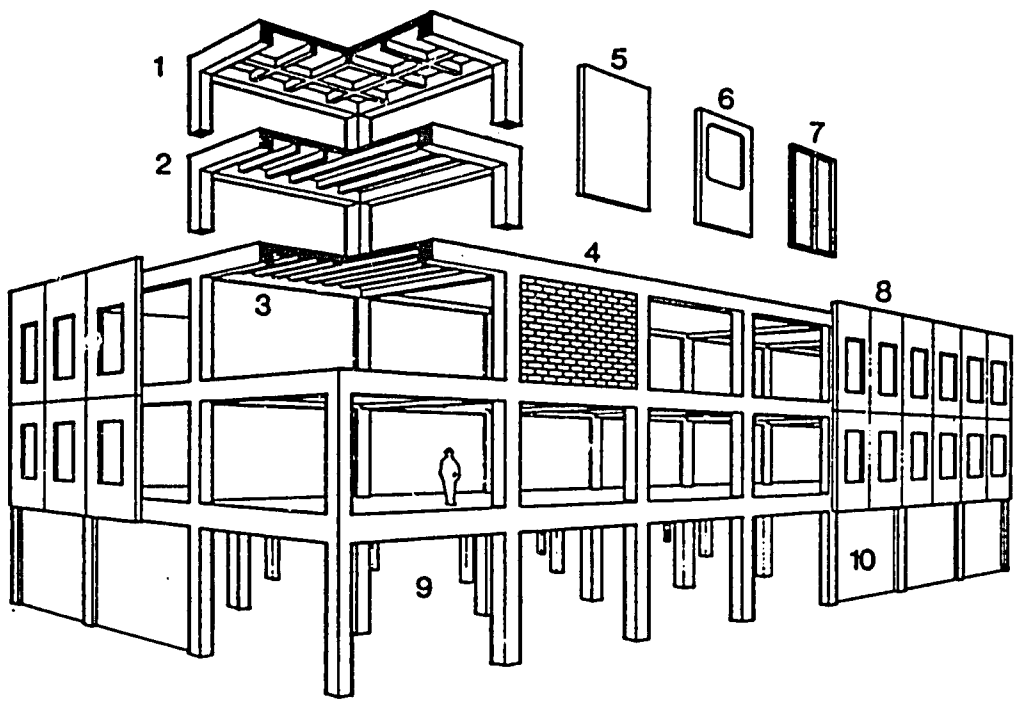


Figure 3 - Failure of an unreinforced masonry building in the 1983 Coalinga, California earthquake. The rubble consists of small chunks of brick, mortar and pieces of wood. This could be removed by rescue personnel without the use of heavy mechanized equipment.

Roof/floor diaphragms:
1. concrete waffle slab
2. concrete joist and slab
3. steel decking with concrete topping

Curtain wall/ non-structural infill:
4. masonry infill walls
5. stone panels
6. metal skin panels
7. glass panels
8. precast concrete panels



Structural system:
9. distributed concrete frame

Details:
10. typical tall first floor (soft story)

Figure 4 Concrete moment resisting frame

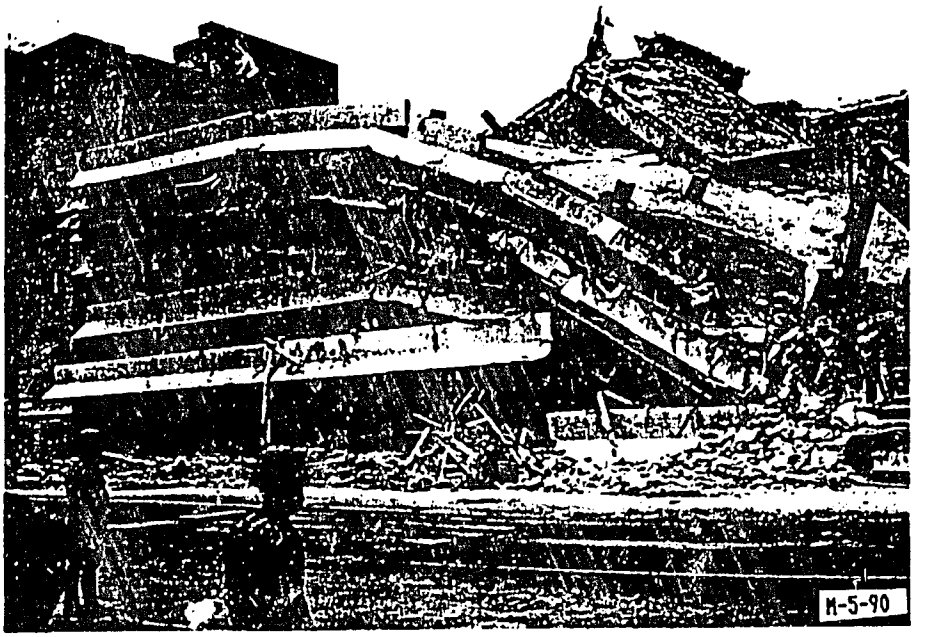


Figure 5 - This pancake collapse of a building in the 1985 Mexico earthquake illustrates the extent of the problems associated with rescue in a heavy debris environment. Access between the upper floors is non-existent; however, victims may be trapped in voids created by furnishings or columns that remain partially intact. Location of the victims would require the use of trained dogs or specialized equipment that can detect sound or heat. These large floor slabs could not be lifted by cranes without extensive cutting and segmenting.

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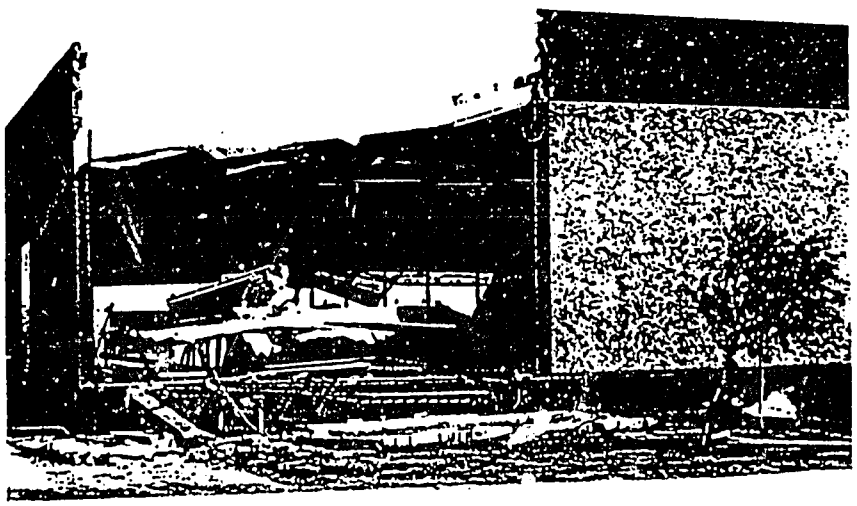
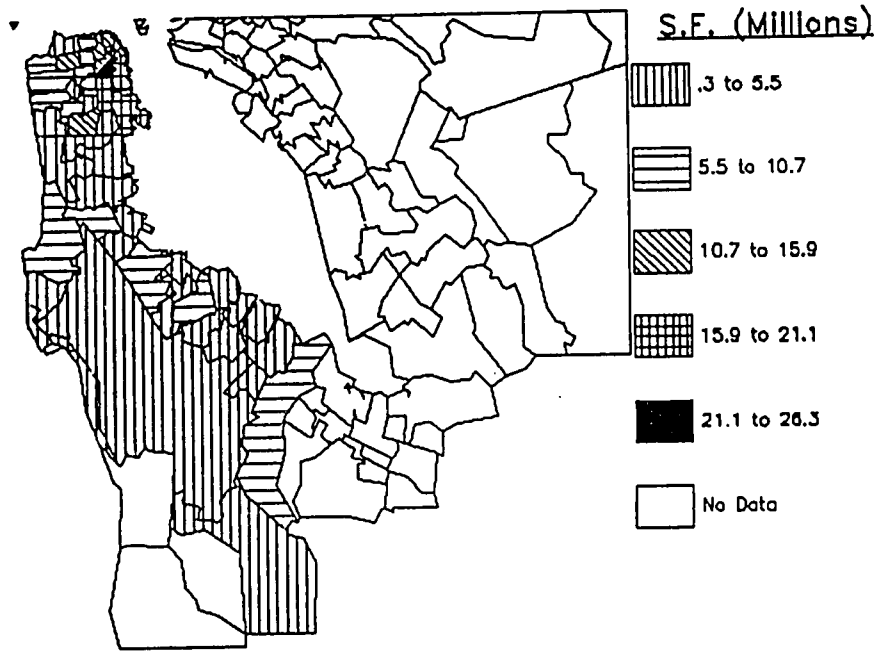


Figure 6: Typical Tilt-up Building Collapse Patterns in 1971 San Fernando Earthquake. (After Steinbrugge, 1982)

San Francisco and San Mateo Counties

Building Inventory -- R.C./Steel/R.M.



Building Inventory -- Wood Frame

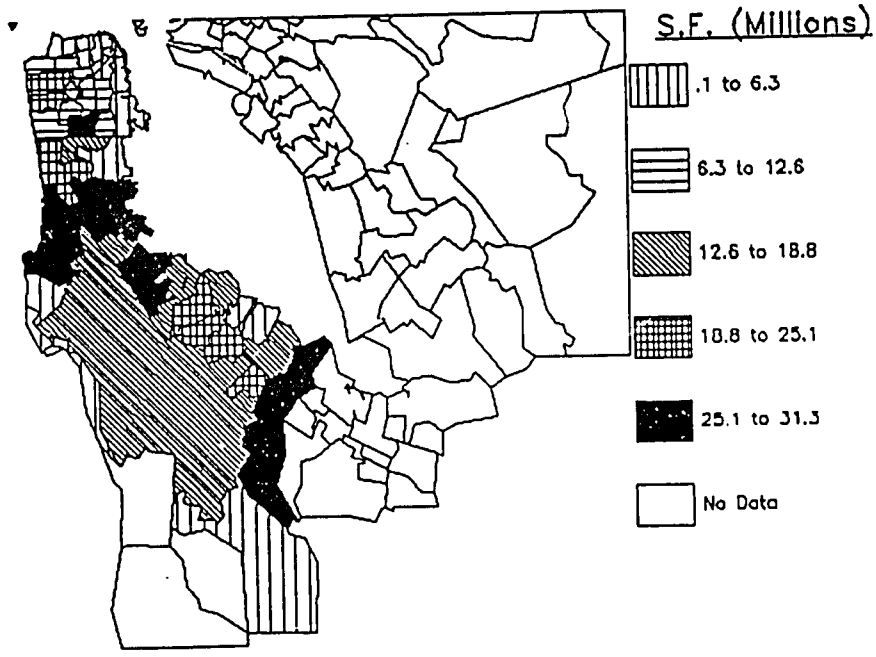


Figure 7: Preliminary Example, Building Inventory Results.

San Francisco and San Mateo Counties

Building Inventory -- URM - Commercial

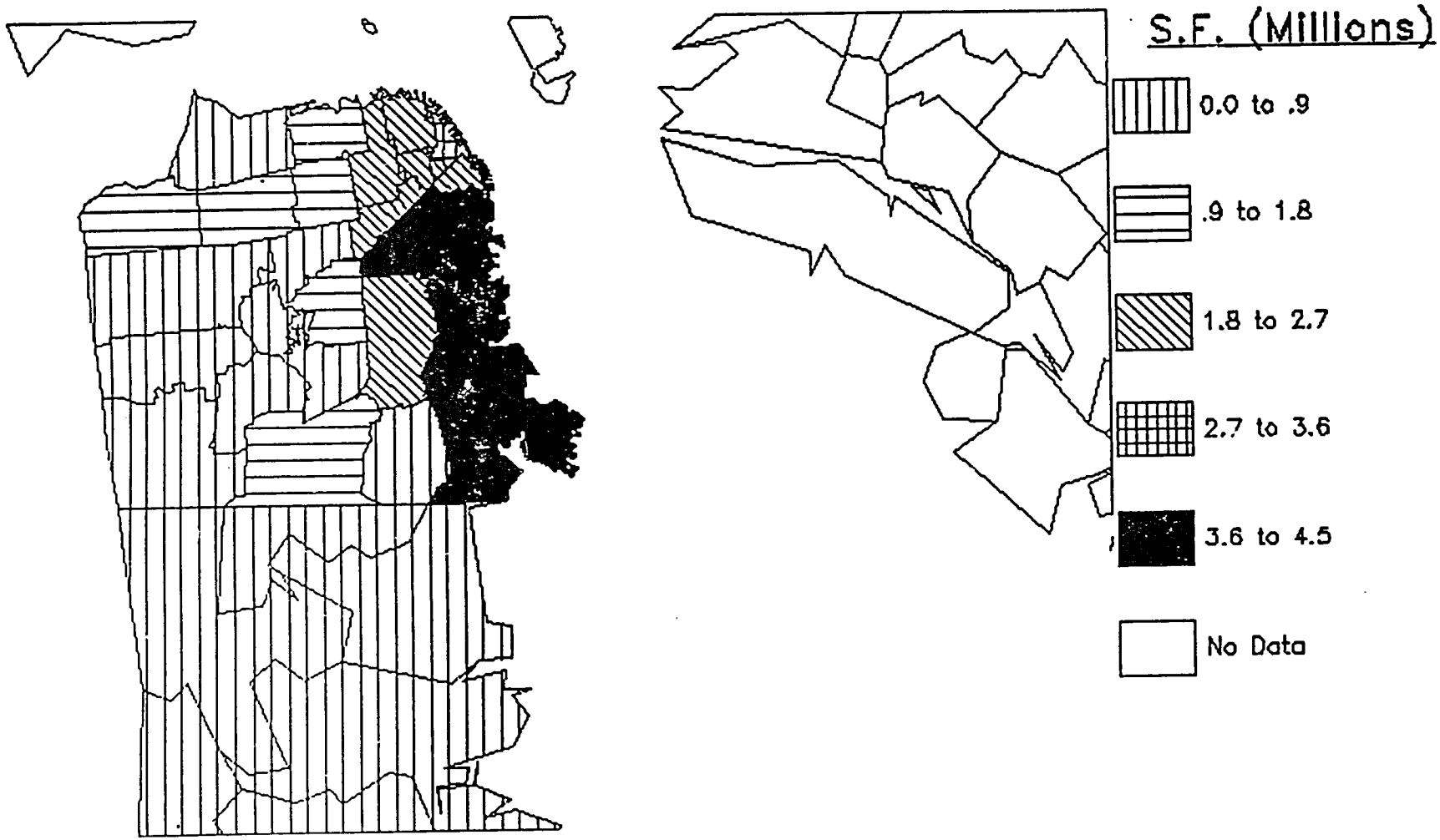


Figure 8: Preliminary Example, Building Inventory Results: URM, San Francisco Detail.

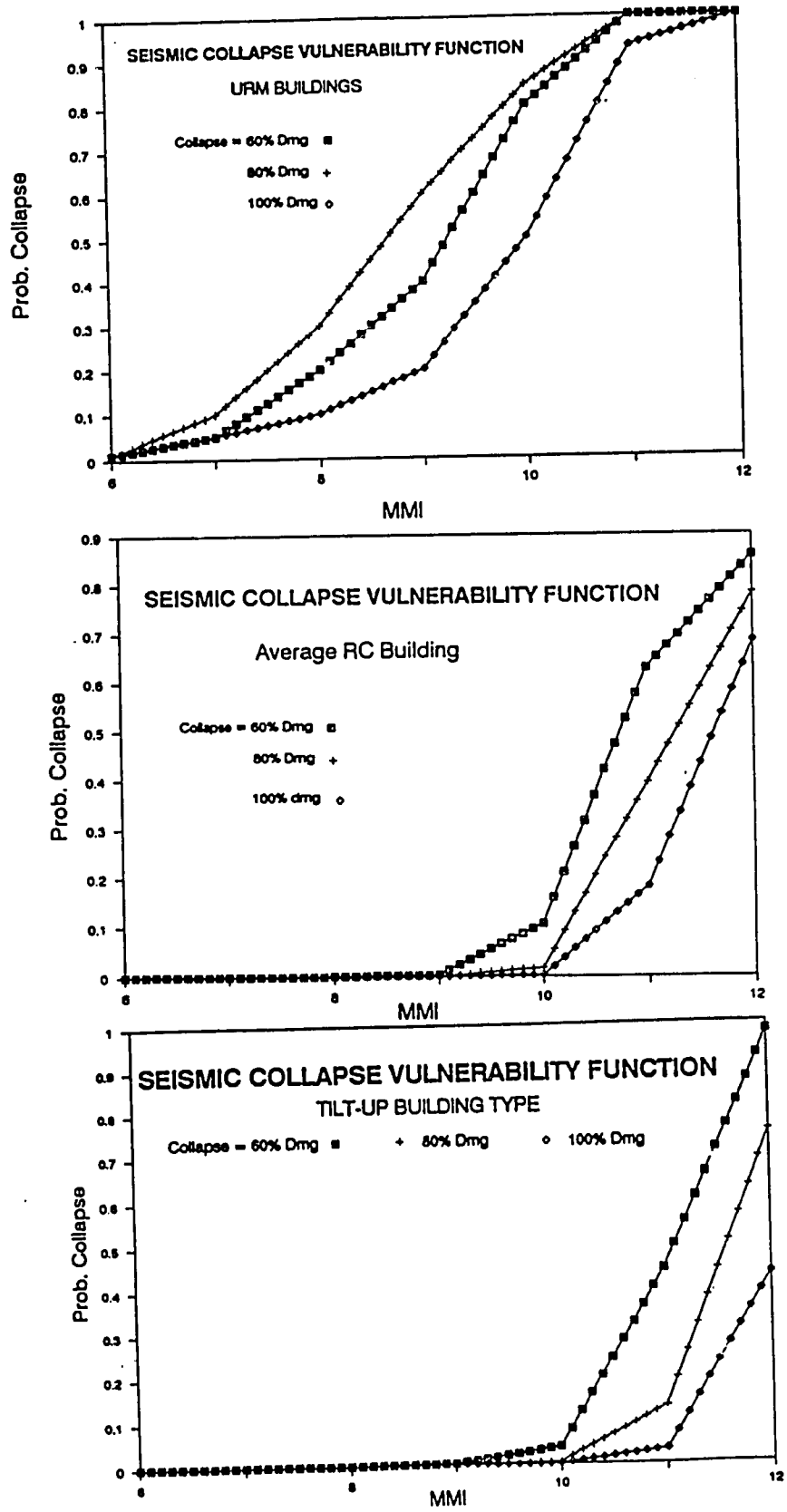
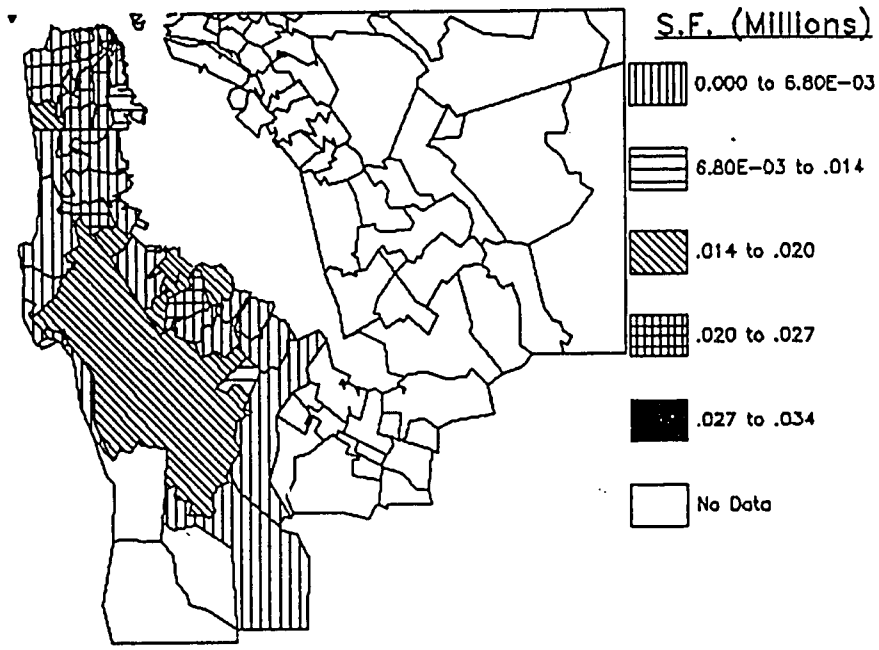


Figure 9: Example Seismic Collapse Vulnerability Functions.

San Francisco and San Mateo Counties

Building Collapses -- R.C./Steel/R.M.



Building Collapses -- Wood

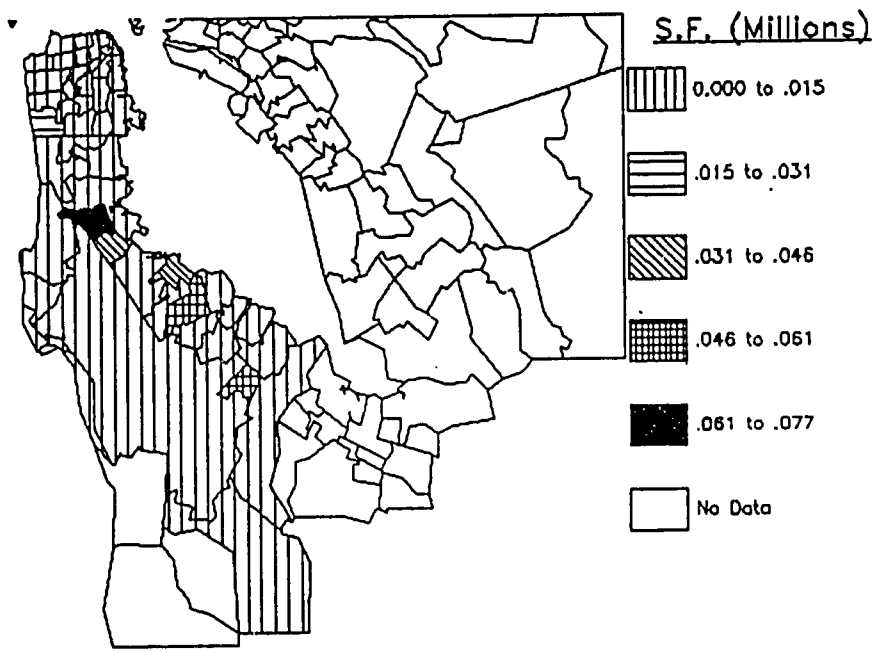
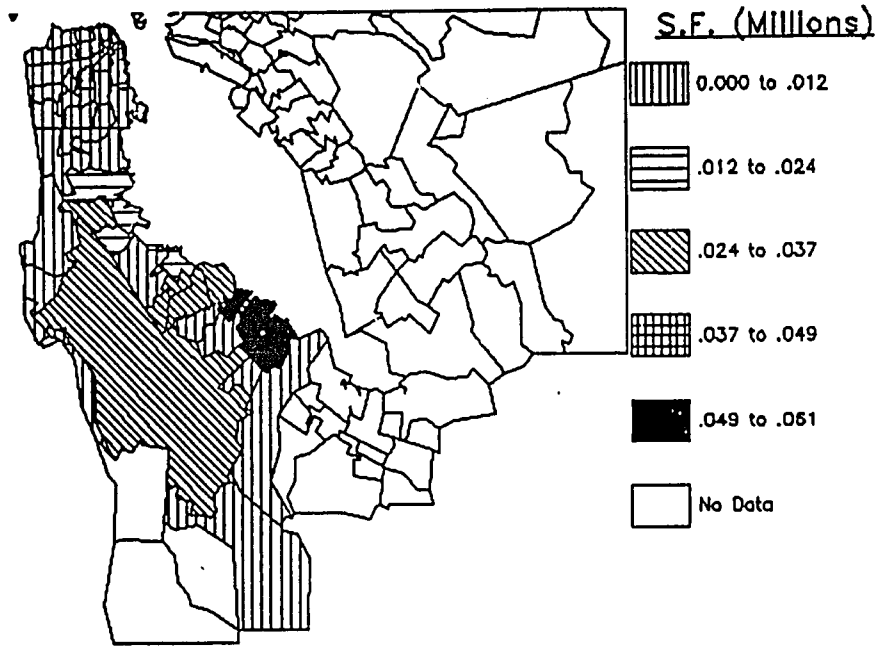


Figure 10: Preliminary Example, Collapse Estimation Results.

San Francisco and San Mateo Counties

Building Collapses -- Tilt-up



Building Collapses -- URM - Commercial

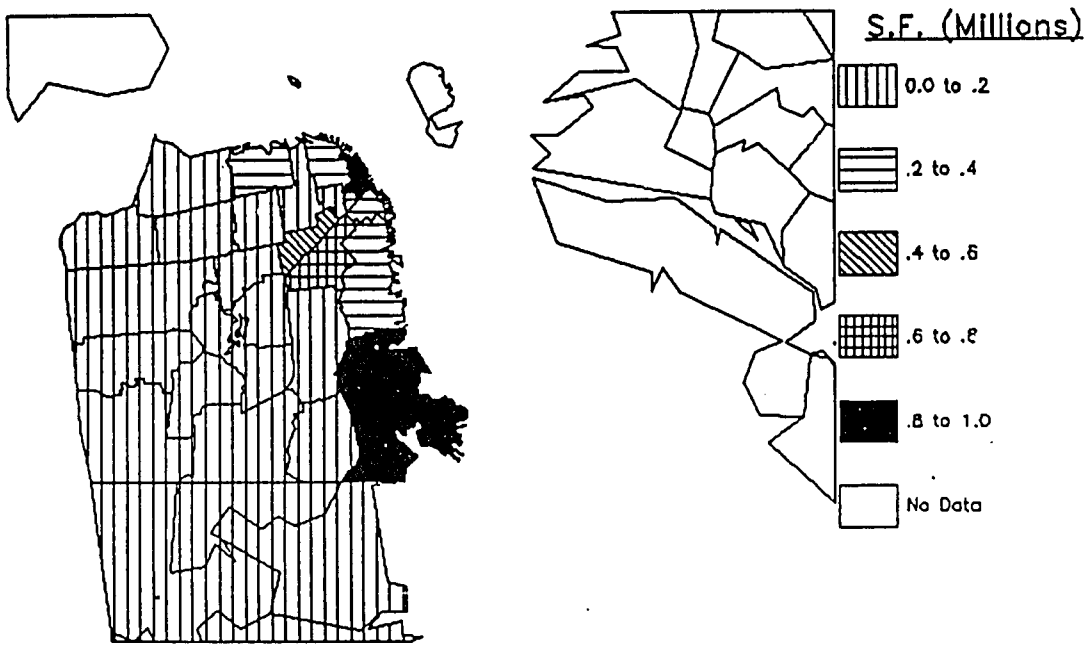


Figure 11: Preliminary Example, Collapse Estimation Results.

REDUCING EARTHQUAKE CASUALTIES: AN OVERVIEW

by

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The International Decade for Natural Disaster Reduction has brought sharper focus on the need for improved international cooperation among the many disciplines which will be involved in this venture. Several limited international networks exist, such as the International Association for Earthquake Engineering and its world conferences. Emphasis in this presentation is given to United States practices, and needs towards international cooperation.

Engineers and other design professionals have directed their efforts towards the construction of earthquake resistive buildings. Their ultimate goal is to essentially eliminate life loss and make a great earthquake no more "than an exciting event". Significant strides are continuing towards accomplishing this goal. Additionally, new earthquake resistive buildings in large cities often require the removal of older non-earthquake resistive structures, thereby also reducing life hazard. In recent years, efforts have been made to retrofit the more hazardous older buildings, but to a standard less than that for new buildings. Further, as we continue to learn from earthquake experience and from research, improvements will occur in our building codes. This will continue, and therefore in the future some of our present practices will be found to be deficient and some of the present "satisfactory" construction will be deemed hazardous.

It will take many, many years before we can reach the long term goal of earthquakes being nothing more than an exciting event. In United States, the realization is growing that many of our older buildings should be preserved for historic reasons or otherwise. "Gentrification" is occurring in older non-earthquake resistive structures, thereby greatly prolonging their useful life. It seems evident that United States will follow the practices in other countries, such as those in Europe, where the useful life of structures is greater than that of much of the United States.

As a result, our inventory of hazardous buildings will remain for a long time. We must pay greater attention to the human aspect of earthquakes.

Overview of the Current Status

By and large, vulnerability studies have emphasized building damage and impairments to community lifelines (public utilities). Quantified losses therefrom normally have been estimates of type of damage, of time to repair lifelines, on the number of homeless and loss of housing, and with estimates of the number of deaths and injuries.

Casualty figures stated in United States earthquake vulnerability studies are of low credibility for a variety of reasons, principally for the lack of American experience data and the failure to use medical diagnostic criteria and reliable, valid measures of the severity of injuries. Injuries are often described as "serious", but without definition as to the type and extent of medical needs. Hospital disaster response plans, however carefully done, can not be expected to fully meet the needs of earthquake victims unless and until those needs are clearly understood from both quantitative and qualitative perspectives. It is not appropriate public policy to give better attention to property damage and economic losses than to casualties.

This serious deficiency is now beginning to be addressed by the medical community. Post-disaster medical studies conduoted after the 1988 Armenia, USSR, earthquake are major beginning steps towards rationally quantified casualty estimates.

Expected damage to buildings, public utilities, and other construction types has reasonable credibility. Far less attention has been paid to the economic consequences of earthquake deaths and injuries; it is not evident that many private and public medical and health plans, including workers compensation, will be able to provide the post-earthquake financial support expected of these plans. In fairness, the data necessary for credible estimates are largely lacking.

Monetary resources for post-earthquake medical and health care needs, particularly long term resource needs, must be shared with other components of long term community recovery. Damage repair costs and costs due to the loss of function can be only crudely approximated since post-earthquake public policy is uncertain. Tax bases are reduced, thereby reducing a community's capability to reconstruct. This, in turn, throws a burden on higher governmental agencies which are often deficit ridden. Experience suggests that a great earthquake in a major population center will require years for full recovery.

Some Current Activities

The Workshop of Earthquake Injury Epidemiology is, in our view, a most important step towards joining the medical and health care workers with the mainstreams of scientists, engineers, design professionals, and the post-earthquake decision makers. Others at this Workshop will be in a position to discuss this background in detail.

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There are two other significant thrusts towards medical and health care improvements having somewhat different but fully compatible goals from those of this Workshop. A brief history may be of interest.

IASPEI Working Group:

To a large extent, the International Decade has its origin and driving force from scientific entities, although its progress must rely on many non-scientific disciplines. One such international entity, The International Association of Seismology and Physics of the Earth's Interior (IASPEI), is showing an increased interest in practical applications of their earthquake risk studies.

Well over a year ago, and before the Armenian earthquake, I was asked to head a small international working group by IASPEI to examine what could be done on an international interdisciplinary basis to reduce earthquake casualties. Walter Hays of the U.S.G.S. was asked to be the Secretariat. It was clearly evident to both of us that medical studies had significantly lagged the interdisciplinary work by physical scientists and others in earthquake risk evaluation and hazard reduction. Clearly evident was the great need for improvements in death and injury estimation methods and their applications in earthquake disaster response planning. This IASPEI Working Group has the mission of examining and reporting on the interdisciplinary approaches on correcting these imbalances. This Working Group will submit its report in August of this year at the IASPEI meeting in Istanbul. The activities of this week's International Workshop will certainly be on the Istanbul agenda.

(United States) Working Group on Earthquake Related Casualties:

Very shortly after the international IASPEI working group was formed, a (United States) ad hoc Working Group on Earthquake Related Casualties was also formed with Walter Hays as Secretariat and myself as chairman. The Working Group has the mission of examining and reporting on interdisciplinary approaches to correcting these imbalances.

The first task of the Working Group is to provide a brief overview of the interdisciplinary relationships needed for vulnerability studies, with particular emphasis on the greater involvement of the medical disciplines.

A second task is to seek methods to strengthen the involvement of medical personnel and other health researchers in obtaining and studying casualty data. The objective is to obtain results which are transferable to other countries. By "transferable" is meant that the information can be applied to needs such as those for vulnerability studies. United States historic data are inadequate, and transferable world-wide information is vital.

The third task is to make recommendations, if any, for national as well as international needs and cooperation.

Research needs within disciplines are not emphasized, rather, examples of interdisciplinary research requirements and potential studies are looked at.

Figure 1 is an oversimplified flow diagram of all-inclusive earthquake vulnerability studies. The first three boxes summarize the products from disciplines which prepare the more usual vulnerability study. The subjects in the fourth box have seen little attention, are uneven in their content, and often are developed outside of the context of vulnerability studies. The last box lists the kinds of end users. The impacts of vulnerability studies have often suffered when the end users have not participated from the beginning.

And Now?

In my view, the activities of the three different working groups are supplementary to each other. I encourage workshops such as these, and the research which I trust will be stimulated.

The (United States) ad hoc Working Group emphasizes interdisciplinary research and application, and the need for rapid implementation of research findings into improved disaster response planning.

The international IASPEI group gives access to the international scientific community.

Undoubtedly other national and international entities will become involved or become known. It is hoped that the International Decade can provide an umbrella for these activities.

It is my personal goal to encourage researchers, practitioners, and response planners to take increased interest in this vital problem -- and it is also my goal to encourage funding entities to significantly support an integrated multidisciplinary approach focusing on medical and health care earthquake problems.

FIGURE 1

PRE-EARTHQUAKE VULNERABILITY ESTIMATION

1. RISK EVALUATION -- GEOPHYSICAL DISCIPLINES

1. Earthquake probability vs. magnitude, focal depth, fault information, etc.
2. Local characteristics: surficial geology (potential for ground failure such as liquefaction, landslide, etc.), motion amplification as function of soils, duration of damaging shaking, spectra, etc.

↓

2. HAZARD EVALUATION -- ENGINEERING AND ARCHITECTURAL DISCIPLINES

NOTE: Estimates must consider life hazard separately from loss of function. Also building contents and equipment for vital occupancies.

1. Buildings/structures: Damage patterns by class of construction, dams.
2. Community lifelines: Damage patterns for utilities (water, electric power, telephones, sewage, etc.)
3. Critical facilities: hospitals, fire and police stations, etc.
4. Ensuing fire. Tsunami.
5. Homeless.

↓

3. HAZARD EVALUATION -- MEDICAL DISCIPLINES

NOTE: Inputs to medical include hazard evaluations by engineers and architects.

1. Death and injury estimates as functions of occupant loads in and about structures, and as a function of time of day.
2. Loss of medical response capabilities: personnel, hospitals, supplies, etc.
3. Effects of toxic materials (gas clouds, liquids spills).

↓

4. INTERRELATED CONSEQUENTIAL ECONOMIC IMPACTS

NOTE: Quantify dimensions of economic consequences -- examples listed.

1. Medical:
   - A. Resources required to rebuild/replace both public and private hospitals, health care facilities, etc.
   - B. Health/injury insurance response capabilities, including workers compensation.
2. Governmental:
   - A. Aggregate property loss estimates for governmental roles in disaster loans and grants.
   - B. Impacts on tax base (property damage, income loss, other).
3. Private: Ability of property insurance companies to pay their losses.

↓

5. RESPONSE PLANNING

1. Public response agencies: Federal, state, and local.
2. Private response agencies: Red Cross, Salvation Army, other.
3. All other: government, companies, private organizations, and individuals.

CASUALTIES AS A FUNCTION OF BUILDING QUALITY AND EARTHQUAKE INTENSITY

Herbert Tiedemann

SYNOPSIS

After discussing the general uncertainties which beset the assessment of the number of people likely to be killed or injured by an earthquake, the most important parameters which determine casualties as a function of earthquake intensity and building quality are presented. The important variables which control the behaviour of buildings and therefore the number and severity of casualties are resonance, quality of the foundation material, shear strength of the building, compatibility of behaviour of building materials, regularity and symmetry, type and behaviour of non-structural elements, hammering between buildings, orientational sensitivity, and liquefaction. The correlation between mean damage ratio, intensity and shear strength and a damage probability matrix is shown in order to facilitate estimates of percentage of buildings likely to collapse or to be damaged in such a manner as to cause casualties. Graphs correlating the death rate observed so far with building quality and intensity are shown. Casualty rates are also influenced by the hour of the day and the season when the earthquake occurs, by local habits, warning foreshocks and problems related to rescue work and medical aid.

INTRODUCTION

Earthquakes have repeatedly killed a large number of people and injured many more. Casualties can not only be caused by the collapse of buildings and failure of parts thereof but by tsunami, fires following earthquakes or explosions, release of toxic substances, landslides, the failure of a dam, or traffic accidents. The probability and extent of contribution of each such source to casualties depends on many parameters, and it is therefore impossible to discuss the entire spectrum of elements at risk and parameters contributing to casualties in a paper of normal length. We will therefore concentrate on the casualties resulting from the complete or partial failure of buildings and investigate the respective variables.

The importance of buildings in earthquake disasters is illustrated by the fact that earthquake building codes are (unfortunately) so far developed for this group of elements at risk only. If we group buildings according to their use, we find that about 30% of all earthquake damage, i.e. direct and indirect property and financial damage, loss of life and injury, is due to residential buildings, whether we look at low income or high income societies. Earthquake damage to residential buildings is about twice as important as the next important item in non-technological societies. In the latter, commercial and factory buildings combined produce damage which is in general about one third above that of residential buildings in the former region. If one adds earthquake damage to all types of buildings, i.e. residential, commercial, administrative and factories in non-technological societies, it is found that this group accounts for somewhat more than 50% of the grand total of earthquake loss and damage. This shows how important this element is. What is particularly important is that loss of life and injury are mostly caused by failures of buildings and their components.

Before discussing the various parameters which control casualties caused by failure of buildings it is, however, important to spent some time on basic problems afflicting casualty statistics. Moreover, when analysing casualties caused by the behaviour of buildings one cannot avoid discussing parameters which

are not directly related to the correlation between building quality, earthquake intensity and casualties but which either influence the data base or indirectly the casualties in buildings.

GENERAL UNCERTAINTIES RELATED TO CASUALTIES

Earthquake literature is extremely short of data on loss of life depending on intensity and general building quality. We have for this reason analysed a large number of earthquakes ourselves in order to improve the data-base. Still considerable uncertainties remain and we shall discuss the most important ones in this chapter. As the heading suggests we will not deal here with parameters controlling the failure of buildings and the uncertainties regarding casualties resulting herefrom. The references in this paper contain adequate information on such aspects.

NUMBER OF CASUALTIES

Everybody who has tried to obtain precise information on casualties will have experienced that this is in general very difficult and often impossible. Damaging earthquakes are exiting events and this may be one of the reasons that the number of casualties is often exaggerated, in particular in articles printed by the popular press. But even "official" figures may be wrong, and for a number of reasons. The author has therefore tried to introduce as many cross-ckecks as possible: consulting different sources and persons known to be reliable and not given to exaggerations, correlating these figures with the number of collapsed and partly collapsed buildings and allowing for the average number of persons per building and room.

If casualties have been caused by different "agents" like failure of buildings, fire, tsunami, cold weather, and in connection with historic earthquakes disease, epidemics, and starvation the result becomes even more uncertain, in particular if a strong tsunami occurred because many of the corpses may have disappeared.

How difficult it is to obtain precise data of casualties caused by earthquakes which happened not too many decades ago, can be illustrated with the help of the M 7½ earthquake which devastated Messina and Calabria at about half past four o'clock in the morning of December 28, 1908.

A large encyclopedia claims that 84,000 of the 120,000 inhabitants of Messina were killed. A different source states that in all, i.e. on both sides of the Straits of Messina, 58,000 people were killed, and another one gives the number of victims as 75,000. Continuing the search in the literature one finds 83,000 killed in Messina out of a population of 138,000 and 20,000 out of 40,000 in Reggio. One realizes that precise and consistent figures cannot be obtained whether for the total loss of life, or per town and the casualties caused by collapsing buildings, or by the 3 m tsunami in Messina which allegedly reached 10.6 m on the Calabrian coast and at least 7 m at quite a number of places, or by exposure or disease. This situation still prevails in many regions of the world rendering risk assessment very difficult and uncertain.

Moreover, one must differentiate between people killed and people injured. Whereas the first is a "binary issue" viz. dead or alive, injuries can range from a simple scratch to very severe trauma, like loss of a limb or paraplegia. As it is already very difficult to obtain accurate figures on loss of life, one can imagine how uncertain figures are on people injured. Let us discuss some factors which contribute to the uncertainties in assessing cases of injury.

Even if those serious injured have been seen by doctors it is not certain that the data will be fed to a central register. The worse the catastrophe and the demand on medical facilities the less likely is reliable reporting.

An ideal data bank would permit obtaining information in the form of an injury probability distribution or matrix. This would require detailed reporting. Anyone who knows that doctors sometimes have difficulties in attending to their routine reports can imagine what happens during and after a severe

earthquake, when they may have to attend to thousands and even hundred thousands (Tangshan) within a short time.

Another problem is that there is no standard concept where injury starts and how degrees of injury are to be classified. As in the assessment of intensities, an issue which will be discussed later, one will have to be prepared for personal and national bias. When the author, for instance, questioned the rather low ratio of people injured to those killed by the Tangshan earthquake he was told by Chinese experts that only cases of severe injury were included in the corresponding figure. Someone familiar with the attitude of the Chinese towards a trauma will correctly guess that something considered a serious wound in many parts of the world would be put aside in China as a mere scratch.

Even when applying all care one should be prepared for a residual error margin. As regards persons killed it can be as small as ten to twenty percent, but it may occasionally amount to a factor of two or three. Information on the numbers of injureds is much more uncertain

CASUALTIES AS A PERCENTAGE OF THE POPULATION

The total number of casualties, even if it were precisely known will only yield useful information in connection with a few questions, but nothing to assist in well aimed risk optimization. Therefore the next problem arises when trying to establish the number of people living or present in the area experiencing certain earthquake intensities, assuming for the time being that the isoseismals are not debated.

The number of people per city, town or village are known in only few countries. Even there modern mobility and, in particular, large numbers of commuters can introduce a sizeable error margin.

PROBLEMS FROM INTENSITY ASSIGNMENTS

Because of the very limited sample from one country or region ione is compelled to use the data from as many earthquakes, i.e. countries as possible. This introduces particular problems as regards intensity estimated per location. Intensity estimates are at any rate uncertain because of the personal bias of those investigating the damage. Another problem is introduced by national bias (1), and to make matters worse there are different intensity scales some of which are not only very imprecise and/or difficult to apply to strong modern buildings (2) but introduce errors when translating an intensity from one scale into another one.

If there are large towns or densely populated rural areas which must be considered isoseismal borderline cases, such data can only be used if one has a large data-bank which permits intelligent interpolation.

POPULATION PER CATEGORY OF BUILDING

To produce standardized data on casualties which consider the quality (vulnerability) of buildings one must also know the number of people which were exposed within buildings satisfying certain quality criteria and "within their range".

This is a very difficult task which we handle by inspecing all buildings exposed to an earthquake and recording all relevant details of the buildings proper and of damage to all essential building components.

PARAMETERS CONTROLLING THE DEATH RATE

In view of the different difficulties in establishing data on people killed and those injured and because of the need to have separate data we shall discuss parameters related to people killed and people injured

separately and start with the death rate, i. e. the percentage of the population which may be killed by an earthquake.

In the most general form one may write

$$DR = f(I, Q, T, S, W, H, M, ...)$$

in which DR is the death rate, i.e. the percentage of the sub-population killed. The DR is a function (f) of the earthquake intensity (I), the hour of the day (time) when the earthquake occurs (T), the season of the year (S), the influence of any warning of the people (W), local habits (H), quality and number of rescue and medical facilities treating those affected by the catastrophe (M), and other less important variables. It is noted in passing that this algorithm (one may also consider it a primitive checklist) can be expanded quite conveniently to include other perils which are not the subject of this paper, like tsunami, fire, explosion, landslide, etc., and even sub-parameters controlling the respective perils. The following discussion will concentrate on the most critical variables.

INTENSITY

Intensity scales are at present the only yardstick to indicate the severity of shaking, albeit a crude one. In addition one may say that their general usefulness breaks down above MM IX (1). Moreover, the limited data on failures of buildings constructed according to the most resistant modern codes (e.g. Japan or New Zealand) means that assessments of casualties in such towns are bound to be uncertain.

We are therefore working on the development of what one may call "isonoxiae", lines of identical damage to specified buildings of selected quality, i.e. strength or vulnerability.

QUALITY OF BUILDINGS

The quality, that is the resistance or strength of a building determines its vulnerability. We have so far analysed the behaviour of about 200,000 buildings exposed to nearly 30 earthquakes in many regions of the world in order to determine and to quantify the important parameters of damage sustained by different components of buildings and by the buildings proper. A detailed account of the parameters contributing to earthquake damage of buildings and therefore implicitly to loss of life and injuries has been provided elsewhere (1, 3 - 22). In short the most important factors are:

- Resonance between predominant frequencies of the foundation material and of the building or structure.
- Quality, i.e. predominantly hardness of the foundation material.
- Shear strength of the building resulting from the combined strength of structural and non-structural parts.
- Compatibility of behaviour of building materials and components under dynamic loads.
- Ease of repair.
- Regularity and symmetry as regards floor plans, elevations, shear strength, distribution of masses and damping.
- Design, quality, arrangement, and fastening of non-structural elements.
- Hammering between buildings
- Orientational sensitivity.
- Liquefaction

Except for ease of repair all other parameters do not only determine the degree and type of damage sustained by the buildings but the risk to human life as well. As the influence of some variables is very critical a detailed assessment is warranted if exposure is considerable (23). Such an analysis cannot be discussed in the space available and we will therefore have to limit ourselves to presenting a general methodology and relevant data, in particular as this is also the basis for a more detailed approach.

The starting point for casualty assessments is the behaviour or buildings during earthquake shaking of a certain intensity. As many parameters determine this behaviour we have standardized our data using the most common condition, viz. moderately irregular and asymmetrical buildings which are founded on alluvium of medium hardness (cf. e.g. 12). In more refined assessments one can correct these data to alow for the beneficial or detrimental influence of specific parameters as illustrated in ref. 21. It is stressed that such corrections are very important if buildings or foundation material differ much from the conditions specified above.

The mean damage rate (MDR) to be expected for such buildings is shown in Fig. 1. It demonstrates that building quality is an immensely important variable.

As the DR depends much on partial or total collapse of buildings it is interesting to know how large the percentage of such buildings is. Let us look, for instance, on the behaviour of 390 modern buildings of a sample analysed by us after the El Asnam earthquake of 1980 (Fig. 2) (cf. also 3).

It is seen that the percentage of buildings which sustained damage of more than 90% of their new replacement value, which is the category which contains most cases of partial or total collapse, depends strongly on the quality of the buildings. This figure, however, also teaches that the uncertainties are very large if the sample does not comprise literally many hundreds of such buildings.

The accuracy of the assessment can be improved further if damage probability distributions (cf., e.g. 5) or damage probability matrices are available. The following Table 1 shows such a damage probability matrix (DPM) for the behaviour of moderately irregular and asymmetrical buildings on medium-hard alluvium, i.e. those represented by Fig. 1. This matrix can also be of use when estimating the equipment needed for rescue operations.

TABLE 1
DAMAGE PROBABILITY MATRIX FOR BUILDINGS

DAMAGE CLASS	MEAN DAMAGE RATIO (%)									
% of value	1.5	3	5	10	25	37.5	50	60	70	85
0 - 1.5	83	73	60	36	9	2				
1.5 - 3	17	25	26	23	9	3				
3 - 6		2	10	18	11	5	2			
6 - 12.5			3	12	18	12	6	2	1	
12.5- 25			1	8	24	24	15	7	3	
25 - 50				3	19	28	29	23	18	10
50 - 100				1	10	29	48	68	78	90

The percentage of buildings in the upper damage class (50 - 100% damage) cannot be used without correction for casualty assessments. Let us illustrate this with a simple example which employs the information provided so far.

According to Fig. 1 unreinforced brick buildings will suffer a MDR between 50 and 60% if exposed to MM VIII and 2-3% g buildings with a frame of reinforced concrete can be expected to have a MDR of 50% if the intensity reaches MM IX. Table 1 tells us that about 50% of all buildings with the latter MDR will be found in the 50-100% damage class. Among the buildings suffering 50-100% damage there will, however, be some having only non-structural damage (cf., e.g. 15) and many sustaining heavy non-structural and some structural damage but not behaving in such a way as to kill many of the tenants. Using Fig. 2. we may estimate that of the 2-3% g reinforced concrete buildings only about 10% will probably collapse but about 40 to 50% of the unreinforced brick buildings.

Even if buildings collapse in a spectacular manner only a percentage of the people in them will be killed

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(cf. e.g. Figs. 21 & 22 in ref. 15). In this case a department store collapsed completely and killed 70% of the human beings in it. This is, however, not the rule because mostly only one or few storeys will fail, in general only the ground floor. The behaviour seen in buildings in Mexico City after the 1985 earthquake (13,16) where several upper storeys collapsed is not typical and due to the special conditions.

Assuming that most of the buildings in a town under study have a reinforced concrete frame of 2-3%g shear strength, that the average number of floors is five and that people in them are uniformly distributed, we could guess that if in ten percent of the buildings the ground floor collapses, only 20% of the people will be exposed to grave danger and that only a percentage, say 30% of them will be killed. Such an approach is a very crude one indeed and open to considerable errors and omissions.

People are not uniformly distributed among all buildings and per building. During shopping hours, for instance, many will be in buildings which have a soft ground floor and other features increasing their failure probability. In some buildings not only the ground floor will collapse. Moreover, people are killed by partial structural failure, by non-structural failure and by falling objects. The above estimate would neglect all such aggravating factors and therefore only produce a lower limit in most cases. We have therefore evaluated our global statistics in order to enhance the accuracy of casualty estimates, and the result is shown in Fig. 3. It must be stressed that the graphs should be used with great care because of the general uncertainties afflicting such data as discussed earlier and because of the many variables which must be considered when allowing for specific conditions. The spectacular failures of pre-fabricated (tilt-up) buildings in several countries, or of buildings constructed according to certain unsuitable methods underscores this need. Many of these buildings failed in a dramatic manner which had not been anticipated by those designing and building them. The references mentioned show how corrections can be applied if buildings are not of moderate irregularity and stand on harder or softer strata than medium-hard alluvium. After discussing parameters controlling injuries we will therefore look at the other variables mentioned earlier.

PARAMETERS CONTROLLING INJURIES

The assessment of the number of injuries presents some additional problems. The percentage of people which suffer injuries of a different degree does not only depend on structural characteristics of buildings but on the behaviour of non-structural items.

Starting with building quality it can be stated that the correlation between vulnerability of buildings and the total number of injuries as well as the ratio of the people killed to the people injured is a very complicated matter. Whereas the DR increases very much as vulnerability grows, the injury rate (IR) decreases.

Buildings which incorporate a high or even very high collapse probability, like those of adobe, torquezal, rubble masonry and buildings having a soft rc-frame with little strenght, a soft ground floor and other grave irregularities will kill many people as they fail. Therefore not many are left to be injured. An extreme example are the adobe buildings in eastern Turkey and in Iran which do not only have collapse-prone walls but very heavy roofs. When collapsing they tend to kill most of the people in them. This general characteristics is seen most clearly when correlating the percentages of people killed to those injured with intensities and building strength.

In this respect our studies provided a picture which is similar to the behaviour of structural and non structural damage. As the quality of buildings goes up the importance of structural failure dwindles whereas the contribution of non-structural damage grows (5). Similarly, as buildings get better, less and less fatalities are observed and most casualties are injuries.

Whereas the "normal ratio" of people killed to people injured is about one in three to one in six, it can be very much higher if building standards are high. A case in point is the Mijagi-Ken-Oki, Japan, earthquake of 1978, which affected a densely populated area. In this case the ratio was 1 : 39. This

exceptional rate is, however, not only the consequence of high building standards but also due to the surprisingly low number of people killed, in spite of some spectacular building failures.

We have so far not been able to produce reliable standardized graphs for injuries, and the reasons herefore are not only statistical uncertainties but the many details and variables controlling the number of injuries to be expected. If, for instance, very resistant buildings incorporate failure-prone non-structural parts, like facadings, suspended ceilings, and collapse-prone partition walls, the number of injuries in and around such buildings will be much higher than in buildings of similar or even lower strength which are not "adorned" by facading likely to be shed during strong shaking, by falling suspended ceilings and other items.

The Alpstadt earthquake of 1978 in Wuerttemberg, FRG, showed which minor details may matter. The earthquake dislodged innumerable roof tiles on the steep roofs of the houses. These heavy tiles would have injured and even killed many people, had the earthquake not happened at 6 o'clock on a Sunday morning. Less inclined roofs would affect injury rates quite considerably.

To underscore uncertainties, Table 2 is presented.

Table 2
Casualty rates of the Guatemala earthquake of 1976
(In permille of the respective population)

PLACE	EPIC. DISTANCE (km)	KILLED	INJURED
Guatemala City	150	2.2	11
El Progreso	90	26	100
Sancatepéquez	180	15.5	85
Chimaltenango	170	67	160
Sololá	200	0.8	2.3
Quiché	30	6.3	18
TOTAL		5.3	18

In this case particulary the number of people injured is uncertain. Moreover, except for Guatemala City there is little scatter in building quality but still casualty figures are far from uniform.

TIME, DAY OF THE WEEK, SEASON, AND LOCAL HABITS

In order to avoid repetitions we shall discuss these variables under one heading.

The number of casualties depends much on the time of the day when the earthquake occurs. Some examples will illustrate this.

The earthquake which devastated Agadir in 1960 occurred in the middle of the night when most people were in bed. Because of the many collapsing buildings a very high percentage of the population was killed or injured.

The Tangshan earthquake (1976) occurred at 3:43 and anyone familiar with the Chinese style of life would correctly guess that except for people who worked in factories and mines operating in three shifts, most of the others were in bed although it was summer.

The Friuli earthquake, Italy, (1976) occurred about at nine o'clock in the evening, when most factories had closed. As many of the pre-fabricated factory buildings suffered partial or total collapse, the casualties would have been much higher, had the earthquake happened during working hours. On the other hand, human loss in the old rubble masonry buildings of Gemona and other places would have been lower, had the earthquake occurred when most people were out.

We have already mentioned the absence of important casualties during the Alpstadt earthquake, FRG, which happened early in the morning on a Sunday. The same earthquake occurring on a workday and in particular during peak shopping or rush hours and, for instance, when everybody is shopping for Christmas, would have caused many casualties.

With respect to seasonal variability of casualties one mostly thinks of a rural society which works in the fields from spring to autumn and attends to chores at home during winter. This is, however, only one of the many alternatives.

Thessaloniki, Greece was rocked by an earthquake during summer 1978. Although the earthquake happened an hour before midnight it is not likely that all inhabitants of this town were already asleep.

Managua, Guatemala was destrojed in 1972 by an earthquake which occurred shortly after midnight. As late-into-the-night open-air life is common in warm Latin American countries, and probably even more so on a Saturday just before Christmas, we may assume that this variable reduced casualty rates.

The Montenegro earthquake of 1979 is well suited not only to warn against assuming too optimistic casualty rates but to illustrate seasonal influence. It occurred on a Sunday morning when most people were up and at a time of the year when most tourist hotels were still empty, a category of buildings which suffered spectacular cases of collapse. As it was a holiday most places which can contribute dramatically to casualties, like department stores, large offices, etc., were empty.

In regions with harsh weather during winter the death toll can be increased by exposure. In this respect one must think of the combination of exposute and delayed rescue.

WARNING

Much has been said or written about earthquake prediction in China, which should more correctly be called earthquake warning. From this country several cases are known where timely warning has reduced casualties dramatically, but others have occurred were the people could not be warned in time. The latter will not concern us here but we will show with the help of some examples that proper reaction of a population to foreshocks has reduced the casualties.

In Managua, Nicaragua, an unknown percentage of the people slept and stayed outdoors because of the alarm caused by foreshocks which occurred about two and a half hour before the main event.

Also the popolation of Thessaloniki, Greece had been warned by foreshocks in the afternoon and earlier seismic activity in May, because of which people had even left the town.

The Montenegro earthquake came in two shocks with enough time between them for people to leave the houses.

MEDICAL AND RESCUE FACILITIES

Very unfortunately it must be said that hospitals are in general not built according to special standards making their survival very likely and keeping them in operation. This could be seen, for instance, after the Mexican earthquake of 1985 and the M 5.4 earthquake which killed and injured many in San Salvador in 1986 (15).

If it is argued in technologically advanced societies that the death toll from traffic accidents would be reduced much if medical help were available very soon after the accident, it is evident that this variable is an important one after a catastrophic earthquake, bound to strain the facilities of any society and in particular of the poorer countries. This brings us to rescue of casualties from damaged or collapsed buildings.

The type of the building affects rescue and therefore casualties. Whereas the debris of buildings of adobe, rubble masonry and brick can be removed with primitive tools, reinforced concrete poses grave problems in particular if not enough special and heavy equipment is available. The Armenian earthquake of 1988 showed this again but it should be noted that facilities in nearly any country will be overtaxed. In this connection one must remember that those seriously injured or exposed require help within a very short time. This requires detailed catastrophe programmes and constant drills.

CONCLUSIONS

The most important conclusion is that casualties depend most prominently on building quality. Therefore the predominant task is to raise building standards in general and specific requirements if the architectural design introduces "penalties" like soft ground floors, pronounced asymmetry, etc..

In most countries very much could be gained if pragmatic earthquake engineering would be made a compulsory subject at the university level and in addition introduced in the training of craftsmen. A first step to achieve this would be the creation of more risk awareness (23).

In many countries of the world there are many buildings which were constructed before earthquake building codes were introduced. In some countries such buildings are likely to contribute most of the casualties. In such cases a detailed stock-taking is advisible which should include modern buildings which constitute important elements at risk because they are either large, of asymmetrical design, or constructed on soft subsoil. Such buildings should be suitably reinforced.

Last but not least a detailed catastrophe plan must be developed and introduced. Those responsible for its execution must be trained well enough and regularly to ensure that nothing important goes wrong even under the enormous stress introduced by a catastrophe.

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Fig. 1. The graphs show the mean damage ratio (MDR) in percent of the new replacement value depending on the earthquake intensity (MMI) and the building quality. The intensity is given according to the Modified Mercalli scale (MM 31). The quality of buildings having a structure of reinforced concrete is stated as base shear. Such buildings are: C = 2 - 3% g, D = 3 - 4% g, E = 6% g, F = 12% g, and G = 20% g. Graph A represents buildings of adobe and frail rubble masonry, graph B is for unreinforced brick buildings. The graphs are valid for medium-hard alluvium, i.e. a bonus must be allowed for harder subsoil and a malus must be applied for softer one (cf. Fig. 4). Liquefaction requires special consideration as discussed in the main text. Moreover, the graphs are valid for buildings which are only moderately asymmetrical. If different buildings are to be evaluated, Fig. 5 and reference (12) give approximate information, details are to be found in (1). The graphs or those shown in Fig. 7 can also be used, for instance, for improving designs which are exposed to orientational sensitivity and for assessing damage/vulnerability relations of other structures and items. If, for instance, the MDR of an element at risk can be estimated with reasonable precision, e.g. 50%, 10%, or 1% at MM VIII, one may use one of the curves shown in this graph or a new one fitting their general characteristics. This approach is possible because we have learned from the analysis of very large numbers of different elements at risk that the damage or loss distribution is very strongly determined by the MDR, i.e. irrespective of the kind of the element at risk and the hazard causing loss or damage, one will find that the distributions are comparable if MDR's are similar.

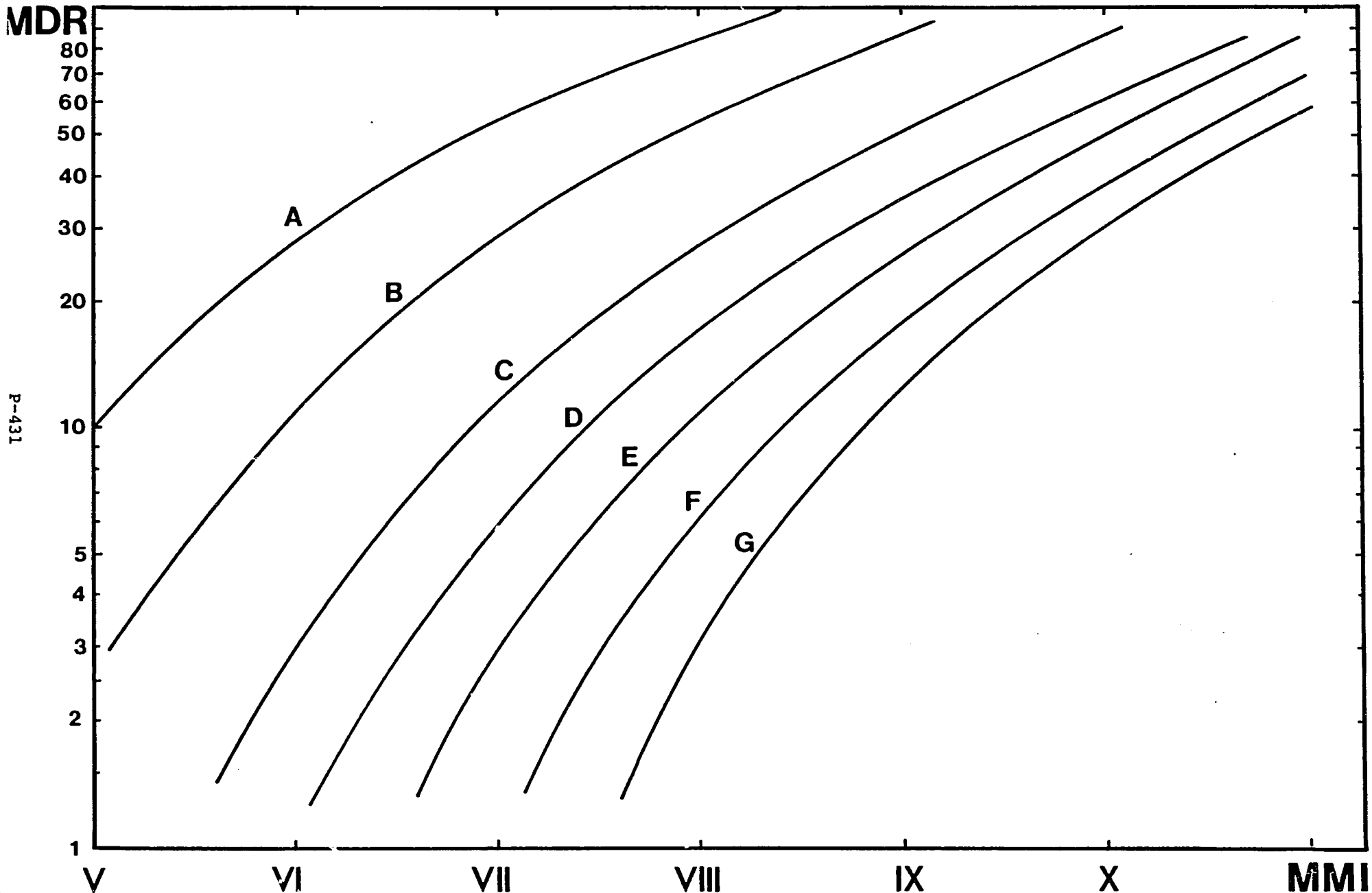

Fig. 1

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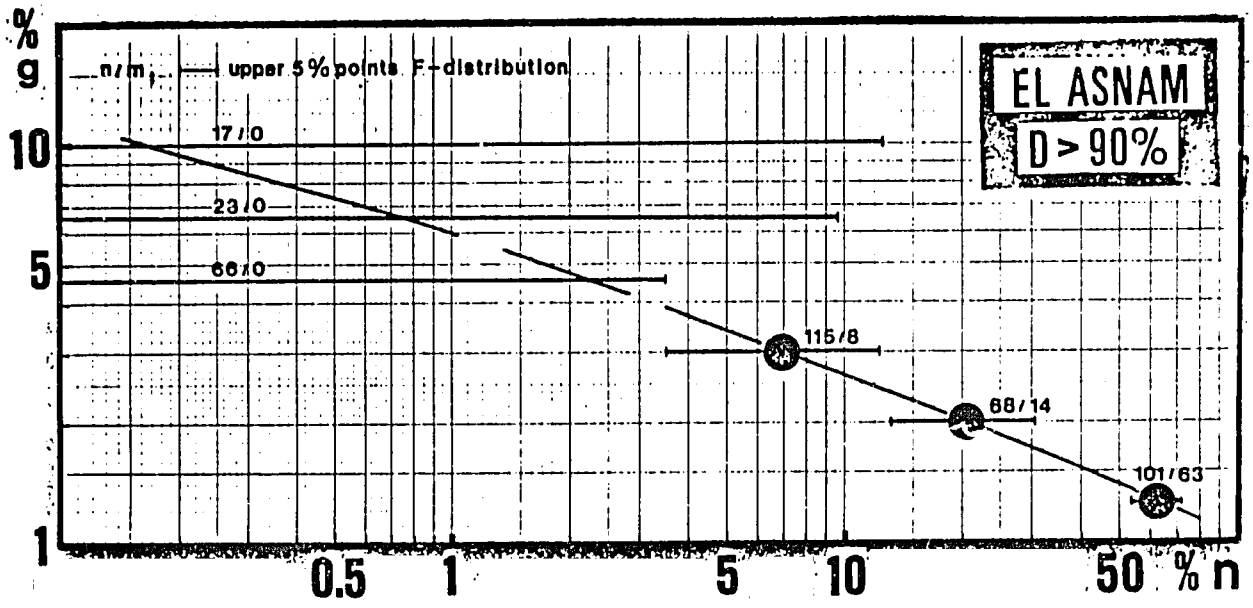
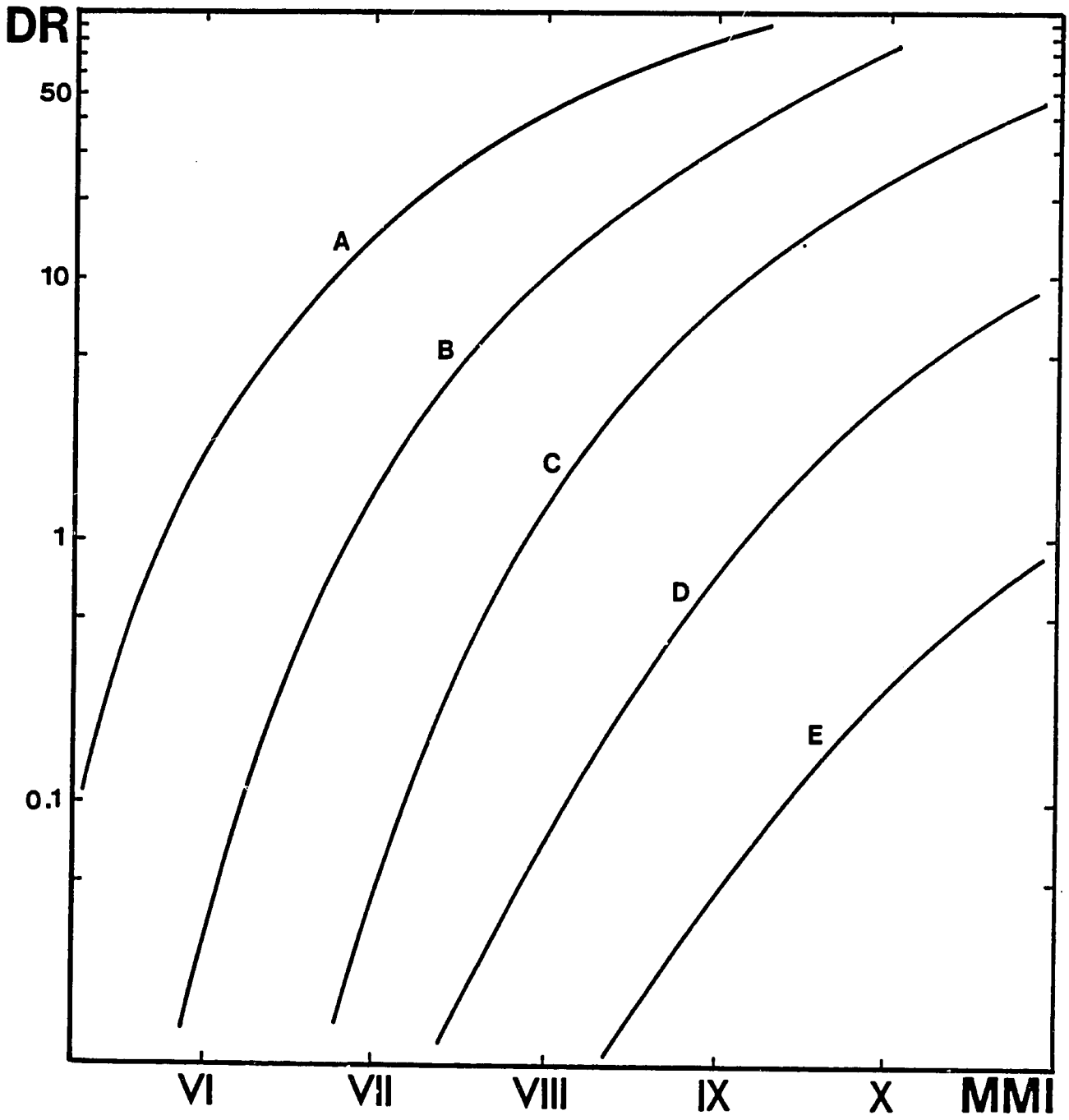


Fig. 2. The above graph is based on a sample of 390 modern buildings which were shaken by the El Asnam, Algeria, earthquake of 1980. The curve shows the correlation between the base shear of the buildings in % of g and the percentage of the respective sub-samples which sustained damage above 90% of their new replacement value. For each sub-sample the size of the sample is given first, followed by the number of buildings with D > 90%. The bars show the 95% confidence range employing the Fisher distribution which appears to produce more realistic results than the binominal distribution if the sample is small. It is seen that there was no case of collapse among the 106 buildings of 4.5% g or better. It must be stressed, however, that these buildings in El Asnam were for all practical purposes regular and stiff, a feature which improves their behaviour considerably (cf. e.g. 16).

Fig. 3. Approximate correlation between quality or vulnerability of buildings (graphs A - E) and death-rate (DR) in percent of the population, depending on the intensity (MMI) of earthquake shaking. The graphs represent: A = buildings of adobe and vulnerable rubble masonry, B = unreinforced brick buildings, C = 2.5% g buildings with a structure of reinforced concrete, D = such buildings of 6% g, and E = such buildings of 20% g. The death rate among people would be, for instance, in brick buildings hit by MM VIII about 10% but only 0.07% if buildings were of 6% g. These graphs hold for average medium hard alluvium and moderately irregular buildings. As explained in the text these graphs should be used with utmost care not only because of the uncertainty introduced by the samples and sub-samples which are not very large, but because of the many parameters controlling the behaviour of buildings and therefore the number of victims. It should be noted that the catastrophic failure of few buildings with many people in them when they collapse, can for instance, affect the DR much. Moreover, the DR is much influenced by the hour of the day, the day of the week, and the season when the earthquake strikes

Fig. 3



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PRESENTATIONS 6

DETECTION AND EXTRICATION IN THE ARMENIAN EARTHQUAKE

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INTRODUCTION

This report summarizes some of the experiences and information gained by a multi-disciplinary research team that studied the resuscitation potential for victims of the Armenia earthquake of December 7, 1988.

The major research goal of the research team was to assess the resuscitation potential for critically injured victims within minutes to hours after the Armenian earthquake event. To accomplish this goal the team was composed of four physician specialists concentrating on medical aspects of life saving resuscitation, a political scientist examining the organizational and communications aspects of the response effort, and an engineer, the author, who studied the detection and extrication components of the response.

Fundamental to this study was the premise that significant numbers of persons could be saved by an ultra-rapid and effective response following the incident that provides immediate detection-extrication-resuscitation actions for the critically injured slowly dying victims. Thus, the study team concentrated a large portion of its efforts on the early period of time (0-24 hours) after the earthquake. In addition data were obtained for the entire response period, 0-15 days, and for the recovery period.

STUDY PROTOCOL

Detection and extrication efforts provide the main focus for this report. Prior to arriving on the scene a protocol was developed by the team leaders. It included a questionnaire (Figure 1) covering extrication designed by the team's engineer. The purpose of the questionnaire was to formalize the approach of obtaining first hand information regarding the search and rescue procedures and equipment employed. Intended interviewees were actual search and rescue team members, on-site medical personnel, government officials, uninjured survivors and volunteers, and recovered victims. By the time the team arrived on the scene, March 19, 1989, the search and rescue teams had already returned home. Consequently, the majority of the information was obtained from other personnel.

The questionnaire was divided into two portions. The first set of questions (Figure 1) was intended to solicit first-hand technical information regarding the search and rescue procedures. Much of that information was not obtainable directly. Some of the questions (e.g.#5) were beyond the scope of the responders queried.

The second set of questions in the protocol was designed to evaluate the need and feasibility of new concepts of and equipment for rescue operations. As such it is mainly directed toward trained technical personnel. The following preliminary summarization of statements are based on the search-rescue questions (Figure 1) resulting from 16 persons interviewed, and the USSR Government data (Tables 1-5). Other medically oriented interview results will be reported separately in more detail (Ricci et al).

CIVIL DEFENSE RESPONSE

Significant information and data were obtained from General Leo Kh. Melkomov, Chief of Civil Defense (CD) Republic of Armenia. Much of what follows is derivable from that interview with corroboration from other sources where possible.

The earthquake occurred at 11:41 a.m., December 7, 1988.(i.e. post-event hour zero). Although CD planning in Armenia is based on 2000 years of historical experience, the event was of such unusual character, at 6.9 Richter, the largest magnitude earthquake on record, that much of the prior preparation was ineffective. At CD headquarters in Yerevan, a slight tremor followed by a second shock 30 seconds later was felt but there was no immediate conjecture nor communication as to what had happened. The CD seismic station in Leninakan was destroyed so the only information received was from the Yerevan Station and from the Institute of Seismology in Georgia several minutes later. Even when this information was received no one at CD headquarters could conceive of the severity of the catastrophe.

At this point in time the only communication channel open was the CD link between Yerevan, Leninakan, and Kirovakan which was an underground telephone network. Three minutes later information concerning the event was received via this link from Leninakan and Kirovakan. No communication was received from the other destroyed sites.

Civil Defense had an officer on operational duty. Quickly, a local government commission was formed to whom CD made an early report. Their first action was to make an assessment of the extent of the damage. Five CD helicopters and five military helicopters were dispatched to the scene. Each had an assigned area of coverage. One and a half hours later CD felt they had sufficient information regarding the catostrophe.

However, helicopter intelligence could not fully evaluate the real extent of the devastation even though air photos of the pre-event condition were available. Observers with some CD training were not able to accurately distinguish between damaged and undamaged buildings still standing. They were too far away to detect details and the observers were not structurally trained. A view from the hill overlooking Spitak confirmed the difficulty of assessing building damage even from a relatively short distance. Additionally, in the larger cities such as Leninakan and Spitak, the ensuing dust cloud prevented accurate aerial reconnaissance. Thus, while it only required one and one-half hours for CD to receive preliminary information it required twenty-hours before complete damage assessment was available.

Civil Defense units were dispatched immediately after the initial assessment. The units which consisted of rescue workers and physicians, transported by helicopter and ground vehicles, first arrived in Leninakan 3 to 4 hours later and in Spitak, Kirovakan and Stepanavan 6 to 7 hours later. They immediately began search and rescue operations. In addition to the formal search and rescue teams, informal groups of student volunteers from Yerevan were mobilized and started to arrive on the scene by 9 p.m. that evening. Together with the local fire and police all participated in the rescue operation. Unfortunately the students had little to no rescue and/or first aid training and the local fire and police proved to be unreliable in following disaster management plans.

Uninjured inhabitants began search and rescue efforts once the initial shock and confusion subsided. These are people untrained in rescue and first aid techniques. While there is no clear evidence of the efficiency, or lack thereof, of their rescue abilities, one thing was consistently verified : the local survivors knew the location of their families and friends buried in the earthquake rubble. They served an important role in the initial search process and are clearly the most responsive and accurate detection devices available, especially in the initial critical stages.

At 9 hours, rescue operations were well under way. In general, there was no electricity or water, so one of the first tasks was to set up portable generators and lights and provide water stations. The water problem in Spitak was aggravated by the lack of electricity to operate the pumps for their artesian well system. Water tanks were brought in to alleviate the situation. Eventually, a special water line was extablished in Spitak. At day 3, the water supply lines in Leninakan were established.

After the event the three existing electrical substations in Leninakan were functioning but the distribution system was damaged. By day 2, 30% of the streets were lighted. One week was required to re-establish the entire network. CD should be congratulated for reestablishing necessary services in such an effective manner.

Waste disposal did not receive much attention initially. Rescue and the saving of lives had higher priority. On day 3 portable disposal equipment was available. By day 8 sanitary conditions were nomalized, a remarkable accomplishment.

The CD rescue teams were able to bring conventional rescue equipment, cranes, bulldozers and excavators starting at 9 hours by overland transportation. From their perspective the quantity of equipment initially available was insufficient for the job at hand. In addition to the quantitative lack of equipment, the absence of small, effective technlogical devices that can be employed early in the rescue operation, severely hampered the efforts.

Perhaps even more important was the lack of training in search and rescue. Some training was available to the rescue teams able to reach the scene early, but nothing that would enable them to cope with the magnitude of the catastrophe nor the type of building collapse encountered. By the second day the rescue teams had gained enough experience to be able to function more effectively. They quickly learned that in general the use of cranes to lift concrete panels was a mistake. The panels simply fractured in mid-air causing additional damage, injuries and fatalities. At this point the rescue teams decided that "jaws-of-life" type equipment would be more suitable for extricating survivors in the cave - type structure formed by the rubble. Government officals and survivors consistently decried the lack of availability of heavy equipment, particularly cranes, but this appears to be a knee-jerk reaction in response to the frustrations of not being able to do anything. Cranes clearly did not prove useful in the early stages of the rescue operation. Heavy equipment however, has an important role to play in later stages of rescue and in the recovery phase.

No information was available to the rescue teams for the management of rubble according to building type. Rescue teams experienced great difficulty in removing rubble to extricate victims without destroying the existing fragile equilibrium and causing additional injuries. Rescue teams experienced more difficulties removing the rubble of the taller buildings in Leninakan many of which suffered a pancake mode of failure versus the low-rise buildings in Spitak. Construction in Spitak led to less rubble. Concrete panels served as cover to form cavities which were easier to penetrate and rescue.

Communication with personnel at various locations was a major problem for Civil Defense. The first day 21 field communication stations and 1350 km of radio relays were established. By day 4 communication links with all villages were installed.

Transportation was a critical element for the evacuation of the recovered injured to intact treatment facilities. 154 km of roads destroyed by the earthquake were repaired to operable condition within 2 days. 70 km of railroad was also destroyed - it required 2½ days to return to usable form, a remarkable achievement that deserves credit.

A special inter-agency commission was formed to oversee the transportation of the injured. Another commission was charged with assessing available hospital space for the evacuation process. Traffic control was eventually stabilized by CD and military personnel. The initial clog of persons seeking family and friends in the emotion charged atmosphere led to a total grid-lock of the vital transportation life-lines.

It was alleged by some surviving non-medical observers of the earthquake that from 20-50% of the victims extricated could have been saved had efficient equipment - cranes, bulldozers and excavators were most often cited been available earlier. While not a quantifiable conclusion that can be verified, and perhaps even an exaggeration, it does appear that rescue teams trained in detection, extrication and life supporting first aid methods with the availability of sufficient small, portable extrication equipment, and a quick response ability, could provide a more efficient path to saving lives in this type of disaster.

EARTHQUAKE CONSEQUENCE AND RESPONSE DATA

The enormity of the earthquake and its consequences and the vastness of the rescue effort may be best appreciated by examining the basic data compiled by Civil Defense Headquarters.

Consequences of the earthquake were devastating (Table 1). 67% of the four cities of Lenivakan, Kirovakan, Spitak and Stepanavan was destroyed as was 66%, 29% and 69% of the industrial, cultural and residential facilities respectively in the region. The initial population in the earthquake affected zone was 590,000 persons or roughly 20% of the Armenian Republic; estimates are that about 400,000 became homeless.

The search and rescue process began on the afternoon and evening of December 7. Initially, 4328 persons were extricated from the rubble, but only 1382 (32%) were extricated alive. Most of the early extrication was accomplished by hand using simple tools. Because of the lack of transportation equipment and facilities early in the process, none of the injured survivors were able to be transported. On the second day a similar situation prevailed, 9,634 were extricated but only 1660 (17%) alive. On that day 2,470 were transported to other medical facilities in Armenia. One can only speculate as to the number of lives that could have been saved had quicker more effective and better equipped rescuers with either first aid knowledge or medical assistance been available.

The remaining sequence of victims extricated and evacuated is shown in Table 2*. On days 3 and 4 the largest number of persons

* The data in Table 2 as well as other data are presented as obtained from CD. No attempts were made to reconcile or adjust the data. The aggregation of the data presented in Table 2 comes to 41,666, 15,457, and 26,209 total, alive, and dead extrications, respectively.

were extricated alive, 59% and 88% respectively. From that time on, the number of live extrications declined significantly. By day 5, 80% of the victims had been extricated, 37% alive and 63% dead. Finally, by day 12, extrication was 99% complete, essentially all of the live victims had been extricated by then. At the culmination of the extrication procedures, 39,795 persons had been rescued -15,254 (38%) alive and 24,541 (62%) dead. Unfortunately, the data available did not discriminate between the types of live extrications - those in need of resucitation, those in need of simple first aid and those who were simply trapped. Furthermore, no information was available as to the number of live extrications who subsequently died.

Based on this discussion, and the time dependent data shown in Figure 2, it seems useful to subdivide the rescue period into three distinct phases - the initial phase, the first 24 hours, an intermediate phase of 4 days, days 2 thru 5, and the final phase, beyond day 5. This observation is based on the data as collected. A more definitive demarcation of phases remains as additional data is collected.

Rescue work was accomplished with the use of equipment supplied by Armenia Civil Defense as well as other Republics, particularly the Georgian Republic, and International sources, (Table 3). Initially most of the equipment was of Armenian origin. By day 5 equipment received was almost equally distributed between Armenia and other Republic sources. From day 6 on, assistance began to arrive from outside Armenia. The daily arrival of rescue equipment was steepest in the initial period from December 7 to December 11, thereafter the inflow was more moderate. By day 5 over half of the incoming heavy rescue equipment had been received.

Personnel mobilized to facilitate the search, rescue and assistance programs is shown in Table 5. 61,000 persons contributed to this massive effort, 16% of whom were CD personnel. Human resources were assigned mainly to Leninakan, the largest of the cities and which suffered major damage, and to Spitak, a much smaller city, which however, was totally obliterated. Equipment was allocated in a similar fashion. Thus, the resources for rescue and treatment purposes were allocated on the basis of perceived need. Between the two, Leninakan and Spitak comprised 43% of the population of the affected region and suffered 50% of the total deaths.

Table 5 summarizes the fate of the affected population and shows the extent of the vast amount of humanitarian aid received to ameliorate the adverse affects of the earthquake.

The data show that the percentage of persons extricated dead increased from a low of 10% in Kirovakan to a high of 98% in the rural areas. Whether this occurred because of the nature of the structures, (87% of the industrial facilities and 68% of the residential building were destroyed in the rural areas), or because of the lack of early attention perhaps due to the disperson of the rural areas, is not clear. The largest percentage (70%) of extricated dead occurred in

Spitak, which also had the highest percentage of fatalities (53%) in the population. Even though Leninakan experienced a lower total death rate (4%), the number of dead extricated was very high (59%) and can be understood by examining the severe nature of the building collapses.

Soviet Minister of Health Yevgeni Chazov has been quoted as estimating the every hour of delay in extrication, and consequently life saving first aid, results in 20 dead for every thousand victims buried or trapped in the rubble. Based on that observation one can make a rough estimate using the time dependent data shown in Table 2. Thus, for each hour the rescue/resucitation response can be advanced, approximately 800 persons could have been saved. A three hour quickening of the response could result in the additional saving of 2,400 lives. Even if that estimate is too optimistic by a factor of two, the saving of 1200 human lives by a three hour speed-up in the response is more than the live extrications in the last 14 1/2 days of the 19 day rescue effort.

EXPERIENCES OF OTHER SEARCH AND RESCUE TEAMS

Search and rescue teams from many nations in the world responded to the Armenian disaster in a remarkable display of concern and caring. Two of those efforts will be very briefly described here -the U.S. and Israeli teams.

One of the U.S. rescue teams consisted of 5 emergency physicians, 10 firefighters from Fairfax County, Virginia, 8 firefighters from Miami - Dade County and 12 dog handlers with eight dogs. Organized by the State Department OFDA, the team with their equipment arrived in Yerevan on December 11. Almost all of the team members had prior emergency resue experience either in the U.S. or overseas.

The Comfort survey of 15 persons (2 medics, 8 firefighters, and 5 dog handlers) provided some important insight regarding the search and rescue operation. It is clear that rescue training including emergency medical procedures ranks high in the desirable background of the team. Particularly important, in their view, was the training they had received in building construction and damage assessment. Significantly, the team listed structural evaluation also as a leading candidate for additional training and skill developement.

Among the major types of equipment and supplies the team brought with them were special extrication equipment such as electric saws, jack hammers and electric generators and simple equipment such as picks, shovels and crow-bars. While the equipment transported to the disaster location was considered to be one of the team's strengths, it was suggested that more hand tools would offer an improvement in rescue operation. By the time the team arrived on the scene most of the live extrication had been completed as indicated in Table 2.

From their experience, 2/3 of the responders indicated that the following, additional information would have permitted them to operate more effectively.

- The extent of the damage, the location of the damaged buildings and estimated number of victims, and the status of the search and rescue operations.
- Other teams capabilities, particularly including specific skills, equipment, etc.
- Communications facilities and access to such.
- Transportation, shelter and logistic support.

Slightly under half of the responders agreed that the following information would have been useful

- Data relating to specific structures
- Knowledge of the disaster management procedures and chain of command

In the judgement of the team, previous experience, training, equipment, skill and quick response were their primary strengths; communications, lack of command structure, distance from site, and coordination with other teams were primary weaknessess. Structural and building collapse evaluation, survival, and general search and rescue proved to be their most valuable training. Interestingly, they cited structural evaluation together with intergroup training and coordination as those areas where training and skills would lead to improvement. Small extrication tools, power tools, communiciation equipment, personal supplies such as food, water, shelter, and cold weather clothing constituted essential elements in their disaster response effort.

Dog teams from the U.S., as well as from many other nations, worked feverishly in the search process. Observers at the scene provided mixed reviews of the efficiency and usefulness of the dog teams in this kind of extreme environment. Except for the Austrian teams which is reported to have located 42 survirors and the Swiss team which is reported to have pulled 25 survivors from the rubble, the other teams had only modest success in locating survivors and extricating them in time to be saved. Exhaustion from overwork, and the severe environment of the tightly packed rubble were responsible for the modest but nevertheless extremely valuable retrievals.

Most of the dog teams agreed that a quicker response would have aided their efforts immensely. Equally, more overhead support including communication, transportation and interpreters would have been of great value.

Israeli search and rescue teams had very similar experiences. They arrived in Leninakan on December 11 and stayed through December 22. During the first 2 days the team managed to rescue three living survivors and recovered approximately 80 bodies. Upon arrival the team had a full complement of extrication equipment - almost all of which would be in the category of small mechanical, hydraulic and pneumatic systems. This array of gear proved reliable, effective and sound. The team included two physicians who were able to supply appropriate medical intervention at the scene.

These examples, as well as others from the many teams that provided humanitarian help for this disaster, reinforce the basic notion that during the critical initial period (0-24 hrs.) most of the detection - extrication - resuciation must come from local sources. International assistance, which at best can only be mobilzied during the intermediate phase of rescue operations is vital and can play an important role during that phase rescuing the live, less critically injured and uninjured victims. Massive humanitarian assistance makes its contribution during the final stage of the response.

SUMMARY

The following preliminary summary is based on the observations and data gathered by the research team blended with many impressions that cannot be demonstrated quantitatively. The final conclusions and recommendations will be presented after synthesis of this information with that compiled by the USSR team.A fundamental premise of this discussion is that detection - extrication - resucitation - evacuation procedures must be applied early (0-24 hours) in the event history to maximize life saving potential. It is convenient to divide the response period into three (perhaps fuzzy and overlapping) phases - an initial phase (0-24 hrs), which has the greatest potential for life saving, an intermediate phase (days 2-5) in which the less critically injured require medical intervention and evacuation if they are to survive and a final stage (> day 6) in which uninjured trapped victims may be extricated. Based on this speculative description the following set of thoughts are presented.

- Reliance on vital information cannot be assigned to aerial reconnaisance. Accurate evaluation requires helicopters to fly over the damage zone at low altitudes and/or employing land and look procedures. Improvement in damage assessment and treatment requirements would occur if the aerial team included persons trained in structural damage evaluation and the associated medical trauma assessment. High resolution photos with a real time interpretive capability could speed up the evaluation process.

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- Search and rescue should take place in locations of greatest life saving potential rather than in locations of greatest damage. Rescuers should be trained to look for buildings with voids where survivors may be trapped, rather that attacking the buildings randomly.

- A major source of detection information, particularly in the initial phase, are the uninjured survivors and the victims' families.

- Most immediately feasible and least costly medical provision measure is the training of the population in an earthquake suceptible region in basic life saving first aid.

- Transportation life lines are essential for evacuating the injured victims. Small bulldozers may be useful to clear a path. Police and Military are necessary to maintain traffic control.

- During the initial phase small hand tools and power equipment proved to be most useful. Horizontal tunnelling into the existing cavities formed by the rubble is more effective than vertical or top-down rescue attempts.

- Cranes generally caused problems during the initial phase and early portion of the intermediate phase. Cranes and sophisticated high-tech detection devices are useful in the later stages of the intermediate phase and the following phase.

- Power saws, drills, cutting devices, jacks and air - bags are all vital gear during the initial phase. Generators and lighting systems are necessary to provide round - the -clock rescue operations.

- An ideal rescue team would include three rescuers, one building technologist and one medical technologist, all with appropriate training and equipped with hand and portable tools. A lower priority would be a team composed of three rescue persons who have appropriate LSFA and building damage assessment knowledge. Because of the urgency of the team arriving at the scene quickly, a helicopter air lift plan should be instituted.

- Some form of information system collating building type probable collapse modes, and associated injury classes with corresponding extrication procedures could prove invaluable. The information must be easy to retrieve and direct to use. An "expert system" would appear to be an ideal format with a "rescue team manual" a second preference. High occupancy building should receive first priority in any information system.

- From a much longer time point of view the feasibility of robotic extrication devices should be explored, as a promising technology in areas of high risk to the rescuers.

FIGURE 1

EXTRICATION QUESTIONNAIRE

1. How was the extrication handled? What equipment and procedures were used? _____

   a. Was the equipment available in Armenia? If not, how did the rescue team get the equipment? _____

2. Of those not immediately accessible for resuscitation, how late were people found under the rubble? _____

3. When were they dug out? _____

4. To what extent did extrication efforts add lethal injuries?

   _____

5. How did dog teams, television, other sensors perform? Any ideas on innovative sensors? _____

6. How did extrication devices perform -- bulldozers (by air or road)? Cranes? Jaws of life? Tunneling? Others?

   _____

Try to obtain an assessment of the following questions:

1. Is it useful and possible to develop relatively light weight (airliftable by helicopter) bulldozer-drill combinations?

   _____

2. Using existing equipment and procedures could modifications lead to improved rescue? _____

3. Were trained persons available to assist in the use of the extrication equipment? _____

TABLE 1

EARTHQUAKE CONSEQUENCES

CITIES AND REGIONS	POPULATION LOCATIONS		INDUSTRIAL FACILITIES		CULTURAL BUILDINGS		RESIDENCES		AGRICULTURAL FACILITIES		DOMESTIC ANIMALS	
	INITIAL	% DESTROYED	INITIAL	DESTROYED	INITIAL	DESTROYED	INITIAL	DESTROYED	INITIAL	DESTROYED	INITIAL	DESTROYED
LENINAKAN	1	75%	40	40	669	323	12450	11250	-	-	-	-
KIROVAKAN	1	25%	34	6	456		7162	2333	-	-	-	-
SPITAK	1	100%	9	6	28	24	433	433	-	-	-	-
STEPANAVAN	1	67%	9	1	134	12	2134	1430	-	-	-	-
RURAL AREAS	169	34%	39	34	581	186	29533	20094	1365	1259	34300*	76500*
TOTAL	173	60%	131	87	1868	545	51712	35540	1365	1259	34300*	76500*

*These data appear to have been interchanged.

TABLE 2

RESCUE AND EVACUATION OF INJURED POPULATION

CLASSIFICATION \ DATE	7.12	8.12	9.12	10.12	11.12	12-18.12	19-25.12	TOTAL
TOTAL EXTRICATED	4328	9634	8243	6437	4419	8187	418	39795
EXTRICATED ALIVE	1382	1660	4825	5682	1757	150	1	15254
TOTAL EVACUATED	-	2470	130	1700	4081	59638	36418	119318
EVACUATED TO OTHER REPUBLICS	-	-	-	-	1300	34980	29235	79750

TABLE 3
EQUIPMENT RECEIVED FOR RESCUE WORK

DAYS OF RECEIPT AND TYPE OF EQUIPMENT					
SOURCE OF EQUIPMENT	TOTAL	CRANES	BULLDOZERS	EXCAVATORS	MOTOR VEHICLES
	7 DECEMBER				
ARMENIA SSR	1530	287	190	183	870
OTHER REPUBLICS	380	32	15	19	314
TOTAL	1910	319	205	202	1184
	8 DECEMBER				
ARMENIA SSR	1980	332	247	201	1200
OTHER REPUBLICS	508	75	27	25	381
TOTAL	2488	407	274	226	1581
	9 DECEMBER				
ARMENIA SSR	2097	354	261	250	1232
OTHER REPUBLICS	1062	267	68	67	660
TOTAL	3159	621	329	317	1892
	10 DECEMBER				
ARMENIA SSR	2203	372	273	256	1302
OTHER REPUBLICS	1261	382	87	89	703
TOTAL	4064	754	360	345	2005
	11 DECEMBER				
ARMENIA SSR	2426	383	287	256	1500
OTHER REPUBLICS	2424	444	220	107	1653
TOTAL	4850	827	507	363	3153
	18 DECEMBER				
ARMENIA SSR	2531	421	291	262	1557
OTHER REPUBLICS	3631	784	451	296	2100
TOTAL	6162	1205	742	558	3657
	31 DECEMBER				
ARMENIA SSR	3036	656	291	268	1821
OTHER REPUBLICS	5922	1335	697	391	3500
TOTAL	8959	1991	988	659	5321

TABLE 4

RESOURCES UTILIZED FOR RESCUE AND TREATMENT

CITIES AND REGIONS	PERSONNEL (in thousands)			EQUIPMENT (units)			
	TOTAL	CONSISTING OF		CRANES	BULLDOZERS	EXCAVATORS	MOTOR VEHICLES
		CIVILIAN	CD UNITS				
LENINAKAN	39.3	30.5	8.8	974	301	167	2389
KIROVAKAN	3.5	3.5	-	178	124	65	474
SPITAK	7.3	6.0	1.3	415	187	103	897
STEPANAVAN	1.65	1.65	-	91	77	29	170
RURAL AREAS	9.6	9.6	-	333	299	275	1391
TOTAL	61.35	51.25	10.1	1991	988	639	5321

TABLE 5

RESPONSE TO EARTHQUAKE CONSEQUENCES

CITIES AND REGIONS	POPULATION					HUMANITARIAN AID					
						PRODUCTS (in tons)			HABITATION		
	INITIAL POPULATION	PERSONS EXTRICATED	PERSONS DEAD	TOTAL PERSONS EVACUATED	PERSONS EVACUATED TO OTHER REPUBLICS	TOTAL	INCLUDING BREAD	INCLUDING MEAT	TENTS	PREFAB HOUSES	HEATERS
LENINAKAN	232.0	16959	9974	58642	39486	1688.5	1404	213.0	2924	1280	3173
KIROVAKAN	171.0	4317	420	34720	23188	1120.6	945	126.7	8280	50	560
SPITAK	18.5	13990	9733	8091	5377	982.0	835	109.0	11086	4774	2303
STEPANAVAN	21.0	108	63	-	-	857.0	747	82.0	5976	250	877
RURAL AREAS	146.5	4421	4352	17865	11699	4752.6	4316	322.0	26431	7363	8320
TOTAL	589.0	39795	24542	119318	79750	9400.9	8247	852.7	54697	14167	15233

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DETECTION - EXTRICATION IN THE ARMENIAN EARTHQUAKE OF DECEMBER, 1988

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THE EARTHQUAKE IN ARMENIA: CONSEQUENCES AND PROBLEMS

R.A.Charchoghlian, R.V.Sekoyan

On December 7, 1988 at 11.41 an earthquake involving 15 regions and 4 towns occured un Armenia. The zone of considerable destructions covered the towns of Leninakan, Spitak, Kirovakan and Stepanavan, and 365 villages in the Akhourian, Spitak, Stepanavan, Goughark, Hamasia, Ghoukasian, Aragats and adjoining regions.

Fifty eight villages are completely destroyed. Almost 514 thousand people lost their shelter. Armenia has lost more than half of the housing, approximately 8 mln sq. metres, existing in that region.

Many of the industrial and agricultural enterprises are either completely destroyed or seriuosly damaged.

Considerable sections of rail- and automobile roads are ruined. Bridges and communication lines are broked, and the public utility services stopped functioning.

By January 3, 1989 109896 people, most of them children, women and older people, were evacuated from the calamity zone: 70210 of them including 64819 people sheltered in sanatoriums and rest-homes, were located beyond the borders of the Armenian SSR.

In the towns and regions, indicated above, by the beginning of 1988 there were 65 hospitals, for 7760 patients, 32 out-patient departments and polyclinics, calculated for 13,400 visits per shift, 314 obstetric and assisting centres, 22 prophylactic-epidemiological stations, 21 ambulance stations and 4 blood transfusion stations. In all these institutions there worked 2,223 physicians, including 1,349 women and 8626 of the assisting medical personnel.

The earthquake ruined all the hospitals, and about 70 per cent of the medical personnel perished. Death of tens of thousands of people is the heaviest and irrestorable loss. There no complete data about the earthquake victims as yet. 23,700 people were found dead in the ruins. 15,252 people were saved. More than 25,000 victims applied for medical help. By January 21, 1988 more than 10,792 victims were hospitalized. According to incomp-

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lete data more than 400 victims were operated, and almost 400 injured patients died in the hospitals. In 14 days after the natural calamity almost 5,000 patients continued their treatment in the hospitals of the country. By January 3, 1988 there were 2476 people in hospitals of Armenia, and 496 people were in the hospitals of other regions.

In the first night more than 2,500 wounded people were carried from the calamity region over to Yerevan by aeroplanes, motor cars and other transport. On December 7, 1988 the medical institutions of Armenia received 3,874 and those of Georgia 193 injured people.

On the very first day of the natural calamity groups of specialists (almost 100 physicians) came to Armenia to render an urgent help to the population of ruined regions.

In the initial period after the earthquake the main problem was to render the wounded the first medical aid and to evacuate them from the stations of medical aid and primary hospitalization located in the regional centres round the earthquake focus to the city hospitals for a more qualified aid. With this aim groups of physicians and consultants were directed to the central regional hospitals in the regions, mentioned above.

As the roads were ruined by the earthquake, the injured and wounded people were evacuted on the very first day by the civil and military aviation which made more than 130 flights, as well as by ambulances and other transport of the medical institutions of the adjoining regions.

Within the first day almost 10,000 beds were prepared in Yerevan and other places along the main directions of evacuation, ready to receive the earthquake victims.

More than 5,000 physicians of the republic were commissioned to render medical aid to the victims; 1,152 medical personnel arrived from the Union republics, almost 800 of them were specialists working in the leading clinics and large hospitals of our country (Moscow, Leningrad Voronezh, etc). In different periods of time 417 medical workers from 17 countries, without including here the rescuers, took part in the work on rendering medical aid. By January 5, 1989 there were 135 medical workers from other Union republics and 55 from other countries working in the republic.

87 per cent of the total number of victims were located in the hospitals of Yerevan, 5 per cent of them with complicated types of joint injuries were taken to specialized centres in Moscow and other towns, and only 8 per cent stayed at the regional hospitals up to the day of their discharge. Composition of patients analized according to the injury graveness by December 21, 1988 showed the following:

Number of patients hospitalized immediately after the earthquake	9976	100%
of them:		
utmost grave condition	2078	20.9
grave condition	2934	29.7
medium grave condition	3325	33.3
satisfactory condition	1639	16.4

Operative analysis regarding distribution of patients according to the trauma localization, performed in the hospitals by December 20, 1988, showed serious injuries. Thus, 12.8 per cent of patients had inferior limb fractures, 7.8 per cent of them suffered from from spinal column and truncal bone fractures, and 5.7 per cent of them underwent traumatic limb amputation; 378 patients were amputated and treated after traumatic amputations, and 843 patients had the crash-syndrome. In the treatment of the latter group it was necessary to use the "artificial kidney" devices whose quantity in the medical institutions of Yerevan was quite insufficient and, as a result, a considerable number of patients was transferred to the Moscow hospitals.In the days that followed technical equipment of hospitals in Yerevan was considerably improved, up to more than 60 "artificial kidney" devices functioning now, and it became possible to perform hemodialysis with more than 800 patients.

The first, sometimes very complicated operations including amputations, were performed immediately in the streets. By December 12, 1988 the sergeons had performed more than 2,500 operations such as neurosurgical, vascular, cavitary, microsurgical, and traumatologic.

It should be stressed that many of the local physicians those who were not injured had either lost their relatives or were in the shocked condition.

The unexpected arrival of numerous victims, sometimes in a very grave condition, disorganized the work of the medical personnel to a certain degree, and especially so that the majority of medical institutions stopped functioning, there was no light and water, and the quantity of dressing and sutural material, splints, litters and transport to transfer the victims in the first hours was obviously insufficient. Very often on the initiative of their relatives using the transport passing by, the victims who had not received the first medical and qualified aid, were transferred to the medical institutions of adjoining regions, and even to the city of Yerevan at the distance of 100-150 km away from the places of their injury.

In the result of all this and because of the road jamming a number of victims received medical aid in 3 or 5 or 15 and even more hours after the injury.

The lack of telephone and radio communication means also affected solutions of many questions. Efficiency of the medical brigades was notably decreased by uncoordinated actions and absence of a unified system and doctrine; besides, it should be noted that the medical personnel was not accordingly trained, and brigades were not sufficiently equipped to carry out purposeful actions in the zone of mass destruction.

Reliable radio communication both among the brigade members and between the brigades and the central or regional medical stuff could considerably improve results of their work.

Medical departments of the civil defence as well as military medical units were rather slow to take up the work; it took them from 1 to 2 or 4 days to develop their activites in this or that area.

The rescue operations were also uncoordinated. Their results were undoubtedly affected by the absence of special units of trained rescuers and corresponding equipment, there were no mechanisms for early detection and extraction of victims out of the ruins, and means for their transportation. the first medical aid was often late.

In the first 2 or 3 days all kinds of work were not coordinated.

In the result of the earthquake there simultaneously ap-

peared several tens of thousands of injuries including such heaviest traumas as craniocerebral injuries, traumas of the spinal column, breast, abdomen and pelvis, as well as injuries or compressions of limbs resulting in the development of of the continuous compression syndrome with acute renal insufficiency.

Majority of traumas are specified as having a combined and joint character. The most difficult and important task in the first minutes and hours after the earthquake is to render the first medical aid and to organize an urgent medical and surgical aid in the place of the accident.

Taking into account that during the earthquakes of this kind the medical institutions are almost completely ruined and that a considerable number of the medical workers perish, it becomes evident that there is a necessity of organizing mobile and autonomous medical groups, something like a separate medical unit, able to take up all the necessary measures immeditely after the earthquake.

The problems of medical aid, evacuation and transport are a subject of a separate discussion. It seems expedient to suggest two principle for solving these problems:

1. The main amount of medical aid is rendered in the network of field hospitals functioning directly in the zone of destruction;

2. The patients are transferred to the medical centres as soon as possible after rendering them the first medical aid.

The experience of Armenia showed that in case of an earthquake of this type main roads cannot provide a sufficiently large stream of autotransport, because the roads are damaged and extremely overloaded. Taking into account that in the majour regions of the globe suffering from earthquake there is no develped network of roads, it becomes evident that both in case of the first and second versions of rendering medical aid (the first and the second versions may be equall used) the main transport is to be presented by the helicopter aviation, and that instead of building helicopters of the "blue thunder" type and different types of rocket carriers, it is necessary to construct special helicopters joined into special avia-units to carry field hospitals and to

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evacuate the victims.

Special stations receiving patients for their further evacuation in the ambulances are to be established round the towns in the dangerous regions at the distance of 15, 20 or 30 km not far from the grade-crossing eliminations structures.

The earthquake experience in Armenia showed that it was imposible to solve the medical provision problems without a large-scale international assistance. Time losses in rendering the necessary specialized assistance may be avoided if in Europe, Asia and Africa, etc. UN could organize continental centres, able to send their units to the disaster zones without coming to the agreement with corresponding govermental bodies and supplied with special code signals to cross the borders. The centres are to function according to the "alarm" principle and be supplied with constant information from the calamity region.

The statistical analysis is coming to its end and is to be presented in the report. Demonstration of a 30 min. videofilm (SECAM system) is also possible.

Suggested Problems for Field Research in Earthquake Disaster Operations

Louise K. Comfort
University of Pittsburgh

Listed below are recurring problems in earthquake disaster operations that would benefit from systematic professional inquiry. Findings from research on these problems may lead to appropriate mitigating action to reduce hazards and increase capacity for response when disasters do occur.

1. Uses of information and telecommunications technology to support the communications processes central to disaster management. New designs for interactive telecommunications and computerized information processing systems offer promising means of increasing the content and exchange of information available to disaster managers in complex, dynamic environments. Exploring means of improving the timeliness and accuracy of information available to multiple participants with emergency responsibilities may facilitate decision-making to reduce hazards or improve response operations when disasters do occur.

2. Coordination of multiple organizations, multiple jurisdictions involved in disaster mitigation and response operations. Improving information capacity increases the demand for coordinated response to hazards. Inquiry into organizational learning processes and the design of feedback mechanisms to facilitate mutual adjustment among organizations participating in achieving common objectives will be useful in increasing the effectiveness of mitigation programs and the efficiency of response operations.

3. Development of interdisciplinary knowledge bases and the creation of computer-assisted reasoning processes to support decision-making in disaster mitigation and response operations. Much of the "knowledge" acquired in disaster operations lapses with the change of experienced personnel. Developing heuristic reasoning processes that provide intelligent corroboration of disaster management decisions from multiple knowledge sources offer a powerful means of reducing the complexity of disaster operations for disaster managers. Such logical inferencing processes will be especially useful in the complex environments of international disaster operations.

4. Creation of an international databank on resources, skills and strategies for timely mobilization of disaster assistance in response to particular types of hazards in regional geographic locations. Such a databank might serve as the focal point for an international center for hazard education that would provide technical assistance and professional resources by geographic region to assist local jurisdictions in increasing

their capacity for hazard reduction and disaster response.

As an initial step in acquiring systematic information to support decision-making in search and rescue operations in international disasters, we are conducting two surveys of field operations personnel who were involved in the Armenian disaster operations. The first is a survey of personnel from approximately 40 international search and rescue teams. Questionnaires have already been received from the U.S. team; questionnaires translated into eight languages, will be mailed to other participating teams during July.

The second survey will be conducted for approximately 270 international physicians who participated in the delivery of medical services to victims within the first four weeks of the disaster. We are planning, with our Soviet colleagues at the Institute of Reanimatology in Moscow and the All-Union Surgical Center in Yerevan, to conduct a counterpart survey of Soviet physicians who provided medical services to victims at the disaster site, in Yerevan hospitals and in hospitals in other cities in the USSR.

The findings from these surveys will be used to identify the information requirements for search and rescue personnel and physicians during disaster operations. The expected research product will be two databases for these particular disciplines, that may be made available to UNIENET (United Nations Emergency Information Network) and accessible to authorized users in the international disaster research and operations community.

A copy of the questionnaire for search and rescue personnel is attached. The questionnaire for the sample of physicians is under development and will be available for the Workshop on Earthquake Injury Epidemiology in Baltimore, MD on July 10-12, 1989.

Reflections on the Armenian Earthquakes

Louise K. Comfort

The earthquakes of December 7, 1988 shattered not only the buildings of Leninakan, Kirovakan and Spitak, they also shattered decades of biases, illusions and assumptions within the Soviet Union toward citizens, government and other nations and in other nations towards the Soviet Union. The Armenian earthquakes, in which 25,000 people were killed in minutes of terror, created a crucible of tragedy that tested the fullest range of physical, emotional, professional and administrative capacities of individuals and organizations engaged in response.

Soberly, we recognize again that disasters occur as the result of the interaction between natural events, such as earthquakes, and human construction, such as the apartment houses, schools, factories and hospitals of the damaged communities. The compelling acknowledgment of human vulnerability in precipitating disaster was amplified through current communications technology across the USSR and the world, engendering empathy, assistance and systematic professional inquiry into causes of collapse in human settlements that may recur in other locations, in other nations. The next event may be in our community, our nation. What can we learn from this disaster that may inform current decisions about future risk?

Three observations from field research in Armenia suggest focus for continuing study. Coordination requires an infrastructure of culture and communication that enables common understanding of diverse functions and multiple tasks required for action. The difficulties experienced in coordinating response to the damaged cities were exacerbated by separate telephone systems for civilian and military personnel, different languages spoken by Armenian citizens, Soviet central government officials, and international response teams, as well as

differing levels of skill and preparedness for disaster operations. Working against time in saving lives, disaster operations personnel confronted extraordinary obstacles and complexity in mobilizing collective action, obstacles that may be substantively reduced with technical assistance and organizational collaboration.

Second, disaster creates opportunity for learning as well as loss. Seeking to restore community functions and to heal human injury, operations personnel are open to methods that work. Given the urgency of need, new methods are tried and discoveries are made that link ideas to action within the constraints of available resources and time. Reviewing actions taken and insights gained into the functions of mobilizing response personnel and equipment, delivery of medical services, design of engineering structures, transportation and communication requirements during the Armenian disaster operations will contribute to our understanding of these complex processes during the ordinary crises of metropolitan communities.

Finally, the intensive study and research findings generated by the Armenian earthquakes are indeed international. Current information technology allows the creation of international databases, communication across time zones and informed action from multiple participants in coordinated response to local need. New patterns of cooperation and collaboration were forged in the rubble of Armenian cities and villages and continue to alter relations between peoples, organizations and nations across the world. The quiet revolution in cultural attitudes, following from shared functions in attending human need, may be the most profound consequence from the Armenian disaster.

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American critical care team at a foreign disaster site: The Armenian experience

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An American critical care team was organized and placed at the site of a major natural disaster in the Republic of Armenia in the Soviet Union. This effort was apparently the first time that an intensive care team from the United States was used for such an undertaking; we would like to share our experiences and summarize the lessons learned.

The earthquake, measuring 6.9 on the Richter scale, hit northwestern Armenia, a predominantly Christian republic of some 3.5 million inhabitants, at 11:41 AM, December 7, 1988. Four towns and some 58 villages were involved. Temperatures in this mountainous area dropped to -20°F at night. Schools, factories, medical facilities, and apartment buildings collapsed. Preliminary estimates of loss of life, including many health care workers, were between 50,000 and 100,000. Due to recent civil unrest precipitated by a deteriorating relationship with the neighboring Islamic Azerbaijan, the republic was under martial law.

Reading about the extent of devastation on December 9, 1988, we realized that our own critical care system with 64 medical-surgical ICU beds backed up by large respiratory therapy and nutritional support services under similar circumstances would be immediately overwhelmed. The decision was made to offer all possible assistance to our medical colleagues there. A blackout on all publicity was imposed internally due to the relative sensitivity of the mission. We received confidential support from our hospital administration; continuous access for FAX communications and purchasing/central supply personnel and space was guaranteed. Advice was sought and received from Drs. Peter Safar (Pittsburgh), Simon Bursztein (Israel), and Luis Ize (Mexico).

We contacted the Armenian Relief Society, the Armenian General Benevolence Union, the local Archdioceses, and the Armenian Medical Outreach Society. They all offered assistance in the form of information, supplies and transportation. The State Department's Office of Foreign Disaster Assistance (OFDA) was gathering data on the physicians who were volunteering. A tremendous volume of donations and aid was pouring in from individuals, societies and business organizations; the New York-based Trump Organization, for instance, donated millions to this effort. Within 24 hours a list of medical professionals from our own system was compiled with priority given, whenever possible, to those fluent in Russian or Armenian and having the appropriate skills and personality traits to function in the field. We made a list of equipment and medical supplies required to support a 10-bed ICU and a critical care transport system in a disaster area. It was decided not to use our hospital equipment but to turn to donations. Contact with medical industry resulted in an unbelievably generous response: most companies, such as Puritan-Bennett, Hewlett-Packard, Protocol, Datascope, Stepic Medical, and others, immediately delivered the equipment. Most of the equipment was donated to this effort. Within a few days we had received all major equipment requested (Table 1). In addition, all the appropriate intubation and respiratory care, intravenous access and invasive monitoring, communication equipment as well as the sterile field supplies, fluids, ICU medications, and other pharmaceuticals were provided. We felt adequately equipped, having worked nonstop for 3 days, to deal with resuscitation, cardiopulmonary-renal failure, and severe infections, in addition to being

TABLE 1. Equipment received from medical industry

10	Ventilators
12	Cardiovascular monitors
4	Defibrillators
4	ECG machines
2	Pulse oximeters
2	Pacemakers
1	Bronchoscope

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self-sufficient in the field.

At this point it was clear that only a few organized American medical teams would be supported by the State Department, Soviet Embassy, Soviet Mission to the United Nations, and the Armenian societies. The ones we were to be loosely linked with were the Seattle-King County Disaster Team of paramedics, firemen, and emergency medical personnel, and the Portland-based Medical Teams International surgical team. Our Montefiore Critical Care Group of New York intensivists was to provide the critical care services for the sickest patients after rescue and trauma surgery. After initial hesitation, all involved understood the concept of the critical care team and actively supported it. Data required for clearance of visa plus language skills and medical qualifications were FAX'd to all authorities involved, and clearances were received. The energy, dedication, and effectiveness of everyone, especially the Armenian Relief Society organizers and workers, were truly overwhelming and humbling.

First, we decided to place an advance team of two physicians on the site to assess the needs and to locate an appropriate working environment. Based on their telephone report (connection took five hours), equipment and personnel (original team had 14 people) were adjusted to the requirements, and the rest of the team and equipment followed shortly. Composition of the team (Table 2) was adequate to staff a ten-bed ICU after supplementation with local personnel. Transportation for the team was provided by Flying Tigers, Aeroflot, and a Chrysler Corporation executive jet. Landing of one of our airplanes at the Yerevan airport on December 13, 1988, was a premonition of the relative chaos to come: two medical aid planes had been lost with all personnel a few days before. One of us had to stay in the cockpit and breach the language barrier between the pilot and air traffic controllers to guide the plane in. Up to 180 planes were landing daily from donor countries. We immediately met with the Minister of Health and finalized plans to work with our Armenian colleagues in establishing a regional critical care center. The group was totally self-sufficient. The State Department's team was coordinating an OFDA assessment team and setting up satellite communications. The OFDA team's primary job was assessment rather than supporting the volunteer teams. The team and equipment were transported on trucks to the largest medical facility in Armenia, the 1200-bed Central Republic Hospital #12, and went to work at the site recommended by our advance team. This institution was a general hospital used as the main teaching hospital for the medical school and functioned as the primary triage center early during the disaster.

The team functioned in a 16-bed "Reanimatolgy Institute," attached to a six-bed hyperbaric facility. A Dutch dialysis team of one physician, one technician, and two nurses was already setting up shop next to us.

TABLE 2. Critical care team

3	Critical care attending physicians
2	Pulmonary critical care specialists
1	Surgical critical care specialist
2	Anesthesiology critical care fellows
1	Biomedical engineer
1	Pharmacist
1	Critical care/dialysis nurse

Many of the physicians staffing the ICU had been working at the epicenters for 4 days without sleep and were exhausted; some of them required mild sedation. We were told that the rates of myocardial infarctions and suicides in the general population doubled. An excellent personal relationship was established with the director of the hospital and chief of intensive care services. The junior and support staff, realizing that we were not there to take over but rather to work and assist, were extremely enthusiastic and helpful.

After establishing sleeping quarters in a partially finished building, we went to work. Our biomedical engineer assessed the electrical, air and oxygen systems, and the existing equipment. There were no capabilities for ECG and hemodynamic monitoring or bedside dialysis. They had a number of eastern bloc ICU monitors that were in the corridors crated but nonfunctional. The ICU laboratory had a blood gas analyzer (ABC #1, Radiometer, Copenhagen, Denmark) but it required repairs; that was used for capillary blood analysis. It took some 45 minutes per sample. Soviet-made volume-cycled RO-2 ventilators were in use, but oxygen supply was inconsistent. Our equipment was immediately unpacked, adapted to the local voltage and current, and put to use within 12 hours. Continuous inservices for the local staff were held. Repairs of existing equipment were begun.

Team personnel were distributed based on assessment of the situation. The pharmacist was charged with setting up an ICU satellite pharmacy stocked for at least one month. He helped organize the supplies delivered by the relief effort trucks to the central pharmacy, and drew on these to supplement our own stock. Our nurse was co-opted to the Dutch dialysis team to function as a trainer/interpreter in addition to working with our ICU nurses. One physician was assigned to be available for work outside the ICU. This included assessing the sickest patients outside of the ICU and providing management such as placement of central access, starting antibiotics, and occasionally providing acute cardiac management. Home visits were made if appropriate. One physician was usually engaged in training and inservices, while the rest, paired up with a local physician and a medical student,

worked with patients. The ICU team worked with the usual U.S. standards: rounds were made three times per day and two U.S. team members were available in the ICU continuously at night. Work was shared equally. Table 3 indicates the scope of ICU activities seen in the ICU over a 2-day period that was representative of the activity throughout our stay.

We found the local medical staff to be extremely bright, dedicated, and pleasant. As time went on, teams of medical students were assigned to the ICU for training and help.

Major problems were related to lack of equipment that we were used to. Sterility precautions were limited by lack of gloves and mask; central access, wound examination, and minor surgical procedures were done with bare hands. Therapy of infections was empiric and inconsistent due to unavailability of microscopes, timely culture reports, and consistent antibiotic supplies. Chest x-rays were done only a few times per week. Infusion pumps and enteral or parenteral nutrition were unavailable. Continuous ICU monitoring and bedside ECG were not in place.

Our surgical colleagues reported severe lack of appropriate monitoring and therapeutic equipment in the OR. Anesthesiologists from our team organized a resupply effort with the Italian and French medical industry consortiums offering help.

Sporadically, there were some very uplifting scenes. We have witnessed reconciliation of the two branches of the Armenian church when the two catholicoses held an unannounced combined Sunday mass in the cathedral city of Echmiadzian. Mother Teresa was active in our hospital. The people in the streets overwhelmed us by their spontaneity and kindness.

Small groups from our team were sent by ambulance to the epicenter towns of Spitak and Leninakan to assess needs and offer help, especially in the area of acute care, transport, and medication supply. The roads were frozen and mostly unpassable at night. The devastation was, as graphically described by many others, beyond belief. Level of activity in the Leninakan Hospital, one of the few facilities left standing, reached 3,500 patients per day in the first few days. Frank discussions with the Deputy Minister of Health focused on the lack of disaster planning and training, overspecialization of the Yerevan hospitals leading to maldistribution of patients and donated equipment, inadequate stabilization of severely injured patients for transport as well as lack of focused critical care backup on site. Massive evacuation of survivors and many of the homeless residents was nearing completion. Multinational search and rescue teams were still working with the Soviet teams. Focus slowly shifted to the delivery of acute ambulatory care of the homeless survivors. Many people with lacerations, bronchitis, gastritis, diarrhea, and other manageable conditions rapidly deteriorated due to housing and weather conditions, as well as the psychological stress and depression.

Our work continued at a brisk pace until December 24, 1988. At this point, the consensus of the State Department officials and team leaders was to move the U.S. personnel back home. The situation on the ground was stabilized and no more survivors were then being rescued. We left most of our equipment behind with appropriate inservices being

TABLE 3. Scope of ICU patient characteristics

Pt.	Age	Sex	Diagnosis	Outcome
1	62	F	Biliary sepsis	Stable
2	32	F	Resp. failure, botulism	Stable
3	15	F	Resp. failure, botulism	Stable
4[a]	37	M	Liver laceration, crush injury	Expired
5[a]	22	M	Meningitis, liver laceration	Expired
6	55	M	Ethanol abuse, skull fracture	Stable, transferred
7[a]	70	M	Resp. failure, skull fracture	Expired
8[a]	27	F	Hypothermia, crush injury	Stable, transferred
9[a]	48	M	Pneumothorax, crushed chest	Stable, transferred
10[a]	65	M	Resp. failure, crush injury	Expired
11[a]	27	M	MVA, skull and leg fractures	Stable, transferred
12[a]	31	F	Hemothorax, crush injuries	Stable
13[a]	34	F	Crush injuries	Stable
14[a]	14	M	Hypothermia, malnutrition	Stable, transferred
15	52	M	Postop with brain tumor	Stable, transferred
16	53	F	Postop cholecystectomy, MI with cardiogenic shock	Stable, transferred
17	58	F	Ruptured, renal cyst	Stable, transferred
18	26	M	Postop, ruptured appendix	Stable
19	47	M	Resp. failure, brain tumor	Stable

[a]Patients injured at the earthquake site.

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completed. Local staff had things under control and were proficient in the use of U.S. devices. General inventory of high technological medical equipment donated from throughout the world has begun. Much of it was not put to use due to lack of familiarity and training (e.g., hemodialysis machines) unless accompanied by medical and technical personnel.

Our group managed to get on a Mississippi Air National Guard C-141 transport plane together with the search and rescue personnel from Seattle. The final scene of U.S. Air National Guardsmen, Soviet paratroopers, Armenian doctors, Seattle firemen, and New York intensivists unloading portable housing and loading our materials back on the plane will stay with us a long time.

After returning to New York via Turkey, West Germany, New Hampshire, and Washington, DC, we decided to proceed in organized fashion to strengthen critical care services in Yerevan. An exchange program has been agreed upon to involve training of Armenian intensivists in our institution and return visits by team members to the Republic Hospital. A program of technical assistance is getting underway and is linked to a training program. The Soviet Academy of Medicine has officially invited us to the Vishewsky Institute in Moscow to develop formal collaborative programs between our institutions. The team leader has developed a relationship with the OFDA and will continue to work as a medical officer for the State Department's assessment team. All team members have expressed willingness to return to Armenia and to be involved in similar work in the future. Some team members are becoming a part of the regional National Medical Disaster Service. The overall decision was to maintain the Montefiore Critical Care Group as a permanent flying intensive care team for both domestic and foreign disaster work and to contact other intensivists, with appropriate training in subspecialties and language skills, to work with us on a volunteer basis in the future.

Despite initial hesitation due to mixed reviews of senior intensivists present at other foreign disasters, our team had an excellent experience both in medical and humans terms. A responsible follow-up program of training and technical assistance is in place. A permanent flying U.S. critical care team clearly should be attached to search and rescue and surgical trauma personnel. Its strength, in addition to stabilizing and salvaging the sickest patients and providing heavily trained subspecialists, should also be acting as a technical and respiratory critical care resource to the other teams.

We are attaching simple recommendations for critical care teams at foreign disaster sites (Table 4). These will be greatly expanded and upgraded upon completion of evaluation meetings currently in progress.

TABLE 4. Recommendations for critical care team at a foreign disaster site

1) Work closely with the OFDA medical officer whose job it is to be the first on site and to assess the needs. He/she has access to assessment reports of previous disasters in similar geographic and circumstantial settings.
2) Be completely self-sufficient in food, shelter, water, and electricity.
3) Keep publicity at a minimum.
4) Overall philosophy should be one of collaborative practice rather than one of taking charge. Working as partners goes further than setting up an isolated superior operation. Start training your local partners as you work.
5) Communication skills are crucial and at least 50% of the team should be proficient in local language.
6) Technical and support personnel are more important than additional medical personnel; bioengineers, respiratory therapists, and pharmacists are necessary.
7) All equipment should have battery packs, be usable for transport and be adaptable for local line voltage and frequency. Tools sufficient to maintain and adapt equipment in the field should be included as essential.
8) Treatment protocols including medication dosages should be rapidly translated and duplicated for use on the ground. Large supply of simple, basic ICU drugs is preferable to huge variety and should be streamlined into the treatment protocols by ICU pharmacist.
9) Remain focused and stay together as a critical care group other than providing transport for the most unstable patients to your facility.

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RETROSPECTIVE DISASTER REANIMATOLOGY STUDY OF THE EARTHQUAKE IN ARMENIA IN DECEMBER, 1988

METHODOLOGY AND PRELIMINARY DATA

by

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*Final joint paper with conclusions and recommendations to be presented in November, 1989.

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1. INTRODUCTION AND BACKGROUND

This project on disaster reanimatology was initiated and organized by Dr. Peter Safar after the December, 1988 earthquake in Armenia, following his ancedotal interviews conducted after the earthquakes of 1970 in Peru and 1980 in Italy. Resuscitation response to major earthquakes is examined to improve every day emergency medical service (EMS) and national disaster medical systems (NDMS). This project was made possible by friendship and communication between Dr. Peter Safar (USA) and Doctors Vladimir Negovsky and Victor Semenov (USSR). Doctor Safar's invitation to the resusciation symposium held in Moscow, USSR in March, 1989 (commemorating Dr. Negovsky's 80th birthday) served as an incentive for planning a research visit to Armenia following the symposium. Doctors Safar and Ricci were unable to attend the Moscow meetings. They developed the research protocol and assembled the US team which travelled to Moscow, and then on to Armenia with the designated Soviet collaborators. In this paper, we describe and assess, in a preliminary fashion, the experience of a study group from the U.S.A. and U.S.S.R. as they attempted to construct a picture of the detection-extrication-resuscitation response to the earthquake which occurred in Armenia on December 7, 1988 at 11:41 a.m. While the main focus of this paper is the description and analysis of the methodological approach followed in this study, some selected preliminary data will be presented to illustrate the utility of the research methods.

As is by now well chronicled, the earthquake, which measured 6.9 on the Richter scale, produced damage and devastation of horrendous proportions. Approximately 21 towns and 300 villages were destroyed. Estimates of the number of persons killed range between 25,000 and

50,000. More than 1/2 million persons were left homeless. Virtually all public services in the earthquake zone were rendered inoperative requiring massive aid from the outside.

The focus of this investigation has been on critically injured victims who die slowly unless modern resuscitation (basic-, advanced-, prolonged life support, with resuscitative surgery as needed) is begun immediately. We postulate that improving medical and engineering responses to major earthquakes would enhance the lifesaving potential in most types of medical mass disasters worldwide.

Ideally, disaster planning, preparedness and responses should be extensions of everyday emergency medical services (EMS) systems at community and national levels. In recent decades, national and international responses to mass disasters in many parts of the world have been fairly effective for helping uninjured survivors not to freeze or starve to death after an earthquake, and for helping to rehabilitate the region (Public Health Response).

In contrast, the preparation for, and delivery of search and rescue, accompanied and followed by resuscitation, to the severely injured who are immediately accessible, or who become progressively more accessible through finding, digging, drilling, and extrication (Reanimatology Response) has been less than adequate in major earthquakes prior to the event in Armenia. There, some lives have been saved with delayed prolonged intensive care, such as artificial ventilation and renal dialysis. The review of emergency medical services data in the U.S.A. implies that the more rapid and effective the emergency resuscitation response--inexpensive Life Supporting

First Aid (LSFA) and more expensive Advanced Trauma Life Support (ATLS)--the more lives could be saved with less need for very expensive long-term resuscitation. The latter, even if ultimately "successful" in terms of survival, often is followed by life long disability. Effective basic and advanced life support can prevent multiple organ failure in some cases.

Disaster reanimatology begins with immediate LSFA by uninjured co-victims. This would require teaching significant numbers of the population of a nation the 6 or 8 most basic steps of LSFA. Life support would have to be continued, after "triage," as ATLS, in selected cases with resuscitative surgery (emergency amputations; and control of lethal intracranial, intrathoracic, or intraabdominal hemorrhage). For this, surgical resuscitation teams would have to be quickly assembled and transported to reach victims as rapidly as possible. Probably little can be done if they arrive at the victim's side later than 6-12 hours after injury. After the earthquake of Mexico and Armenia, relatively early arrival of medical personnel, including physicians, was available. The final step in the disaster reanimatology process should include secondary triage and rapid transport (with life support) of potentially salvageable victims to the most appropriate hospitals, for definitive surgical care and life support. Some of these hospitals may be far from the disaster area.

Triage, which must be applied repeatedly at several levels of the life support chain, is part of the daily practice of medicine in general and resuscitation medicine in particular. It merely means selecting the "most appropriate level of care" for individual patients, while considering available resources, which are always

finite. In an earthquake, for example, this may even require that certain types of injuries be selected for preferential advanced life support, while others may be selected for "letting die early".

A key factor in earthquakes is, of course, accessibility of victims. It would be most helpful for physicians to study needs and to advise and urge engineers to develop airliftable effective extrication devices, which do not injure those buried. Another key factor in earthquake response is the earliest possible mobilization of basic, advanced and prolonged life support throughout the life support chain from scene via transport to hospital, with timely and appropriate coordination of outside help.

In the past, aid across national borders has come late, with little impact on immediate life saving. Although well meant, this aid is often in the form of specialized skills, equipment, and supplies that are not needed at that time. It has become evident that preparation for mass disasters must first aim for an expanded basic response by local and regional Emergency Medical Services (EMS) combined with rapid mobilization and transport of victims to hospitals and/or trained teams to the site. Thus, a retrospective study of every major earthquake is warranted, in order to learn how to improve the total medical and public health response.

2. <u>GOALS OF THE RESEARCH</u>

a. To obtain detailed scientifically credible information about the detection-extrication-resuscitation response to the Armenian earthquake.

b. To learn about the actual human salvage in Armenia, and the potential future salvage of lives with human mentation,

using modern detection, extrication, resuscitation (basic-advanced-prolonged life support), triage, resuscitative surgery in the field, transportation and definitive surgery.

c. To use the results of this study for recommending a cost-effective resuscitation-extrication component for disaster planning-preparedness-response, which would be added to existing Public Health oriented responses and National Disaster Medical Systems (NDMS) plans.

d. To help achieve through improved disaster preparedness, more effective community-wide EMS for everyday emergencies, wherever they occur.

e. To identify ways to help countries help each other in mass disasters with the most rapid and cost-effective resuscitation planning, preparedness and relief.

f. To design and test a systematic approach to obtain scientifically credible data about earthquake response activity.

3. ASSUMPTIONS

The number of people killed and severely disabled by major earthquakes can be significantly reduced by adding to the existing Public Health response for uninjured survivors, an immediate detection-extrication-resuscitation response for critically injured slowly dying victims.

Admittedly, this team had certain assumptions or biases prior to the design of this study. The following basic assumptions guided the design of the data collection effort (P. Safar).

a. The necessary life support chain, to save so far unsalvageable earthquake victims, must be started by uninjured lay persons (co-victims) giving Life Supporting First Aid (LSFA) and continued as early as possible by medical/surgical resuscitation teams giving advanced and prolonged life support, including resuscitative surgery, in the field, during transport, and in trauma hospitals.

b. LSFA is expected to save lives primarily when started within seconds or minutes of impact. ATLS is expected to save lives primarily when airway control, i.v. fluid loading, and oxygen inhalation (with or without positive pressure or intubation) are begun during extrication. This requires pre-planned special immediate alert that the disaster occurred, communication, organization, dispatch, and transportation of the best trained personnel with the necessary supplies and equipment.

c. National Disaster Medical Systems should be established worldwide and be designed to respond to all major disasters based especially upon each country's history of events and a careful analysis of the potential for future disasters.

These assumptions which were present during the planning phase will be reexamined in the conclusions to the final report to be presented in December, 1989.

4. RESEARCH DESIGN AND PLANNING

A. Background

The research protocol prepared for this study incorporates elements of field research methods which have been used by University

of Pittsburgh teams to systematically study emergency care planning and response in approximately 30 emergency care planning regions in the United States (E. Ricci and colleagues). In these U.S. studies, multi-disciplinary research teams visited the communities and, using a carefully designed protocol, were able to document the historical and current structure and operation of the systems. Borrowing from this experience a plan was developed for studying the Armenian earthquake.

The approach followed was based upon 4 very basic ideas, namely:

(1) A record of important medical/social events is always created (in the form of journalistic reports and photographs, official organizational records and in the chronicles of other trained reporters, e.g. historians, scholars and others) and in the minds and memories of the participants.

(2) Both of these major sources of data (written and verbal accounts) can be accessed after the event; however, no single source should be used without validation through cross-checking with the other sources. In the case of reports by participants, it is necessary to obtain information from several different categories of persons and from numerous persons in each category, in order to obtain a multidimensional picture of events. Engineers tend to visualize and remember collapsed buildings; MDs and laypersons collapsed bodies; disaster managers collapsed transportation and communication systems.

(3) The research team should be multi-disciplinary, multi-professional and multinational. Team members can thus debate and discuss among themselves, from their own points of view, the interpretation and analysis of events.

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(4) Thorough pre-planning should include selection and training of team members, preparation of sampling plan and data collection instruments and design of overall research strategy; however, adjustments to the protocol are always necessary once the research team begins work in the field setting.

One can envision a wide variety of approaches to the design of a study of disaster response. For example:

(1) A single trained observer could visit the disaster site, interview participants and review any available data. Obviously, such an approach would be limited in many ways and would probably not result in a scientifically credible report.

(2) At the other extreme, one could envision a systematic survey using structured instruments of lay persons in the disaster zone and of professionals who responded based upon probability sampling of sufficient size to allow statistical generalization. Such a study could also involve a review of a probability sample of medical records. While this approach would have scientific credibility, it would be quite costly and complex to design and administer especially within a time period of close proximity to the actual event. Obviously as one gets further in time from the event, recall becomes more difficult making the survey technique less reliable.

(3) A third approach lies somewhere between the 2 just described in that it strives to obtain more data in a systematic fashion than could be obtained by a single observer, but falls short of developing probability samples of records and participants. It is this approach which is described and critiqued below. The approach can be mounted quickly, at reasonable cost and allows for the collection of both

quantifiable and qualitative data. The steps and procedures associated with this approach follow.

B. Pre-planning

Prior to the actual visit to Armenia of the research team in March 1989, extensive planning and preparation was required starting in January, 1989 (P. Safar, E. Ricci). This included:

(1) Safar contacted USSR collaborators (Semenov, Negovsky) to discuss the possibility of conducting the research study.

(2) Assembling the multi-disciplinary research team in Pittsburgh and Moscow-Armenia and obtaining international clearances and approvals for travel.

(3) Conducting interviews with U.S. physicians and organizational representatives who participated in the immediate medical and public health response to the earthquake in December, 1988, in order to learn from them what successes and problems they experienced and to obtain their advice in finalizing the protocol.

(4) Reviewing written observational and journalistic accounts of the Armenian experience in order to recreate a sketch of what occurred in the days immediately following the earthquake.

(5) Preparation of sample plan and questionnaires to be used in Armenia. These were shared with and discussed with the Russian collaborators in Moscow prior to traveling to Armenia of the Pittsburgh and Moscow team members to join with Armenian participants to the research group.

C. Question Catagories

Using designed questionnaires, the combined Soviet/U.S./Armenian research team attempted to obtain information about: (1) number of injured, geographic distribution, types of injuries; (2) pathophysiologic and therapeutic processes and time factors in dying of those not immediately killed; (3) medical response including LSFA, advanced trauma life support (ATLS), resuscitative surgery; (4) effects of the medical response upon morbidity and mortality separately for LSFA, ATLS and resuscitative surgery; (5) difficulties encountered in providing the medical response; (6) extrication procedures, results, needs, problems, successes; and (7) organization and delivery of the resuscitation response.

D. Sample of Respondents and Cities

The original plan called for the research team to work for five days in three communities in Armenia namely, Yerevan, Leninakan and Nalban. In each area, they were to select a sample of bystanders, health care providers, administrators and medical records as indicated in Table 1.

While admittedly not a probability sample, this approach did allow for obtaining information from a range of sites and involved persons.

E. Planned Procedures for Data Collection and Operation of Team

The research plan called for an organized approach to data collection using methods for research of this type which have been developed in U.S. based emergency care research. The research plan incorporated numerous features designed to increase the rigor of the data collection process.

TABLE 1

PROPOSED SAMPLING PLAN FOR ARMENIAN EARTHQUAKE

Location	Population	Number of Hospitals	Sample	Number
Yerevan	1,200,000	67	Hospitals	3
			Providers	15
			Medical Records	30
			Detection and Rescue Personnel .	5-8
Leninakan	250,000	4 (3 destroyed)	Hospital	1
			Bystanders	10
			Providers	10
			Medical Records	25
			Detection and Rescue Personnel .	5-8
Nalban (Near Spitak the Epicenter)	3,500	0	Clinic	1
			Bystanders	10
			Providers	5
			Detection and Rescue Personnel .	5-8

Each team member was equipped with a hardbacked portfolio for use in the field which contained reduced copies of each of the questionnaires which the interviewer would use for quick reference and a tablet for note taking. Each interviewer also had numerous copies of each questionnaire and these could either be used during the interview or could be completed later from notes. The functions of the U.S. research team leaier (Klain) were identified in the protocol as were the functions of team members. The team leader had the responsibility to: (1) assign and coordinate daily research tasks, (2) adjust schedule and protocols as necessary, (3) conduct daily debriefing sessions, (4) coordinate with Russian colleagues and Armenian hosts and (5) conduct and write-up interviews. Team members were expected to: (1) conduct interviews as assigned, (2) write-up

interviews using forms provided, (3) participate in daily debriefings and (4) critique and otherwise contribute to final report as requested.

At the end of each day of interviewing, and following the completion of the site visit, the research team was to have gathered for formal debriefing sessions. These sessions were to have been coordinated by the team leader. During these sessions, issues related to the research goals were to have been assessed to determine what additional data and interviews would be necessary, and what validation (triangulation) techniques may be required. At each debriefing, the data collection strategy for the next day was to have been finalized.

The debriefing sessions were generally to have followed the following format:

Each interviewer was to summarize his/her interviews in an order determined by the team leader. Each verbal summary was to conclude with the interviewers general impressions of the interview, including an identification of those topic areas where data may be missing or where verification may be in order. The team was to have assessed whether other persons, not originally scheduled for interview, should be interviewed while on site or later.

The team leader was responsible for noting key issues and problems raised by each team member. These were to provide the basic topic areas for discussion following the presentation of all the interview material by each member of the team.

In summary, numerous features of the protocol were expected to increase the scientific rigor of the data collection process, namely:

the multi-disciplinarity of the team, which had representations of U.S., Russian and Armenian scientists; use of semi-structured interviews; the pre-design of a sample in order to get information from numerous respondents of various participant types in differing locations; the planned daily debriefings; and the careful validation of information by cross-checking sources.

F. Comments About Methodology

Once the research team began to work, certain factors intervened to prevent strict adherence to the designed protocol. Problems encountered which restricted the ability of the research team to follow the sample plan were the size of the research team, which when finally assembled in Armenia exceeded our expectations, and the necessity to communicate with double translations (English to Russian to Armenian and back). These factors made the process of identifying respondents and conducting interviews more cumbersome than expected.

In addition to the factors noted (size of combined research team and translation complexities) there was also an unexpectedly heavy ceremonial schedule which drew time from the debriefing and interview functions and made the conduct of the daily debriefings virtually impossible. Also, we did not expect in advance that much time would be devoted to formal presentations by Soviet and Armenian officials; however, a number of these presentations were made for the entire research team.

Certain aspects of the questionnaires may have been too detailed and too complex for the respondents. For example, the medical providers had difficulty answering the questions: How many of the patients who died might have lived if they had received LSFA? Can

you estimate how many of the patients you saw who survived, would have survived in better condition if they had received immediate care? It should be noted, however, that the Russian members of the team obtained a significantly better response to these questions than did the U.S. team members.

On the other hand, the questions which were designed to learn about the personal experiences of the persons being interviewed were easily answered as were questions which probed their observations about the medical and extrication-detection problems encountered and availability of material and equipment.

Another problem of some importance was the relative inexperience of both U.S. and Russian participants in the conduct of interview studies and other aspects of the protocol. This inexperience made it difficult for the team to adapt to the unique conditions which they encountered in Armenia.

Finally, one dimension of the study was almost entirely abandoned, that being the proposed record review. The team did not have sufficient time to carefully select and review a sample of hospital records. Only 7 hospital records were carefully reviewed.

In spite of these difficulties, the team managed to administer in each of the targeted cities (Yerevan, Leninakan and Nalbran). (Refer to Table 2.)

While the tabulation and analysis of these questionnaires is still in process, we present in the next section a few selected items to illustrate the types of information which is becoming available through application of the protocol.

TABLE 2

ACTUAL NUMBER OF INTERVIEWS CONDUCTED BY TYPE OF RESPONDENT (SUMMARY)

	Number of Interviews
Medical Providers	32
Bystanders (Lay Eyewitnesses)	49
Extrication/Detection Personnel	20
Medical Administrators	12
Records Review	7
Total	120

In all, these numbers exceeded our planned targets in terms of medical providers (planned 30), bystanders (planned 20), extrication/detection personnel (planned 15-24).

5. ILLUSTRATIVE PRELIMINARY FINDINGS

The findings which are presented below are limited and preliminary because the research team has not had sufficient time to permit the thorough analysis of all collected data and to incorporate U.S. with Soviet data and interpretations of the earthquake response. We concentrate on the detection-extrication and medical functions and provide this information only to illustrate the types of data collected using the protocol described in this paper. We also illustrate here how the quantitative and qualitative data can be usefully blended to provide an overall understanding of the earthquake experience.

A. Detection-Extrication*

The respondents who were interviewed revealed that detection and extrication of trapped but surviving victims was carried out almost exclusively by relatives in a random haphazard manner, through non-technical means using any tool at hand and sometimes with their own bare hands. Those fortunate non-injured survivors with access to rudimentary tools such as picks and shovels who were lucky enough to locate their loved ones in the ruins, attempted extrication, many times with dire consequences. Cranes were in limited supply their usefulness was limited due to logistical problems such as access to victims, blocked roads and adverse weather conditions. In general, more effective were the manual extrication methods, namely hand-held tools. Rarely was amputation necessary for extrication. In many instances, further injury was caused upon release of crushed extremities, probably as a result of self-intoxication with ischemic metabolites and/or uncontrolled hemorrhage. Only days later did experienced search and rescue teams arrive from abroad with sophisticated detection-extrication gear. These, however, were also of limited utility.

When asked in open-ended fashion: "How was the extrication handled?" the majority of respondents (60%) pointed out that the initial response was made by relatives and bystanders using manual equipment (Table 3).

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*Refer to presentation by J. Abrams for a more complete discussion of the detection-extrication response.

TABLE 3

How was the extrication handled (initially)?

	N	%
Relatives and bystanders used manual equipment	12	60
Military and civil defense arrived within hours ...	3	15
No response	5	25
Total	20	100

In addition, it appears that heavy equipment was not available until 2-3 days after the earthquake event (Table 4).

TABLE 4

What extrication equipment was available in Armenia?

	N	%
Cranes, Bulldozers, no other equipment ..... immediately available	14	70
No response	6	30
Total	20	100

Numerous respondents documented the difficulties and hardships faced immediately by the citizens of Armenia as they tried to carry out the early detection and extrication activities. For example:

> "During the early hours, roads were impassable and traffic control nonexistent. Search operations were based on survivor, bystander and relatives' knowledge."

> "At the moment the earthquake struck, I was in the hospital at Spitak on the second floor in the trauma department. After the first shock, the ground fell. My leg was pressed by a concrete panel and I remained trapped for 6 hours. I have 3 sons and 2 of them found me and freed me. They got help from my husband and a physician. All used picks and shovels. Another woman, a physician was freed at the same time."

Several respondents mentioned how the heavy dust made breathing difficult. For example:

> "I was at home (in Leninakan) at the time of the earthquake. When I felt the first shake, I tried to run out of the apartment from the third floor. The major shock hit as I was in the stairway between the second and third floor. The stairway collapsed. There was a lot of dust making it hard to breathe. Some friends dug me out with hand tools after 6 hours and carried me on a mattress."

From a review of the interview data, it was clear that the detection-extrication effort occurred in 3 general phases. In the first phase, those who survived tried to find their family members and/or friends and they used what ever hand tools were available to do so. This is, of course, a natural response and, in Armenia the process was facilitated by the close kinship ties which exist, making it likely that family members had the best knowledge of where to find each other. The second phase occurred when the heavy equipment arrived on the evening of the first day and during the second and third days. The third phase involved the long term search for the dead. (Refer to Abrams presentation.)

B. Medical Response

The research team learned a great deal from formal briefings and interviews with medical administrators about the Ministry of Health response to the disaster, very little concerning the Civil Defense response, and almost nothing concerning military units. It was clear, however, that the military played a major role, as would be expected, in the transportation and deployment of medical teams from

around the Soviet Union to the disaster zone. How this was coordinated and the communication links utilized for this massive undertaking will not be discussed in this paper but was explored more fully by L. Comfort. We present below some of the information obtained from interviews, again to give a sense of the utility of the protocol.

Notification of the disaster was received at approximately 12:10 p.m. by the Soviet Ministry of Health in Moscow. The Moscow government group was headed by the Soviet Minister of Health, Yevgeni Chazov, who then alerted, by telephone, other medical institutes situated in Moscow, such as the Sklifsovsky Institute, the Vishniefsky Institute, the Surgical Institute, etc. Approximately 30 teams left for Yerevan at approximately 3:00 p.m., the same afternoon, via military transport. At that point in time, there appeared to be no clear plan for deployment of medical teams throughout the disaster area because information about the disaster was incomplete. These decisions were made by Minister Chazov himself upon arrival to the Yerevan Airport, where a temporary headquarters was set up. Subsequently, command and control of local operations in Yerevan and the coordination of international rescue teams was left to the Armenian Minister of Health, Dr. Gabrielyan.

Sklifsovsky Institute: Details of the medical response of the Department of Emergency Medicine, Sklifsovsky Institute, under the leadership of Professor Gazetov were presented to the research team by Dr. Vladislav G. Teriaev, on Saturday, March 18. Upon arrival to Yerevan, this team of physicians was deployed 18 kilometers to the south of Leninakan to a small town named Maralik. There they took

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over a tiny health clinic (50 bed capacity) and transformed it into a casualty receiving center. In the first two days, according to Professor Gazetov, 810 patients were transported to the center, 158 of which were operated on, and 133 were given other medical assistance.

A military field hospital was deployed near the town of Kirovakan. This team carried medical supplies sufficient to function independently for a week. In 18 days, they performed 1,253 operations and transported many patients to hospitals in Moscow and Leningrad. Both teams worked independently and there was no apparent direct communication between these teams or with medical units in Leninakan. Procedures performed at these centers included amputations, fasciotomies, and debridement of wounds. Cranial injuries were found in 32% of casualties and resulted in procedures such as trephinations and craniotomies; also general orthopedic procedures were done.

Yerevan Surgical Institute: Medical teams from this Institute were the first to be deployed by ambulance within 2-3 hours of the earthquake. However, they were unable to do much at the scene, many returning to base with only a few casualties. They were designated as the primary receiving center for crush syndrome patients and eventually received many dialysis machines donated by international organizations. Medical teams from Moscow, Kiev, Georgia and other nations, etc. were directed to the Institute, and in fact these medical personnel worked and lived there for three weeks.

At one time, there were more than 200 people, in addition to patients, housed at the Institute. Overall, they received 308 crush

syndrome patients on the evening of December 7-8; 108 of them had to be evacuated to Moscow immediately because the dialysis capacity was exceeded. There were greater than 100 hemodialyses performed per day at this Institute on crush syndrome patients. In the first few hours to days, 500-600 victims were being cared for at any given time. Patients were transferred from there to other cities within the Soviet Union in addition to the United States and the Federal Republic of Germany for definitive care.

The director of the Yerevan Children's Hospital provided a picture which appears typical of the experience of Armenian hospitals. The Yerevan Children's Hospital directed 14 surgeons to Leninakan and they arrived at 2:00 p.m. on December 7. However, the team could do little because they had limited supplies and returned to the hospital at 4:00 p.m. By 6:00 p.m. on the 7th of December, injured patients began arriving at the hospital. In total, they received 819 patients of which 217 were children. Of the persons treated, 111 were found to have had no major injuries and were sent home; 454 had sustained severe injuries. One hundred fifteen patients suffered from crush injuries; 76 required hemodialysis; 17 children died, all from crush syndrome. More than 60% of the persons treated at this hospital were transported by friends and relatives in private vehicles. According to the Director of the Children's Hospital:

> "Many people died due to the effects of uncontrolled bleeding after removal from the rubble. In general, the public did not know what to do."

Numerous lay respondents documented the infrequent application of LSFA (Table 5).

TABLE 5

Which and how many life saving procedures did you see performed in the field by others? (Bystander Responses/Partial Data)

	N	%
Saw no first aid provided in the field	10	50
Saw students stopping bleeding	1	1
No response or not sure	9	49
Total	20	100

If we combine the "uncertain and non-responses" with the respondents who stated they did not see first aid being administered, we can see that only 1 of 20 bystanders interviewed saw anyone administering first aid in the field.

When asked to identify the kinds of injuries which the medical teams encountered, the medical providers listed the following in order of frequency: open lacerations, fractures, crush injuries, shock, limbs requiring amputation, airway obstruction/hypoventilation from dust, infections, coma. The major causes of death as reported by medical providers were: crush syndrome, hypovolemic shock and exsanguination, cranial trauma, multiple injuries, complications and effects of trauma.

6. CONCLUDING COMMENTS

In this concluding section, we present comments about the methods used in this study. Subsequent papers will report on the complete findings concerning the medical, engineering and public health response to the disaster.

While much of the protocol prepared for use in this project appears useful, certain alterations would increase the quality and rigor of the data collection effort. At this time, prior to final debriefing of participants and thorough review of the data, we would suggest the following:

(1) Brief formal training of interviewers in the methodology and use of the questionnaires appears to be necessary. Professional education in fields of relevance for disaster response does not in itself prepare individuals for research of this sort. Without doubt the accuracy, completeness and reliability of the interviews can be improved through interviewer training.

(2) The interview schedules used in this project were not pilot tested due to time constraints. Had sufficient time been available, we would have created a "mock situation" in which the interview schedules would have been tried on persons who could simulate earthquake participants. Experienced survey researchers have learned how invaluable this step is for refining questionnaires. In the near future, we will be able to revise the questionnaire used in this study on the basis of our analysis of their utility, and they will be available for use in future research. Certainly, we will suggest changes in the questionnaire content, wording of questions and order in which the questions were asked.

(3) Time estimates for data collection must be inflated by at least 50% over what they would be if the researchers were working in their home countries. Working with translators, ceremonial functions, on-site planning, travel arrangements and adjustments to a foreign culture all require time over and above what would be needed

if the research were to be carried out in the home country of the research team.

(4) The entire issue of probability sampling must be given careful consideration. For some target groups (administrators, extrication/detection persons and medical providers) it should be possible to develop sampling frames from which probability samples can be drawn; or, a significant number of the entire subgroup can be interviewed making sampling unnecessary. In the case of lay eyewitnesses and medical records, probability sampling will be both difficult and costly due to the inevitable gaps in medical record taking in disasters and the destruction of streets and homes which make systematic household surveys difficult until months after the event. Our approach, which involved getting sufficient numbers of persons in varying locations, using predesigned interview schedules, is enabling us to identify patterns of response. Where there is little variation in response, our confidence in the external validity (generalizability) of our findings increase. Where there is great variation, we look for explanation in the location or characteristics of the respondent.

(5) Certain aspects of the protocol are very important to keep. The multi-disciplinary, multi-professional and multi-cultural nature of the research team is of fundamental importance. Validation of information by using different sources (interviews with various types of persons involved in the disaster, official records, both medical and organizational, and photographic records) is absolutely essential. Rules for research team organization and functioning should be followed as carefully as possible (roles of team members,

field debriefing, sampling targets, etc.). And finally, the use of tested predesigned questionnaires seems essential to the systematic collection of data which has sufficient reliability and validity to be of scientific value.

We will report in the future further refinements of this protocol and these materials and plans will be available for use in future research.

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DINNER

DATA ACQUISITION FOR EARTHQUAKE HAZARD MITIGATION

ABSTRACT

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Immediately after a damaging earthquake (such as, for example, the September 19,1985, Spitak (SSR) earthquake), data should be collected in five basic categories: geologic studies, seismological studies, engineering seismology studies, engineering studies, and societal studies. These data can be used in windows of opportunity provided by the event to:

- Change professional practices of siting, design, and construction.
- Expand the capability for hazard and risk assessment.
- Increase public awareness of hazards and risk.

Such actions will over time transform the tragedy of a devastated community into an opportunity to make the urban center less vulnerable to future earthquake occurrences.

INTRODUCTION

In the aftermath of a damaging earthquake, the reconstruction and recovery processes receive highest priority. Many communities seek an immediate investment of capital to rebuild their community just as it was before the earthquake struck. However, a tragedy also provides a window of opportunity for adopting mitigation measures that will prevent a repitition of the disaster. The communities that utilize the opportunity of the damaging event to acquire basic data are the ones that are most likely to incorporate mitigation measures in the reconstruction process.

A damaging earthquake provides the best source of data for earthquake hazard mitigation. After a damaging earthquake, several types of post-earthquake investigations should be undertaken to advance fundamental knowledge and to foster mitigation. These are:

- Geological Studies - field investigations to determine the cause, nature, degree, and spatial distribution of faulting, regional tectonic deformation, landslides, liquefaction, and wave inundation from seiches, tsunamis, and dam failures.

- Seismological Studies - measurement programs using arrays of permanent and mobile seismographs to locate the main shock and individual earthquakes of the aftershock sequence, to define the spatial extent of the rupture zone of the causative fault, and to determine the focal mechanism of the main shock.

- Engineering Seismology Studies - measurement programs using arrays of permanent and portable strong motion accelerographs to measure the amplitude, spectral composition, and duration of strong ground motion for a wide range of magnitudes, epicentral distances, and soil profiles.

- Engineering Studies - investigations of individual buildings to determine the failure mechanisms, nature, degree, and spatial distribution of damage to the entire range of structures, exposed to the physical effects of the earthquake, including: single family dwellings, low-to-high rise buildings, schools, industrial facilities, lifeline systems, and critical facilities.

- Societal Studies - interviews and on-site observations to determine how the populace reacted before, during, and after the earthquake, focusing especially on behavior during the response and recovery periods.

These investigations provide the data and experience needed for devising and adopting effective earthquake hazard mitigation measures which can be implemented before the next damaging. These measures should be based on technical and social strategies such as:

- Planning and building to withstand the physical effects of ground shaking, permanent ground failure, regional tectonic deformation, tsunami runup, flooding from seiches and potential dam failure, fire, and the aftershock sequence.

- Identifying and avoiding the sites where the physical effects of an earthquake are expected to be most severe.

- Predicting the occurrence of a major earthquake with a comprehensive scenario of the physical effects.

- Initiating emergency preparedness and emergency medical response programs designed to reduce life loss.

- Implementing damage control measures in communities located in earthquake-prone regions.

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CRITICAL QUESTIONS GUIDING DATA ACQUISITION

The goal of earthquake hazard mitigation is to reduce the destructiveness, morbidity (injuries), and mortality (deaths) associated with future earthquakes, using one or more of the technical or social strategies listed above. Destructiveness is primarily related to three factors:

1) The magnitude or energy release of the earthquake,

2) The proximity of the earthquake focus to an urban center, and

3) The extent to which mitigation measures have been adopted and implemented in the urban center when the earthquake strikes.

Data acquisition should be planned to build a database that quantifies the nature and extent of the earthquake hazards and facilitates the assessment of the risk. To quantify the hazards and risk, data must be collected to answer questions in eight categories:

- Deaths, Injuries, and Destructiveness - How did morbidity (injuries), mortality (deaths), and economic losses correlate with the distribution of buildings and facilities in the affected area? What was the state-of-preparedness in the urban area?

- Failure Mechanisms - For each type of building or facility in the affected urban area, what were the primary and secondary failure mechanisms? Why did some buildings of a specific type not fail?

- Design and Construction - To what standard (code) was each damaged building designed? When? What was the actual demand on the building? What was the design capacity? During design and construction, what practices were followed to ensure strength, ductility, and redundancy? How was quality controlled?

- Siting - What physical characteristics controlled the critical design parameters: magnitude, wave attenuation, local soil response for the damaged building or facility?

- Affected Area - What were the spatial dimensions of the geographic area affected by the earthquake? What controlled them?

- Severity - How severe were the primary and secondary physical effects in the near- and far-source regions of the earthquake? What geologic parameters controlled them?

- Impact Time and Duration - How much time was there between the first precursors of the earthquake and its maximum physical effects. How long did the physical effects last?

- Frequency - How often on the average is an earthquake of this severity expected to occur in this region? After each damaging earthquake, these data are entered into a database which provides a technical basis for extrapolating to other locations and other events.

DATABASE

The quantity and quality of the technical data in the data base are the two most important factors that facilitate its use in earthquake hazard mitigation. If the database is complete and integrated, mitigation strategies evolve rapidly with minimal controversy. The technical data base should be developed on the following scales as developed in the International Atomic Energy Agency's Safety Guide, Number 1, developed in 1989:

- o Regional (map scale of 1:500,000) - to determine all of the factors which contribute to the seismic hazard at a site. The radial extent of data acquisition is typically 150 km or more from the site area.

- o Near regional (map scale of 1:50,000 or smaller) - to determine the seismotectonic model. The radial extent of data acquisition is typically 150 km or less from the site area.

- o Site vicinity (map scale of 1:5,000 or smaller) - to determine the physical parameters (and their range of values) that control the site-specific characteristics of hazards such as ground shaking, ground failure, surface faulting, and tsunami runup. Data acquisition encompasses a distance of about 5 km from the site area.

- o Site area (map scale of 1:500 or smaller) - to determine the failure mechanisms of specific structures, facilities, and lifeline systems and the societal impact of their failure.

The database typically contains information such as the following:

- o Societal Data (partial list)

  -- deaths and injuries
  -- homeless
  -- economic losses
  -- loss of function
  -- political and legal considerations
  -- cultural (museum, art, architectural losses)

- o Engineering Data (partial list)

  -- construction data
  -- damage distribution for each class of buildings
  -- building plans
  -- building codes

- o Engineering Seismology data (partial list)

  -- building and free field strong ground motion records
  -- geologic properties of the building foundation
  -- isoseismal map
  -- microzonation maps

- Seismological Data (partial list)

  -- seismicity
  -- seismic wave propagation
  -- soil response
  -- seismicity
  -- focal mechanism
  -- stress field

- Geologic Data (Partial list)

  -- faults
  -- seismogenic zones
  -- bedrock geology
  -- liquefaction and landslide inventory
  -- water table
  -- quaternary geology
  -- seismotectonic model
  -- topography

KNOWLEDGE UTILIZATION

Knowledge utilization for earthquake hazard mitigation is beyond the scope of this paper. However, it should be pointed out that knowledge alone makes no contribution to earthquake hazard mitigation if it is unknown, misunderstood, inappropriate, unintelligible, misdirected, or ignored by practitioners. The reference report by U.S. Geological Survey discusses knowledge utilization more fully.

SPITAK EARTHQUAKE

To illustrate the concepts of this paper, information derived from the December 7, 1988, Spitak earthquake is contained in Appendix I. When completed, the database for this earthquake will guide reconstruction and research for long-term hazard mitigation.

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APPENDIX I:
EXAMPLE OF THE KINDS OF DATA AVAILABLE FROM
THE DECEMBER 7, 1988, SPITAK EARTHQUAKE

BACKGROUND

The magnitude 6.3 Spitak earthquake which struck Soviet Armenia at 11:41 a.m. local time on Wednesday, December 7, 1988, produced considerable data. They are summarized below as an example, which even though incomplete, illustrates the importance of data acquisition:

1. Societal Data

- o 20,000 injured,
- o an estimated 60,000 dead, (the exact number may never be known),
- o 510,00 homeless.

2. Engineering data

- o extensive social disruption (for example, relocation of children, injured, and the homeless),

- o reconstruction costs that are estimated to reach $16 billion or more.

  -- in Spitak: damage to 100% of the building stock, with at least 12,000 to 15,000 dead,
  -- in Leninakan: damage to 80% of the building stock with at least 10,000 to 12,000 dead, and
  -- in Kirovakan: damage to 50% of the building stock, with at least 450 dead.

In Armenia, the principal building types were:

-- Stone-bearing wall buildings, the traditional construction technique until 1970. These buildings were limited in height to five stories. The masonry walls are thick, lack steel reinforcement, and provide both lateral and vertical support for the hollow core concrete plank floors and roofs which were introduced in the 1950's and 1960's.

-- Composite frame and stone wall buildings, mostly 4- and 5-story buildings consisting of exterior stone shear walls and framing system cast within the walls as well as the interior of the building.

-- Precast concrete frame buildings, which began in the 1970's and today are the predominant design for residential and industrial structures. In the affected area, the tallest of these buildings was nine stories with one-story penthouses. Floors and roofs are precast hollow-core concrete planks that bear on the walls but have no connections. The buildings have steel reinforcement.

-- Precast concrete-panel buildings, a contemporary building type in Armenia which was just beginning to be widely constructed for

public and residential use. They ranged in height to nine stories. Floor and roofs are also precast hollow-core concrete planks. They are relatively stiff.

-- Concrete lift-slab buildings, which involve either one central core or double cores of cast-in-place concrete shear walls. Floor and roof slabs are cast in grade, lifted into place, and supported by columns. The cores provide lateral stability for the structure. Building performance depends strongly on the quality of the attachments of the slabs of the cores. Only two buildings of this type--one of 10 stories and another of 16 stories--had been erected in Leninakan at the time for the Spitak earthquake.

o In the 400 square kilometer epicentral region affected most severely by the Spitak earthquake, the damage statistics for the four principal types of buildings stone bearing wall, composite frame and stone wall, precast concrete frame, and precast concrete-panel are:

-- 314 buildings collapsed,
-- 641 needed to be demolished,
-- 1,264 needed repairs or strengthening, and
-- only 712 (24%) remained habitable after the earthquake.

o Failure Mechanisms of Stone-Bearing-Wall Buildings

-- Damage to stone-bearing-wall buildings, which were the predominant construction type in Spitak, occurred in a variety of ways:

-- The onset of damage typically occurred at building corners with almost every surviving building showing visible cracks.

-- In some buildings, the walls tilted away from the concrete plank floors, resulting in the collapse of the planks.

-- In some buildings, the end walls collapsed; whereas, in others, the end walls remained upright and the middle collapsed as a consequence of the failure of the precast hollow-core concrete planks to act as an effective floor diaphragm, causing the transfer of forces to the masonry walls.

o Failure Mechanisms of Precast Concrete Frame Buildings

-- Precast concrete frame buildings in Armenia were typically constructed in long rectangular configurations with columns and beams providing the vertical load carrying system. The floor and roof systems were hollow-core precast concrete plans, without topping slabs or positive connections to the building frame. Perimeter walls and selected interior walls of unreinforced masonry infill, precast fascia panels, and precast-concrete-shear panels were designed to provide lateral stability in the longitudinal direction; whereas, the frames were designed to provide the lateral-load resisting path in the transverse direction.

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-- The most common failure patterns included:
-- Separation at wall, floor, and corner connections.
-- Loss of longitudinal stability due to infill masonry (typically volcanic tuff) falling out of the frames.
-- Damage at corner splices, which consisted of lap welds of reinforcing steel bars extending from the upper and lower column sections. Due to poor quality control in the field, these splices were often eccentric.
-- Loss of containment due to minimal hoop reinforcement.
-- Buckling of columns at reinforcing splices.
-- Failure of frames due to the rigid, heavy, precast infill panels.

3. Engineering Seismology

o The Spitak earthquake produced evidence of two important effects:

-- the "direct hit" which Spitak took because of its location in the near field on the up-thrown block of the causative thrust fault.

-- the amplifying effects of the 200-300 m thick clay lake-bed deposits underlying Leninakan. These deposits, which had a shear wave velocity of 300-350 m/sec, amplified the foundation ground motion in the 1-2 second range by a factor of ten or more, relative to rock.

o Armenian engineers rated the epicentral intensity as IX to X (MSK scale). They estimated that levels of horizontal peak ground acceleration may have reached 0.50 to 1.0 g in Spitak, with possibly a large vertical component as well because of the thrust fault.

o The estimated level of horizontal acceleration in Leninakan was about 0.40 g. Based on seismoscope record.

o Recorded peak ground acceleration values are 0.21 g at Ghoukasian (located 33 km from the epicenter) and 0.06 g at Yerevan (located 100 km from the epicenter).

o In Armenia, most buildings were designed for an intensity (MSK scale) of VII to VIII, with reductions being permitted for bedrock (volcanic tuff) foundation materials.

4. Seismological Data

o The U.S. Geological survey collected data from 1750 aftershocks on conventional and broad band seismometers. These data will be analyzed to delineate the rupture zone and the rupture mechanisms.

5. Geologic Data

o Field mapping in the spring of 1989 has shown that the causative fault broke the surface over a distance of 15 km. Snow cover had prevented the earlier determination of the full surface break.

When all the categories of data have been collected, the Spitak earthquake will be a valuable resource for research.

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APPENDIX A:
QUESTIONS AND MATERIAL FOR BREAKOUTS

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Questions for Breakout Session 1: Tuesday 11 July: 1:15 p.m. – 3:00 p.m.

Topic: Comprehensive Reference to Existing Data

1. What is the value of data taken from past earthquakes in answering questions about occupant survival?

2. Are there sources of information on past earthquakes which have not been tapped (e.g., hospital records?) Could appropriate research retrieve this data?

3. Is it possible to get more detailed data on building collapse from past earthquakes? Surveys of photographic archives? Interview of professional investigators?

4. Is it possible to structure existing data from past earthquakes to provide a more comprehensive understanding of damage-injury relationships, and how should this be done?

5. Do we need retroactive review of existing data ....

6. How good are existing data sources?

7. Do we have any more specific injury data?

8. Do we have data on individual rescue efforts from international teams?

9. How were injury and death calculations/estimations made in previous earthquakes?

10. How many people died after rescue?

11. Evaluation and discussion of existing information from past events of causes of death and injury patterns. Which earthquakes have the best available data? Is it worth expending time and resources going back to study earthquakes 100 years ago, 50 years ago, 10 years ago?

12. Review should be conducted of previous research on casualty estimation.

13. Identify relevant expertise. Who are the individuals/organizations who have made, or have the potential for making, significant contributions in the area.

14. What databases are currently available and appropriate?

    (a) Japanese, Latin American, Italian, Chinese and Turkish earthquakes, etc.

    (b) Mine collapses – U.S. and international

    (c) CIA – terrorist attacks

    (d) Vehicle extrication (train, automobile, etc.)

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Specific Building Studies

1. San Fernando Veterans Hospital – 1971, 49 dead
2. L'Ambiance Plaza, Bridgeport, Connecticut – 1987, 28 dead
3. New World Hotel, Singapore – 1986
4. Hospital of San Angelo de Lombardi, Italy – 1980
5. Juarez Hospital, Mexico – 1985, 700(?) dead
6. General Hospital, Mexico – 1985 (Durkin)
7. Kalamata Apartment House, Greece – 1986
8. Ruben Dario, San Salvador – 1986, 300(?) dead
9. U.S. Marine Barracks, Beirut, Lebanon – 1983
10. Southern Towers, Bailie's Cross Roads, Virginia – 1970
11. Planning Department, San Salvador – 1986 (Durkin)
12. Amigo Department Store, Brownsville, Texas – 1988

Possible Building Data Related to Injury

1. Diyarbakir, Turkey – 1985-6 (Oktay Ergunay)
2. Skopje – 1963 (Zoran Lutonivitch)
3. Kyushu Hotel – 1975 (Ohta)
4. Caracas, Venezuela – 1967 (Rene Torres)
5. El Esham, Algeria – 1980
6. Tangshan, China – 1976 (Zhang Ziyang-Tongji)
7. Mexico City – 1985 (20 buildings) (Juan Diaz de la Garza)
8. Armenia – 1988 (individual building cases)

Questions for Breakout Session 2: Tuesday 11 July: 3:15 p.m. – 5:00 p.m.

Topic: Consensus on Field Research Protocol and Implementation

1. What are the fundamental questions that need to be answered?
2. What critical variables do we need to record at the aggregate level – gross numbers for the entire event?
3. What critical variables do we need to record at the site (single building collapse) level?
4. What critical variables do we need to record at the individual victim/rescue level?
5. What is the feasibility of comprehensive data collection in the field? How do we allocate data collection capability over the disaster area?
6. How do we collect *early data* – that relating to the spontaneous rescue period: the first few hours after the event when most rescues are accomplished?
7. How can we formalize data collection in organized rescue and medical groups? How can data collection be made compatible with rescue activity? What information should rescue and on-site medical personnel be prepared to collect or relay to researchers?
8. Develop a standard list of variable definitions.
9. Standardized data collection form to increase numbers.
10. Can satellites/balloons/aerial photography be used to provide useful data to rapidly assess casualties?
11. Should we do case control?
12. Is there a role for expert computer systems in this research field?
13. How do researchers access information obtainable only from on-site personnel?
14. How can we rapidly set up reporting system, surveillance scheme?
15. How important is data collection at the time of the earthquake? Can good data be collected retrospectively weeks or months later? Is there such a thing as "perishable" data in epidemiology? Is it important to have "on the spot" information systems for monitoring health needs? What is the best time to carry out assessment of health effects?
16. How to collect data in less developed countries. Is it necessary to have collaborators from these countries?

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17. What is the best way in which to foster inter-country cooperation and collaboration in earthquake research, particularly among countries exposed to similar types of hazards?

18. How can we develop better record linkages?

19. Is it possible to conduct randomized, controlled, prospective studies in this setting? How can we choose control group? Can we make conclusions regarding cause and effect without doing the above? Can we determine cohorts defined by type and level of exposure? Can we determine proportion of risk attributable to disaster? Are only observational studies (e.g., descriptive survey, "before and after," or retrospective case comparison) possible?

20. Which profession(s) should perform the research (note multidisciplinary efforts needed)? What should be the makeup of an onsite team?

21. What classes of events should be studied?

    - Major urban (over 1 million)
    - Small town (up to 250,000)
    - Rural areas (no town above 10,000)

22. What other causes of collapse should be considered as relevant?

    - Blast (e.g., terrorist)
    - Construction failure
    - Ground failure (landslide, subsidence, etc.)
    - Wind

23. Are there analogies for the structural collapse problem from which lessons on data collection methodology can be learned? For example, mine disasters, aircraft or train crashes, wartime experiences, and so on.

24. Choice of the suitable data collection methods in order to quantify the selected indices (how to measure?).

25. What minimum information can be realistically gathered in the health field for rapid decision making after an earthquake? The data on damages collected in actual disasters are usually crude estimates based on superficial observations of limited technical and statistical validity.

DATA COLLECTION FORM

I. Building Information (for each building with victims.)

Pre-event Data

1. Address/location
2. Function
3. Occupancy
4. Type of construction/number of floors
5. Sketch of original dimensions – plan and elevation
6. Pre-event photo (if possible)

II. Damage Data

1. Photos of damage (4 aspects)
2. Estimate of volume loss -% loss of interior space
3. Verbal damage description

III Casualty Data (for each victim) General Victim Descriptors

1. Age
2. Sex
3. Health status (percent)
4. Occupant status
5. Height/weight

Morbidity

1. Discovery time
2. First treatment time
3. Extrication time
4. Hospital arrival time
5. Injury severity and affected body part

6. Location in building and circumstances of entrapment and injury

Morbidity

1. Time of extrication/discovery
2. Cause of death/retroactive injury severity assessment
3. Time of death (estimated)
4. Location in building and circumstances of entrapment and injury

IV Treatment and Injury Outcome

1. Time of Arrival at Hospital
2. Treatment
3. Time of Release
4. Condition at Time of Release

Victim Tagging - Extricated Victims should be tagged at site to allow follow through to hospital and subsequent treatment. **Hypotheses:**

1. Casualty ratio is related to the ratio of interior space loss in the building
2. Morbidity/Mortality ratio related to type of construction
3. Injury severity distribution is constant for a given construction type and ratio of interior space loss

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Johns Hopkins July 11 1989

Phase 1 - Perishable - hrs - days
2 - Intermediate days - weeks
3 - Longterm - never lost Records etc.

MASTER DATA FORM

I. DISASTER EVENT

a. Type:

b. Time occurred: AM/PM Date: Duration_____

c. Onset: Sudden_____ Gradual_____

d. Magnitude (Richter or Mercalli scale)_____

e. Warning: Yes_____ No_____ # hours/min. prior_____

f. Evacuation plan available for building/town:

Yes_____ (followed ?) No_____

g. Attempts to evacuate:
Yes_____ No_____

h. Location: (of impacted area)

i. Date and time of interview:

j. Were the injured triaged upon removal?

Yes_____ No_____ Unsure_____

k. Was the search and rescue team trained to treat the injured?

Yes_____ No_____ Unsure_____

l. Was there a disruption of transportation routes?

Yes_____ No_____

m. Degree of communication disruption:

a. Local
b. Hospital
c. Communication with outside (state/country)

n. Population per square mile/kilometer _____

Building(s)

1. Previous earthquake?

2. Previous injuries or deaths?

3. Last major renovations

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ON SITE FORM

I. TYPE OF INJURY

1. a. Person injured:

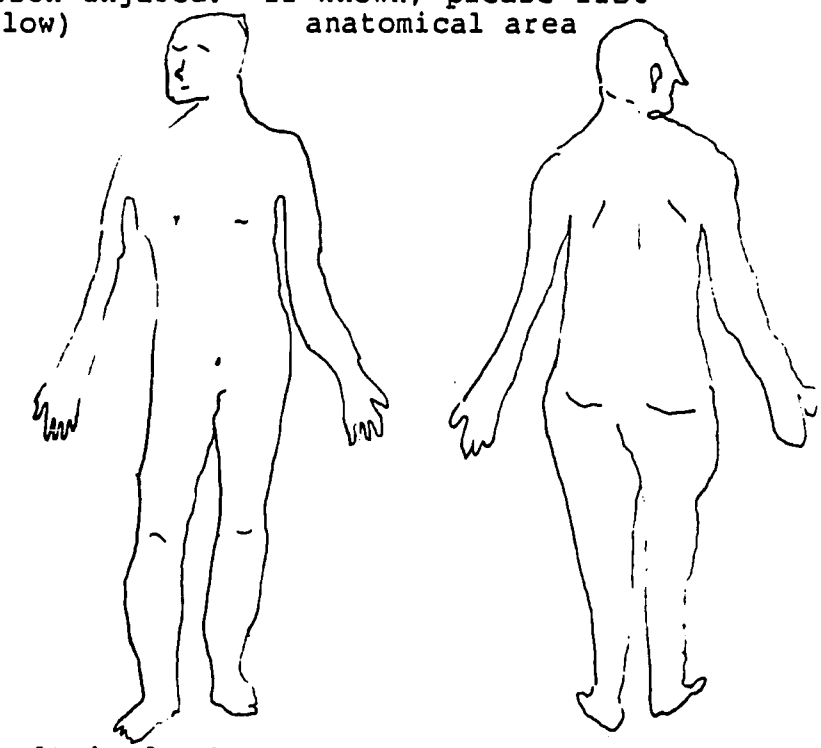
   b. Approximate age: M/F

      <1 ____ 1-5 yrs.____ 5-14 _____ 15-44_____ 45+____

   c. Cause of injury: (i.e. struck by beam, brick, burn etc.)

      _____

   d. Where was the person injured? If known, please list anatomical area
      (please label below)



#= fracture
o=contusion
/=laceration
~~=traumatic amputation
? ---= other (or shading)

   e. Did the injury result in death?

      Yes_____ No _____

   f. If deceased, was cause of death due to:

      1. trauma

      2. other(cold/heat exposure, electrocution, asphyxiation)

   g. If deceased, was there rigor mortis?

      Yes_____ No_____

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h. Was there any evidence of decomposition?

Yes_____ No _____

e. Did the injured have a previous handicap or existing disease?

Yes_____ No_____ Unknown_____

Wound:

deep/gaping_____ superficial_____

f. Upon extrication was the person (patient/victim):

1. Bleeding: severely _____ minimally_____

2. Conscious: yes _____ no_____

speaking_____ not speaking_____

3. Breathing:

Yes_____ Normally_____ With difficulty_____

No_____

4. Circulation: Does the injured have a pulse?

Yes_____ No_____

5. Moving extremities?

Yes _____ No_____ all_____

6. Abdomen:

normal, non-tender_____ tender or painful_____

open wound_____

II. SEARCH AND RESCUE EFFORTS

1. How long (minutes/hours) passed before Search and Rescue arrived?

2. How much time elapsed before medical/paramedical assistance arrived?

3. What form of assistance arrived:

fire_____ ambulance/hospital_____ police_____

other (please specify)_____

4. How much time elapsed from the actual incident to time of extrication?

5. How much time elapsed from extrication to medical or para-medical attention?

6. How much time passed until arrival at hospital?

7. Was anyone with the injured during entrapment?

yes_____ no_____

8. If yes, was there:

human contact_____ voice _____

9. Was the injured person rescued by family/neighbors or search and rescue members?

10. After rescue did the victim receive any form of treatment by medical personnel?

Yes_____ No_____

If yes, professional at site

_____

11. What type of care was administered? (on site)

a. CPR (Chest compressions/artificial breathing) _____
b. Basic first aid _____
c. IV support initiated _____

12. Was the injured person taken to a hospital?

Yes_____ No_____

13. How was the injured transported?

ambulance_____ family_____ other_____

III. LOCATION OF INJURED PERSONS

1. What part of the building did the injured people come from?

floor# _____ center_____lateral rooms_____ basement_____

2. What area of the building did the unharmed people come from?

3. Where were the deceased people found?

4. How did the building collapse?

walls crumbled_____ ceiling caved in _____

(Sketches will replace these questions)

IV. DECEASED

1. Was the individual discovered alive but died before rescue?

Yes _____ No_____

2. Was the individual extricated successfully but subsequently died?

Yes_____ No_____

HOSPITAL SUMMARY

Total deaths _____

Total injuries _____

Major injuries seen (surgery/trauma, burns electrocution etc.) _____

Hospital:

DOA _____

Treated & released _____

Treated & admitted _____

Complications (Please List)

Prior disaster experience, type _____

Prior use of disaster plan _____

BUILDING will be expanded later

1. Age of building

2. Floor Plan (L, H, T or rectangular shape)

3. Type of: construction frame
   internal reinforcement support cables

4. Type of walls roof

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Variables to be considered for studying the
Epidemiology of Injuries following earthquakes
DRAFT for Discussion

I. Independent/Predictor Variables:

A. Seismological factors:

1. Intensity: measured on the modified mercalli scale,
2. Magnitude: measured on the Richter scale,
3. Location of/distance from the epicenter,
4. Depth to the hypocenter,
5. Vertical/horizontal acceleration,
6. Surface wave magnitude (Ms) and Body wave magnitude (Mb).

B. Demographic factors:

1. Population density and variability,
2. Age structure of the population,
3. Age and birth order of children,
4. Sex,
5. Absence/presence of company in the building,
6. Average inhabitants per building,
7. Single vs. multiple occupant.

C. Socio-economic and behavioral factors:

1. Urban/Rural,
2. Level of education and occupation,
3. Social customs,
4. Behavior during earthquake (? fright and flight)

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D. Geo-physical factors:

1. Soil characteristics,
2. Houses/buildings destroyed (from aerial survey),
3. Number homeless after event,
4. Direction in which the walls fell.

E. Engineering/housing factors:

1. Dominant building material/type of construction,
2. Type of roof (Heavy vs. Light),
3. Size of house/building,
4. Age of building or years of last major renovation,
5. Number of rooms, doorways, and windows,
6. Floor plan of house at the time of quake -- configuration,
7. Occupancy -- single vs. multiple occupant,
8. Collapse pattern -- loss of intrinsic space,
9. Date of construction,
10. Building codes -- Did building meet these codes?

F. Temporal factors:

1. Time of day of seismic event,
2. Time at which injuries were sustained,
3. Day of week,
4. Time of year,
5. Temperature.

G. Spatial factors:

1. Entrapment,
2. Location at time of the event.

H. Medical factors:

1. Rapidity of medical response,

2. Distance from health care facility,

3. Availability of and accessibility of rescue and medical care.

I. Clinical factors:

1. Exact description of injuries (International Classification of Diseases [ICD-9] Codes),

1. Cause of death determination

2. Autopsy (post-mortem findings),

3. Estimation of time of death -- early vs. late deaths.

J. Survival factors:

1. Fade-away time

a. Animation Score

b. Injury Severity Score

c. Environmental factors

d. Pre-collapse health status

K. Rescue factors:

1. Rapidity of search and rescue response,

2. Extraction difficulty -- Time (man hours),

3. Equivalent man hour,

4. Effective rescue manpower.

L. McClure Variability

1. Life Safety Ratio - number of fatalities per 10,000 for a particular class of building.

2. Equivalent Construction Occupancy - number of 24 hour/365 day occupant.

3. Life Safety Ratio Goal - estimated as attainable by class of building.

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M. Post-event factors:

1. Aftershocks,
2. Landslides,
3. Liquefication of the ground,
4. Exposure/Temperature,
5. Epidemics,
6. Loss of food supplies.

N. Societal factors:

1. Homeless
2. Economic losses
3. Loss of function
4. Political and legal considerations

II. Dependent/Outcome variables:

1. Health care needs,
2. Injury rate,
3. Death rate,
4. Proportion with fractures (severe injuries),
5. Proportion with survivable injuries.

POSSIBLE RESEARCH APPROACHES

1. What is the construction material/building system as relates to:

   a. collapse pattern - void space

   b. extraction difficulty - RC/Unit ???? heavy, long units, hard to penetrate

2. Building Shock (Collapse Potential)

   a. Take a given Building Shock

   b. Take a given Event

<u>Output</u>: #, size, type of collapsed buildings

3. Building Occupancy (Time dependent, function dependent)

   a. Take given number of collapsed buildings

   b. Occupant behavior

<u>Output</u>: Distribution of victims.

- Injury Severity (Fade-away time)
- Extricability -- 1 m/u
  -- 10 m/u
  -- 100 m/u

4. Rescue Resource Demand

   a. Based on Event (Automatic)

   b. Based on Collapse Volume (???????)

   c. Based on Occupancy (Site collected)

5. Rescue Resource Allocation

   a. Optimize over multiple sites of various conditions

   b. Arrival time/<u>Ratio of Application</u>

6. Optimal Resource Allocation over time.

Questions for Breakout Session 3: Wednesday 12 July: 9:00 a.m. – 10:15 a.m.

Topic: Research Applications/Implementation/Dissemination

1. Who will use casualty estimates?
   - disaster planners
   - insurance companies
   - health planners
   - search and rescue organizations
   - building designers
   - code developers
   - building occupants
2. What are the principal questions of these groups? How does the rescue program is this area respond to the information needs of these groups?
3. What form should presentation of results take?
4. What agencies – local, national, international – should be addressed by research results?
   - fire departments
   - emergency managers
   - emergency physicians
   - health services
   - FEMA
   - WHO/UNDRO
   - engineers and architects
   - EERI
   - NCARB/AIA
5. How do the research findings relate to practical issues of search and rescue?
6. What is the best mechanism for disseminating results of earthquake injury research to the targeted user(s)?
7. What types of research applications and products have users found useful and why?
8. How applicable is data obtained from many different countries to earthquakes and search and rescue efforts in the U.S.? Can we learn from earthquakes in other countries? What differences must be taken into consideration?

9. Is it possible to develop "Real time response modelling," That is, the development of a casualty estimation system for optimization of rescue and on-site medical activities.

10. Is it possible to develop models of spatial distribution of casualties identified by building context and injury severity in order to develop specific management directives.

11. Is it possible to predict the following post-earthquake needs:

    (a) Manpower and equipment demands

    (b) Mobilization and logistics

    (c) Resource allocation over time of rescue operation

    (d) Medical response and facilities allocation

12. Are researchers of any value to responders at the time of the event, or should they restrict their activities simply to observation?

13. How can we enhance communication between the research community and the user or practitioner community concerned with life safety in buildings

Questions for Breakout Session 4: Wednesday 12 July: 10:30 a.m. – 12:00 p.m.

Topic: Research Needs and Agenda: Multidisciplinary

1. Selection of appropriate indices; their measurement will provide the necessary information (what to measure?)
2. We need to determine life-safety ratios or levels of lethality for all classes of construction.
3. We need to determine useful measures of extrication difficulty related to construction type, interior space loss and patterns of collapse.
4. We need to determine how key factors affect extrication efficiency.
5. We need to determine the relationship between availability of treatment/treatment method and survival.
6. We need to find better methods for rapid assessment of building stock damage.
7. We need to accurately relate damage estimates and occupancy estimates to to injury distribution for various building types and functions.
8. We need to relate survival to future mitigation measures.
9. Further development of disaster severity index.
10. Is it possible to develop sophisticated (or non-so sophisticated) mathematical models of a disaster in which several and more specific variables are included.
11. Can such a model be tested by applying it retrospectively to past disasters?
12. What are the current "weak links" in life saving (e.g., search and rescue, medical care, transportation, etc.).
13. Is it possible to incorporate predicted injury patterns into a community vulnerability or risk analysis?
14. What types of occupant behaviors lead to injuries in building collapse (e.g., how victims were trapped, what they did while waiting for help, and how SAR personnel handled their recovery)?
15. Need to answer questions regarding efficacy of various search and rescue techniques and equipment.
16. Is it possible to determine the probability of injury (or fatality) at a given level of intensity for a given type of construction

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17. In the immediate postdisaster period, is it possible, with prior knowledge of the distribution of populations and structures and the event intensity, to estimate rapidly the probable level of injuries and fatalities.

18. What practical advice should be given to rescuers for situations when optimal heavy rescue equipment is unavailable?

19. Are there straightforward guidelines for selecting the appropriate level of rescue capability (e.g., light, medium, heavy urban rescue)?

20. What are the patterns of death and injury in collapsed structures and how are they related to patterns of building collapse? survival? How is information on location of both survivors and victims usable? What are optimal locations for safety?

21. How does occupant behavior contribute to survival or injury?

22. What is the value of "heroic" rescue measures? Do the rescue activities actually make any difference?

23. What research is needed to improve post-disaster decision- making/resources management/planning to obtain reduced future vulnerability?

24. What parts of the population are most vulnerable to death and injury (e.g., elderly, young, sick, poor, etc.)?

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Questions for Breakout Session 5: Wednesday 12 July: 1:15 p.m. – 3:00 p.m.

Topic: Research Needs and Agenda: Intradisciplinary – **MEDICAL/HEALTH**

1. Further development of injury severity index.
2. What is the role of post-mortem examinations to determine cause and time of death?
3. What is the precise cause of death and injury in earthquakes (bleeding, asphixiation, crushing, hypothermia, etc?) and the associated severity score?
4. When do people die – one minute, one hour, one day or one week after the earthquake?

Questions for Breakout Session 5: Wednesday 12 July: 1:15 p.m. – 3:00 p.m.

Topic: Research Needs and Agenda: Intradisciplinary – **PUBLIC HEALTH**

1. Further development of injury severity index.
2. What is the precise cause of death and injury in earthquakes (bleeding, asphixiation, crushing, hypothermia, etc?) and the associated severity score?
3. When do people die – one minute, one hour, one day or one week after the earthquake?
4. If dead, could the person have been saved if reached in time?

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Questions for Breakout Session 5: Wednesday 12 July: 1:15 p.m. – 3:00 p.m.

Topic: Research Needs and Agenda: Intradisciplinary – **ORGANIZATIONAL**

1. We must study the informal search and rescue function of the spontaneous phase.
2. We must understand the relationship between specialized equipment and extrication efficiency.
3. We must understand the organization of search and rescue manpower to maximize effective manpower.
4. We must look at the multidisciplinary roles in the search and rescue function:
   - building expertise
   - demolition and debris handling
   - emergency medicine
   - transportation
   - long-term treatment.
5. What is the place of casualty estimation in disaster planning?
6. What is the optimal composition of a response team? A research team? Should the two be separated?
7. Which agencies/research sponsors are interested in funding research in this area, and specifically what aspects?

Questions for Breakout Session 5: Wednesday 12 July: 1:15 p.m. – 3:00 p.m.

Topic: Research Needs and Agenda: Intradisciplinary – **BUILDING**

1. Do we have acceptable classifications for building types with regard to their potential to:
   - predict injuries
   - predict voids for rescue
2. How do we document in detail the physical failure of a building?

APPENDIX B:
PARTICIPANT ADDRESS LIST

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Medical Corps USN
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APPENDIX C:
BIOSKETCHES OF PARTICPANTS

Joel I. Abrams P.E.
Professor of Civil Engineering
Director Public Works Program

Dr. Engineering
The Johns Hopkins University, 1956

Dr. Abrams' research interests center on structural mechanics and structural design with special emphasis on structural dynamics, plates and shell structures, finite element analysis and structural reliability. He has also worked in the area of public works systems, project management and construction productivity. He was Chairman of the Department of Civil Engineering from 1965 to 1987, and has served as Director of the Public Works Program from 1980. He has served as consultant to a number of industries in the areas of seismic design and computer applications to structures and foundations, and on a number of governmental Task Forces and Study Committees. He has served as Director, Vice President and President of the Pittsburgh Section ASCE, and as Program Chairman of the 1978 ASCE Annual Meeting. Dr. Abrams was Director-At-Large of the American Public Works Association, and Trustee and Chairman of the Educational Foundation of APWA. He was Chairman and member of CC&A-ASCE. Dr. Abrams recently served as a member of the President's Private Sector Survey on Cost Control, and was active on the infrastructure Task Force of the Economic Development Committee, Allegheny Conference on Community Development. He also serves ABET/EAC as an Accreditation Visitor and as a member of the International Commission, and ASCE as a member of Education Planning Committee and Committee on Public Works. He is Chairman of the Gold Medal Award Jury of the World Environment Center and a consultant to the United States Department of Technical Cooperation for Development.

DAVID E. ALEXANDER: BIOGRAPHICAL SKETCH

David Alexander was born in London, England, in 1953 and attended the London School of Economics (B.Sc. Geography, 1974) and University College London (Ph.D. in Mediterranean Geomorphology, 1977). From 1978 until 1980 he was Research Fellow in Mediterranean Geomorphology at U.C.L., during which time he studied erosional processes in clay badlands.

On 23rd November 1980, while living in southern Italy, he survived the magnitude 6.8 earthquake which on that day killed 2735 people and injured 8841 in the Regions of Basilicata and Campania. Although made homeless by the disaster, he quickly made use of the opportunity for academic study that it provided. In the subsequent years he has written reports, working papers and journal articles on seismic landslides, post-earthquake housing and urban planning problems, logistical aspects of disaster preparedness, the sociology of panic and the epidemiology of disasters.

In 1981 Alexander joined the faculty of the University of Massachusetts at Amherst, U.S.A., where he currently teaches physical geography, geomorphology, natural hazards, disaster studies and Western European studies. He has recently been appointed Director of the Geography Programme at this university. In the summer of 1985 he was Visiting Professor at the University of the South Pacific in Fiji, and during 1988-1989 has taught disaster studies at the Universities of Siena and Urbino, where he was appointed Contract Professor.

Alexander maintains a principal research interest in tectonic geomorphology, which he is studying in the Italian Apennines and Peruvian Cordillera Oriental. He is presently supervising student research (at the Universities of Massachusetts, Siena and Urbino) on the relationship between neotectonic stresses and landsliding, and also running a consultancy team to advise Italian communities on their urban landslide problems (he devised the equivalent of the Mercalli Scale for landslide damage to buildings and settlements).

His second research interest is in natural disasters, and he is currently about to publish a book entitled "Calamità Naturali: Appunti di Geologia Ambientale e Studio dei Disastri" ("Natural Disasters: Lessons in Environmental Geology and Disaster Studies") in Bologna. He has also recently toured Bangladesh and is an architect of the 'Dhaka Declaration' on flood alleviation in that country.

David Alexander is Editor-in-Chief of the international bimonthly journal "Environmental Management" (published by Springer-Verlag New York), which each year is an interdisciplinary forum for about 75 articles on various aspects of applied ecology in the widest sense of the term.

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BIOGRAPHICAL SKETCH

Give the following information for the key personnel and consultants listed on page 2. Begin with the Principal Investigator/Program Director. Photocopy this page for each person.

NAME	POSITION TITLE	BIRTHDATE *(Mo., Day, Yr.)*
Haroutune K. Armenian	Professor	

EDUCATION *(Begin with baccalaureate or other initial professional education, such as nursing, and include postdoctoral training.)*

INSTITUTION AND LOCATION	DEGREE	YEAR CONFERRED	FIELD OF STUDY
American University of Beirut	BS	1964	Premed
American University of Beirut School of Medicine	MD	1968	Medicine
Johns Hopkins University, School of Hygiene and Public Health	Dr.P.H.	1974	Epidemiology

RESEARCH AND PROFESSIONAL EXPERIENCE: Concluding with present position, list, in chronological order, previous employment, experience, and honors. Include present membership on any Federal Government public advisory committee. List, in chronological order, the titles and complete references to all publications during the past three years and to representative earlier publications pertinent to this application. DO NOT EXCEED TWO PAGES.

1967-71 Internship and Residency in Internal Medicine, American University of Beirut Medical Center.
1971-74 Commonwealth Fund Exchange Fellowship Program, Johns Hopkins School of Hygiene and Public Health.
1974-79 Assistant Professor of Epidemiology, School of Public Health, American University of Beirut.
1976-79 Manager, Health Services Research and Development, AUB Services Corp. and Coordinator, Office of Professional Standards and Systems Analysis, Ministry of Health, Bahrain.
1979-84 Associate Professor of Epidemiology, Faculty of Health Sciences, American University of Beirut.
1981-83 Coordinator, In-service Program Development, Ministry of Public Health, State of Qatar.
1981-88 Acting Dean and starting 1983, Dean of the Faculty of Health Sciences, American University of Beirut.
1984-85 Coordinator, Interfaculty Research Project for the Study of the Status of Children in Lebanon.
1984-88 Professor of Epidemiology, American University of Beirut.
1986-87 Visiting Professor of Epidemiology, School of Hygiene and Public Health, The Johns Hopkins University.
1988 Planning Coordinator of the Joint Outbreak Response Teams Program, Epidemiology and Disease Control, State of Maryland and Department of Epidemiology, School of Hygiene and Public Health, Johns Hopkins University.
1988 Professor of Epidemiology and Deputy Chairman, Department of Epidemiology, Johns Hopkins University.

HONORS AND RELATED ACTIVITIES

Alpha Omega Alpha, Honor Medical Society, 1979.
Delta Omega, National Honorary Public Health Society, 1985.
Society of Scholars, The Johns Hopkins University, 1986.
Editor in Chief, Epidemiologic Reviews, 1988.
Consultant, Ministries of Health of Bahrain, United Arab Emirates, Qatar, Iraq, Lebanon, Oman, WHO, UNICEF, Red Cross, Save the Children.

RECENT PUBLICATIONS

Armenian HK. Perceptions from epidemiologic research in an endemic war. Social Science and Medicine, 28:643-47, 1989.
Armenian HK, Halabi SS, Khlat M. Epidemiology of primary health problems in Beirut. Journal of Epidemiology and Community Health, 43:1989.

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Sibai AM, Armenian HK, Alam S. Wartime determinants of arteriographically confirmed coronary artery disease in Beirut. American Journal of Epidemiology, October 1989.

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Armenian HK, Chamieh MA, Darwish MH: The use of the lognormal distribution to study the time of occurrence of drug induced diseases. Journal of Clinical Research and Drug Development, 2:101-13;1988.

Armenian HA, Acra A: From the missionaries to the endemic war: public health action and research at the American University of Beirut. Journal of Public Health Policy, 9:261-72;1988.

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Armenian HK: Incubation periods of cancer: old and new. Journal of Chronic Diseases, 40:95-155;1987.

Darwish MJ, Armenian HK: A case-control study of rheumatoid arthritis in Lebanon. International Journal of Epidemiology, 16;420-24;1987.

Armenian HK, Saadeh FM, Armenian SL: Widowhood and mortality in an Armenian church Parish in Lebanon. American Journal of Epidemiology, 125:127-32;1987.

Obermeyer CM, Armenian HK, Azoury R: Endometriosis in Lebanon. A case-control study. American Journal of Epidemiology, 124:762-67;1986.

Editor with J. Bryce and author of three chapters: In Wartime: the State of Children in Lebanon. American University of Beirut, 1986.

Lockwood HL, Armenian HK, Zurayk H, Af'fi L: A population-based survey of loss and psychological distress during war. Social Science Medicine, 23:269-75;1986.

Armenian HK, Zurayk HC, Kazandjian VA: The epidemiology of infant deaths in the Armenian Parish records of Lebanon. International Journal of Epidemiology, 15:372-77;1986.

Armenian HK, Sha'ar KH: Epidemiologic observations in familial paroxysmal polyserositis. Epidemiologic Reviews, 8:106-16;1986.

Armenian HK: In wartime: options for epidemiology. American Journal of Epidemiology, 124:28-32;1986.

Yazigi A, Zahr L, Armenian KH: Patient compliance in a well baby clinic. Effect of two modes of intervention. Tropical and Geographical Medicine, 38(2):104-09;1986.

Editor with H. Zurayk and Author of a Chapter: Beirut 1984. A Population and Health Profile. American University of Beirut Press, 1985.

Armenian HK, Lilienfeld AM: Incubation period of disease. Epidemiologic Reviews, 5:1-15;1983.

Armenian HK: Enrollment bias and variation in clinical manifestations: a review of consecutive cases of familial paroxysmal polyserositis. Journal of Chronic Disease, 36:209-12;1983.

Armenian HK: The Office of Professional Standards and Systems Analysis, A Model for a University Extension Program. In, The Role of the University in Extension Education. American University of Beirut, 198[illegible].

Armenian HK, Dajani AW, Fakhro AM: Impact of Peer Review and Itemized Medical Record Forms on Medical Care in a Health Center in Bahrain. Quality Review Bulletin 7:6-11 September 1981.

Armenian HK, Khuri M: Age at onset of genetic disease. An application for Sartwell's model of the distribution of incubation periods. American Journal of Epidemiology, 113:596-605;1981.

Armenian HK: Model Systems for Primary Health Care in Developing Countries. In, Human Resources for Primary Health Care in the Middle East. American University of Beirut, Beirut, Lebanon, 1980.

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SAMUEL ARONI

Dr. Aroni is Professor of Architecture and Urban Design at UCLA since 1970. He served as Acting Dean of the Graduate School of Architecture and Urban Planning, and Chairman of the Board of the Urban Innovations Group, the independent practice arm of the School. Dr. Aroni is an engineer, researcher, and building technologist of international reputation concerned with social, economic, and technical aspects of urban building technology.

He was a member of the Committee on the Socioeconomic Effects of Earthquake Predictions of the National Academy of Sciences and the National Academy of Engineering (1976-1978). During 1981-1982 he served as Chairman of the UCLA Academic Senate. In 1983 he was elected a member of the Board of Governor of the Ben-Gurion University of the Negev in Israel. In November 1985 he was elected national Vice President of the Architectural Research Centers Consortium (ARCC), an organization representing over forty Schools of Architecture committed to research, and in the same year he was appointed to an advisory committee of the National Science Foundation (NSF), serving the Division of Mechanics, Structures and Materials Engineering (MSME), of the Engineering Directorate. Since 1983, Dr. Aroni has chaired the UCLA Joint Senate-Administration Earthquake Safety Committee.

He has published widely in the fields of structures, concrete materials, statistical methods, building systems, and housing, and was awarded the J. James R. Croes Gold Medal for 1981 of the American Society of Civil Engineers. He serves on the editorial boards of the **Architectural Science Review** (Australia) and the **International Journal for Development Technology**.

He is an active member of the American Society of Civil Engineers; the Earthquake Engineering Research Institute; American Concrete Institute; and the Society of Sigma XI.

Dr. Aroni holds a BCE from the University of Melbourne, Australia, where he also studied Town and Regional Planning, and an M.S. and Ph.D. in Structural Engineering from the University of California at Berkeley.

GARRY L. BRIESE, C.A.E., Executive Director
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Currently serving in his fourth year as the Executive Director of the International Association of Fire Chiefs, the professional association for senior fire and emergency services managers, Mr. Briese spent the previous fourteen years working with the American College of Emergency Pysicians as the Executive Director of the Florida Chapter.

Mr. Briese has twenty-one years experience in the fire service, twenty as a volunteer and one as a paid firefighter. He has served in various positions throughout this time, most recently as the volunteer Battalion Chief in charge of the 150 person reserve component of the 600 person Orange County (FL) Fire Department. Prior to the fire consolidation which consolidated sixteen fire departments into the OCFC, Mr. Briese served as the Chairman of the Board of Fire Commissioners for the Killarney Fire District in Orange County.

Mr. Briese has had the unique experience of being associated with two fire departments which experienced consolidation (Jacksonville/Duval County and 16 districts in Orange County, Florida).

A well known author and lecturer in the emergency services area, Mr. Briese is the co-author of a first responder text book for emergency services personnel. Additionally, he has done extensive work in the areas of private sector fire service; terrorism and emergency services; and disaster management.

Professionally, Mr. Briese holds the certification from the American Society of Association Executives as a Certified Association Executive (CAE), only one of 2500 holding the designation in the United States. He holds a Bachelors Degree in International Relations from the University of South Florida and has completed major work towards a Doctoral Degree in Public Administration from Nova University.

He is married to Roni and has two sons. His hobbies are white-water open canoeing, stamp collecting, fishing and downhill skiing.

BO BRISMAR

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Assoc Prof. Department of Surgery, Karolinska Institute, Huddinge University Hospital, S-14186 Huddinge (Sweden)

Teacher (Course leader) Disaster Medicine, Karolinska Institute, Stockholm

Head, Emergency Department and Operation Center, Huddinge University Hospital

Expert in Disaster and War Preparedness Planning National Board of Health and Welfare

Member, Disaster Committee, Stockholm County Council

Member, Radiation Disaster Committee, National Board of Health and Welfare

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CHAIRMAN, REGIONAL MEDICAL CENTER EARTHQUAKE COMMITTEE
KAISER PERMANENTE HEALTH PLAN, NORTHERN CALIFORNIA

Dr. Donald H. Cheu is a Board Certified General Surgeon, Fellow of the American College of Surgeons, and a member of the Surgery Department Staff at the Kaiser Permanente Medical Center in So. San Francisco, California. He received his bachelor's degree from Stanford University and his medical degree from the University of California, San Francisco. He has been the Chairman and is now a consultant to the California Medical Association's Committee on Disaster Medical Care. He is chairman of the Northern California Kaiser Permanente Regional Medical Center Earthquake Committee. He was a Vice-chairman of the Governor's Earthquake Task Force responsible for the Response Group of Committees. He also chairs the following committees: State Office of Emergency Service's Disaster Medical Care Committee, the San Mateo County Medical Society's Ad Hoc Committee on Trauma and its Committee on Emergency and Disaster Care. He has been a Stanford Research International Consultant to the Ministry of Planning, Saudi Arabia. He is a member of the Seismic Safety Commission's Emergency Response and Planning Committee, Peninsula Blood Bank Executive Committee, the American Red Cross's Western Regional Disaster Health Service Advisory Committee and the U.S.Geological Survey's Working Group on Earthquake Related Casualties. He is also the President-elect of the San Mateo County Medical Society.

He wrote the Medical Report on the Coalinga Earthquake for the Seismic Safety Commission. He is a consultant and teaches regularly for the California Specialized Training Institute.

ANDREW WILLIAM COBURN, M.A., Dip. Arch., Ph.D.

Dr. Andrew Coburn is a director of Cambridge Architectural Research Limited, a private consultancy, and a Research Fellow at The Martin Centre for Architectural and Urban Studies of the University of Cambridge in United Kingdom. Dr. Coburn is an architect-planner specializing in Earthquake Protection Planning and has worked with national and local governments on regional mitigation programs in Eastern Turkey, Southern Italy and Sicily, Yemen Arab Republic, and currently in Mexico City. His PhD was on Seismic Vulnerability and Risk Reduction Strategies for Housing in Eastern Turkey, and he is a member of the Earthquake Engineering Field Investigation Team of United Kingdom carrying out field investigations and quantified damage surveying after the earthquakes of Campernia, Italy 1980, Dhamar, Yemen Arab Republic 1982, Central Turkey 1982, Eastern Erzurum, Turkey 1983, and Senkenya 1984, and Kalamata, Greece, 1986. He spent four months as Research Associate at Hokkaido University, Japan and is currently conducting research programs in Cambridge on Seismic Risk Modelling and data-gathering for Vulnerability Analysis; Dynamic Testing of Unreinforced Masonry Buildings; and Reduction of Human Casualties in Mass-Collapse Disasters. He has published a number of conference papers, contributions to periodicals and reports, and is currently working on a book, Earthquake Protection Planning, Jointly authored by Dr. Robin Spence, to be published by John Wiley and Sons in 1990.

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ANNE COULSON

Anne Hersey Coulson is a research epidemiologist and a senior lecturer in the Department of Epidemiology at the UCLA School of Public Health. Her graduate education was in Experimental Psychology at Columbia University, Graduate Faculty of Pure Sciences. She has worked in a number of epidemiologic and public health research interests at the local, national and international level. Her present research interests include development and applications of epidemiologic methodology to new areas, research into rare events, earthquake injury research, environmental epidemiology, reproductive epidemiology and AIDS.

Mrs. Coulson's involvement with earthquake research stems from many years of epidemiologic consulting to architectural and structural studies and was enhanced by her role in the initial research activity following the Coalinga(CA) earthquake. She was co-principal investigator for the NSF study headed by Professor Sam Aroni at the University of California, Los Angeles. She has been involved in epidemiologic work on the Coalinga, Chile, San Salvador, Mexico City, and Whittier earthquakes, and retrospectively, on the San Fernando, Imperial County and Santa Barbara quakes.

In addition to her work at UCLA, Mrs. Coulson has consulted for many agencies and organizations including the Rand Corporation, the Los Angeles Regional Family Planning Council and Union Oil Company. She is a member of the Vital Statistics Advisory Board for the State of California.

Mrs. Coulson has been active in professional organizations. She is a fellow of the American College of Epidemiology, for which she has been a member of the Board of Directors. She is also a Fellow of the Council on Epidemiology of the American Heart Association. She is a member of the International Epidemiological Association, the Society for Epidemiologic Research, the Biometrics Society and the American Statistical Association and the American Public Health Association, in which she has held a number of offices.

Mrs. Coulson has more than 80 articles in the professional literature covering a variety of epidemiologic research areas and is co-author, with Gary Spivey, M.D., of a manual of environmental epidemiology.

CALVIN FREEMAN

Calvin Freeman, Administrative Deputy of the California State Emergency Medical Services Authority, has been responsible for the state's disaster medical preparedness program since 1981. His principal task is to plan the state's medical response to a catastrophic earthquake. Mr. Freeman has participated in studies of the medical effects of the Mexico City, Coalinga and Whittier-Narrows earthquakes.

DAVID J. HAMMOND

David Hammond is a licensed Structural Engineer in private practice in Palo Alto, CA. since 1960. He was the leader/support person for U.S. SAR Dog Team 3 in Mexico City Earthquake 1985, and a member of Disaster Emergency Services Committee, Structural Engineer Association of CA. He was a lecturer at Stanford University from 1965-76 and has taught private courses in structures for architects taking the California State Board Exams since 1960.

He is the current chairman, Engineering Committee, USAR Inc. (West coast non-profit research and development corporation dedicated to developing standards, training, and education in the field of Urban Search & Rescue.)

CONSTANCE HOLLAND

Constance Holland is a consultant in hazard mitigation and response. Her primary focus is hazard policy and organizational response. She has most recently been associated with VSP Associates of Sacramento where she was project coordinator. Prior to this she worked for Scientific Service, Inc. on non-structural mitigation and hazardous materials response policy and training. She holds a Master's degree in sociology from the University of Denver.

Her other research interests include comparative community responses to disaster in Third World countries and the impact of disasters upon development.

Biographical Sketch – Nicholas P. Jones

Dr. Nicholas P. Jones received his undergraduate degree (B.E. (Civil) with First Class Honors) from the University of Auckland, New Zealand and his M.S. in Civil Engineering from the California Institute of Technology. He received his Ph.D in June, 1986, also from the California Institute of Technology, in the area of structural dynamics (flow-induced vibration). Prior to attending Caltech, he worked for approximately nine months as a design engineer in New Zealand.

In January, 1986, Dr. Jones joined the faculty at The Johns Hopkins University as an Assistant Professor of Civil Engineering. His research interests include various aspects of structural dynamics, flow-induced vibration, earthquake engineering and wind engineering.

Consistent with his interest in earthquake engineering, Dr. Jones is concerned with hazard mitigation from a global sense, and is interested in a more interdisciplinary approach to the problem. This approach involves collaborative work with colleagues in the Johns Hopkins Schools of Medicine and Public Health as well as those in the architectural and engineering disciplines. Of particular interest is the study of death and injury patterns in collapsed and severly damaged structures, in both the temporal and spatial domains, and the application of the results of the study to search and rescue technology.

In 1989 he was awarded a Presidential Young Investigator Award by the National Science Foundation to pursue his research in this area.

CURRICULUM VITAE SUMMARY

Miroslav Klain, M.D., Ph.D.
Department of Anesthesiology/Critical Care Medicine, University of Pittsburgh
Director of Anesthesiology/Critical Care Medicine Research, Montefiore Hospital

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3459 Fifth Avenue, Pittsburgh, PA 15213
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Education: School of Medicine, Charles University, Prague, Czechoslovakia; M.D. 1951
Czechoslovak Academy of Sciences, Prague, Czechoslovakia; Ph.D. 1963

Hospital training: 1951-55 Internship and residency in surgery; County Hospital Zacler, Czechoslovakia
1965-66 Research Fellowship; Department of Artificial Organs, Division of Surgery, Cleveland Clinic, Cleveland, OH
1972-74 Anesthesiology and Critical Care Medicine; University of Pittsburgh, Pittsburgh, PA

Professional appointments: Professor, Department of Anesthesiology and Critical Care Medicine, University of Pittsburgh School of Medicine

Certification: 1974 American Board of Anesthesiology
1955 Czechoslovak Board of Surgery

Licensures: Pennsylvania State Medical License
Czechoslovak Medical License

Professional activities/committees: Institutional Review Board; Animal Care Committee; Scientific Affairs Committee (1984-85 Acting Chairman); Editorial Board Critical Care Medicine

Membership in professional and scientific socities:
American Society for Artificial Internal Organs; American Medical Association; American Society of Anesthesiologists; Pennsylvania Medical Society; Pennsylvania Society of Anesthesiologists; Society for Critical Care Medicine, (Member, Liaison with Industry Committee); Association for Advancement of Medical Instrumentation; International Anesthesia Research Society; International Society for Artificial Organs; Chilean Society of Anesthesiologists (Honorary member); Association of University Anesthetists; World Association of Emergency and Disaster Medicine;

Grants: Design and Evaluation of a Natural Rubber Wave Pulsating Total Heart
Principal Co-Investigator, 1969-1972 from NHLI
High Frequency Jet Ventilation
Principal Investigator, 1979-1981 from NHLI
Intrapulmonary Drug Administration for Cardiopulmonary Resuscitation
Principal Investigator, 1982-1983 from Laerdal Foundation
Acute Medicine Learning Laboratory
Co-Investigator, 1982-1983 from Laerdal Foundation

Selected bibliography:
Klain M, Keszler H, High-frequency jet ventilation, Surg Clin North Am 65(4):917-930, 1985; Matuschak GM, Pinsky MR, Klain M, Hemodynamic effects of synchronous high-frequency jet ventilation during acute hypovolemia, J Appl Physiol 6(1):44-53, 1986; Pinsky MR, Marquez J, Martin D, Klain M, Ventricular assist by cardiac-cycle specific increases in intrathoracic pressure, Chest:91-709-715, 1987; Bayly R, Sladen A, Guntupalli K, Klain M, Synchronous versus nonsynchronous high-frequency jet ventilation: effects on cardiorespiratory variables and airway pressures in postoperative patients, Crit Care Med 15(10):915-917, 1987; Bayly R, Sladen A, Tyler IL, Echegaray RF, Klain M, Guntupalli K, Driving pressure and arterial carbon dioxide tension during high-frequency jet ventilation in postoperative patients, Crit Care Med 16(1):58-61, 1988

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FREDERICK KRIMGOLD

Associate Dean for Research and Extension
Virginia Polytechnic Institute and State University

Dr. Frederick Krimgold is the Associate Dean for Research and Extension, College of Architecture and Urban Studies, Virginia Polytechnic Institute and State University.

Dr. Krimgold's previous positions include Research Associate for the Department of Civil Engineering at the Massachusetts Institute of Technology, and Program Director, Earthquake Hazard Mitigation Program, National Science Foundation. He is a member of the National Research Council, Building Research Board, Earthquake Engineering Research Institute, and the Architectural Research Centers Consortium. His current research is on Search and Rescue in Collapsed Buildings and Earthquake Injury Epidemiology, supported by the National Center for Earthquake Engineering Research, the National Science Foundation, and the Office of U.S. Foreign Disaster Assistance.

Dr. Krimgold holds a B.A. in Architecture from Yale University and a Doctor of Technology from the Royal Institute of Technology, Stockholm.

CURRICULUM VITAE
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DATE OF BIRTH:. . . . . .

PLACE OF BIRTH: . . . . . .

MILITARY OBLIGATION:. . . . Major USAF Reserves (Inactive)

EDUCATION:. . . . . Gettysburg College, Gettysburg, PA .
BA Biology/Chemistry, Cum Laude, 1967

University of Pittsburgh School of Medicine
Pittsburgh, PA M.D., 1971

POST GRADUATE:. . . . . Montifiore Hospital, Pittsburgh, PA
Mixed internship 1971-72

University of Kentucky
Lexington, Kentucky, 1976-1978
Emergency Medicine Residency
Chief Resident (PGY-3)

CERTIFICATION:. . . . . Basic Life Support

Advanced Cardiac Life Support
(Provider, Instructor, Affiliate Faculty)

Advanced Trauma Life Support
(Provider, Instructor)

Armed Forces Institute of Pathology
Aviation Accident Pathology Certified

Armed Forces Institute of Pathology
Forensic Pathology Certified

Basic Rescue Practices Certified State of
Pennsylvania

Hazardous Materials Management
Certified County of Westmoreland

Flight Medical Officer Certified
School of Aerospace Medicine, Brooks AFB, Texas

LICENSURE:. . . . . Pennsylvania - Active
Kentucky - Inactive

MEMBERSHIPS:. . . . . Diplomate National Board of Medical Examiners
Pts. I, II, III

Fellow American College of Emergency Physicians

American Association for the Advancement of Science

President & Medical Director Special Medical
Response Team Inc

The World Assn. for Emergency & Disaster Medicine

National Association of EMS Physicians

National Association for Search and Rescue

INTERESTS:. . . . . Disaster Medicine, Delivery of Acute Medical Care
in Pre-Hospital Care Setting

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HENRY J. LAGORIO is a Professor of Architecture and a Research Architect at the University of California, Berkeley, a practicing Architect licensed in the states of California and Hawaii, and a member of the American Institute of Architects. He has served as Associate Dean of the College of Environmental Design at Berkeley, Director of the Center for Environmental Design Research, Director of the University of California Study Center in Italy, a member of the California Seismic Safety Commission, Secretary/Treasurer of the Earthquake Engineering Research Institute, Program Manager at the National Science Foundation, Secretary of the Wood Products Research Council, and member of the Executive Committee of the Earthquake Engineering Research Center. He has published extensively on the Architect's role in seismic safety, the architectural considerations of earthquake engineering, urban planning and design concerns in earthquake hazards reduction, and has participated in the development of numerous earthquake vulnerability studies in the United States and earthquake reconnaissance reports throughout the world.

Michel F. LECHAT, M.D. (Louvain), DTM (Antwerp), M.P.H., Dr P.H. (JHU), 62

Dean of the School of Public Health, Catholic University of Louvain in Brussels, Professor and Head of Department (Epidemiology and Preventive Medicine).

Director, Research Centre on Disaster Epidemiology (CRED), WHO Collaborating Centre

Past positions : Medical-Director, Iyonda Leprosy Hospital, Mbandaka, Zaïre (1953-59); Instructor, Department of Pathobiology, Johns Hopkins School of Hygiene and Public Health (1960-62); Medical Officer, WHO/PAHO, Mexico (1965-66)

Expert, Leprosy, WHO

Member, Royal Academy of Medicine, Belgium

President, International Leprosy Association, 1978-1988

Served as Consultant to Belgian Government, World Bank, Swedish International Development Agency, French Government, National Academy of Science/Natural Science Foundation, WHO, various NGO's.

Member of the Group of Experts to the United Nations Secretary General for the preparation of the International Decade for Natural Disaster Reduction (IDNDR)

RESUME

NAME:	Frank E. McClure
ADDRESS:	54 Sleepy Hollow Lane Orinda, CA 94563
TELEPHONE:	(415) 254-8231 (home) (415) 486-5715 (work)
EDUCATION:	BS, Civil Engineering with Structural Engineering Major, University of California, Berkeley, 1944
PROFESSIONAL STATUS:	California Registered Civil Engineer, since 1952 California Registered Structural Engineer, since 1954 California Registered Architect, since 1986
AFFILIATIONS:	President, Earthquake Engineering Research Institute, a national earthquake engineering society, 1986-1988 Member, Committee on Earthquake Engineering, Commission on Engineering and Technical Systems, National Research Council, 1983-1985
EXPERIENCE:	**1978-Present: Senior Structural Engineer and Civil-Structural Section Leader for Lawrence Berkeley Laboratory, Berkeley, CA.** Responsible for managing plant civil-structural design, long range planning, consulting, and project management of new construction and facilities rehabilitation of buildings, roads, site, and other civil works facilities. **1976-1978: University Engineer, University of California Systemwide Administration, Berkeley, CA.** Responsible for implementation of University seismic rehabilitation plan, technical consultation with UC General Counsel, fiscal control, engineering consultation and analysis of capital improvement program, Facilities Manual preparation, and analysis of State and Federal legislation. **1955-1976: Partner, Frank E. McClure and David L. Messinger Consulting Structural Engineers, Oakland, CA.** Professional services included all aspects of consulting engineering related to the structural design of public, industrial and commercial buildings, and earthquake engineering. **1946-1955: Structural Engineer in various private consulting structural engineering offices, and public agencies.** **1944-1946: United States Navy, Civil Engineer Corps, USNR, Lt. (j.g.), Seabees, Okinawa.**

1/27/88
MISC

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Biographical Sketch – Eric K. Noji

Eric K. Noji, M.D. is an Assistant Professor of Emergency Medicine at The Johns Hopkins University School of Medicine. Dr. Noji has had a long-standing interest in disaster medicine that began during his residency training in emergency medicine at the University of Chicago where he also served as a flight physician for the University's medical helicopter program. His current major areas of academic interest revolve around the medical response to mass-casualty incidents and the hospital response to hazardous chemical accidents. Current projects include the development of disaster severity scales to determine resuscitation potentials for mass casualties, and the development of protocols for the management of toxic chemical and radiation contamination in the field and in health care facilities. These latter protocols will be summarized in Manual of Toxicologic Emergencies (Year Book Medical Publishers) for which he is also the editor. Dr. Noji also serves on advisory committees for disaster planning for the Federal Emergency Management Agency, the American College of Emergency Physicians as well as on the Mayor of Baltimore's Hazardous Materials Committee.

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E.L. Quarantelli
Director, Disaster Research Center, Professor of Sociology
University of Delaware

Born New York City in 1924.
Ph. D. university of Chicago, 1959. Phi Beta Kappa.

Co-founder, Disaster Research Center, Ohio State University 1963.
Moved Center to University of Delaware 1985.

First President, International Research Committee on Disasters, 1982-1986
First Editor, International Journal of Mass Emergencies and Disasters, 1983-1987.

Undertook first field studies on disasters in 1949 with Charles Fritz as part of the National Opinion Research Center (NORC) team that undertook initial systematic social science research in the area. University of Chicago.

Over 120 publications on disaster topics including such works as:
Evacuation Behavior and Problems: Findings & Implications from the Research Literature.
Delivery of Emergency Medical Services in Disasters: Assumptions and Realities.
Sociobehavioral Responses to Chemical Hazards: Preparations for and Responses to Acute Chemical Emergencies at the Local Community Level.
A Perspective on Disaster Planning.
The Handling of the Dead in Large Mass Casualty Situations.
Emergent Citizen Groups in Disaster Preparedness and Recovery Activities.
A Comparison of Japan-United States Mass Media Reporting on Disasters.
Organizational Communications and Decision Making in Crises.
Realities and Mythologies in Disaster Films.
Converting Disaster Scholarship into Effective Disaster Management.
The Controversyon the Mental Health Consequences of Disasters.
The Functioning of the Local Emergency Services Offices in Disasters.
What is a Disaster? An Agent Specific or an All Disaster Spectrum Approach to Socio-Behavioral Aspects of Earthquakes.
Inventory of the Japanese Disaster Research Literature in the Social Sciences.
Police Department Perceptions of the Occurrence of Civil Disturbances
Panic Behavior in Fire Situations: Findings and a Model .

Currently undertaking research on mass media operations in disasters, organizational and citizen behaviors in the Mexican city earthquake, and police and fire departments as well as hospital planning and response in large mass casualty situations. Have just initiated a study of preparations and responses in disaster by lifeline organizations. Writing on a variety of topics in the disaster area particularly cross-societal work.

University Health Center of Pittsburgh
Resuscitation Research Center
March 1988

Biographic Sketch

PETER SAFAR, M.D., Dr.h.c.

Distinguished Service Professor of Resuscitation Medicine
Director, Resuscitation Research Center (RRC), University of Pittsburgh
3434 Fifth Avenue, Pittsburgh, PA, 15260, U.S.A.
Phone: 412-624-6735 (office), 412-343-2954 (home)
Social Security No. 217-34-8178

Education:

Born April 12, 1924, Vienna, Austria. Piaristengymnasium, Vienna, 1934-42 (Matura). University of Vienna School of Medicine 1943-48 (M.D.). Pathology (with Feyrter and Chiari) and Surgery (with Schoenbauer and Fuchsig), University of Vienna 1948/49. Surgery and Oncology, Yale University/New Haven Hospital, New Haven, CT, USA (with Harvey, Lindskog, Taffel) 1949/50. Resident in Anesthesiology, Hospital University of Pennsylvania, Philadelphia, PA (with R.D. Dripps, P. Dumke, J. Eckenhoff, A. Lamont, L. Vandam) 1950-52. Medical faculty training program, Univ. PA (with J. Comroe) 1957. USA National Boards 1954. Maryland and PA State Boards. American College Anes. 1952. Anesthesiology Specialty Board 1957.

Past and Present Positions:

(1) 1952-53: Founder and Chief Dept. of Anesthesiology, National Cancer Hospital, Lima, Peru. Founded first anesthesiology residency in Peru.

(2) 1954-61: Anesthesiologist Johns Hopkins Hospital, 1954/55, Baltimore, MD, USA. Founder and Chief Dept. of Anesthesiology, Baltimore City Hospitals, Assistant Prof. Johns Hopkins Univ., Assoc. Prof. Univ. Maryland, 1955-61.

(3) 1961-78: Founder and Chairman, Professor, Department of Anesthesiology and Critical Care Medicine, University of Pittsburgh School of Medicine 1961-78. Anesthesiologist-in-Chief Health Center Hospitals (Presbyterian-University, Children's, Eye and Ear, Montefiore, Magee-Womens, Veterans -- with 55,000 anes/yr, 3000 ICU pts/yr, 5000 pain trtmts/yr). Developed department from 3 to 100 full-time M.D.s; 200 non-physicians; 10 training programs (in anesthesia, anesthesia subspecialties, pain control, respiratory therapy, resuscitation, emergency medical services, critical care medicine, anesthesia research, resuscitation research, medical students 4 years).

(4) 1978-present: Resigned as Department Chairman. Founder and Director Resuscitation Research Center (RRC) 1978, opened July 1979. (World's 2nd RRC; 1st is Negovsky's in Moscow). Distinguished Service Professor of Resuscitation Medicine. Professor of Anesthesiology. Professor of Physiology (Graduate School).

(5) Acute Medicine: Member and co-founder of committees on resuscitation (1950s) and Emergency Medical Services (EMS) (1960s, 1970s) of National Research Council/National Academy of Sciences; American Medical Association; American Heart Association (AHA); American Society of Anesthesiologists (ASA Committee on Acute Medicine, 1st Chairman 1965-68); World Federation of Societies of Anesthesiologists (WFSA) CPR Committee; U.S. White House (President Ford's) Committee on EMS; PA State Governor's Subcommittee on EMS of Task Force on Human Services; Pittsburgh (Allegheny County) and Western PA EMS Community Council. Founder, Medical Committee of GASP (Group Against Smog and Pollution, Pittsburgh).

U.S. Army Resuscitation Research contractor, 1966-69; Consultant, Medical Science Review Board, Combat Casualty Care, Division Army Institute of Research, 1984-.

NIH Ad Hoc Grant Review Committees.

Research Grants 1960-87: Approximately $5.5 million. (U.S. Army, USPHS, NIH, Dept. of Transportation, foundations, PA Dept. of Health, etc.).

Anesthesiology Societies, President Maryland (1950s) and Pennsylvania (1960s).
Medico team to Indochina (Viet Nam, Laos, Cambodia) and India, 1959.
Around the world teaching tour on CPR, 1960.
Freedom House Ambulance Service of Pittsburgh, founder and medical director (pilot tested national EMS standards 1968-75) and proved potentials of "unemployable" blacks (with Drs. Benson and Caroline).
Society of Critical Care Medicine (SCCM) co-founder (with Drs. Weil and Shoemaker) 1968-71; President (1972/73); initiator (with Shoemaker, editor) of journal Critical Care Medicine 1972; author SCCM ICU Organization and Guidelines, and CCM Physician Education Guidelines.
Visiting Scientist, Cardiovascular Research Institute (CVRI) Univ. California in San Francisco 1969/70 (with Severinghaus and Comroe), sabbatical.
"Club of Mainz"--World Association for Emergency and Disaster Medicine (WAEDM), Co-founder (1977), Acting President and President (1981-85).
U.S. House of Representatives. Testimonies on transplant surgery and brain death, 1980s; Committee on Health, testimonies on EMS and resuscitation research (1970s).
Physicians for Social Responsibility, International Physicians for the Prevention of Nuclear War. Missions to USSR (1983) and Hiroshima-Nagasaki (1984).
Consultant, U.S. National Disaster Medical System.
Editorships. Initiator and Editor-in-Chief journal Disaster Medicine (1983), Journal of the World Association of Emergency and Disaster Medicine (J WAEDM)(1985), Official journal of the WAEDM; Chairman, Editorial Board 1986-. Critical Care Medicine, co-initiator and member Editorial Board 1973-. Resuscitation (Elsevier) member Editorial Board 1970s-. American Journal of Emergency Medicine consulting editor 1980s-. Asian Archives of Anaesthesiology & Resuscitation member Editorial Board 1988-.

Credited with:
Initiation and development of 3 new anesthesiology departments and residency training programs (Peru, Baltimore City Hospitals, Univ. Pittsburgh) with over 300 physician alumni; Resuscitation Research Laboratory at Baltimore City Hospitals (1950s) and Univ. Pittsburgh Dept. Anes (1960s); first brain resuscitation (for cardiac arrest) laboratory research program (1970-); Resuscitation Research Center (RRC) at the Univ. of Pittsburgh (1978).
Initiated and developed first physician staffed medical-surgical intensive care unit in the USA (at Baltimore City Hospitals 1957-61); first major change in the USA from use of the iron lung to intratracheal IPPV via cuffed tubes for prolonged ventilation.
First Critical Care Medicine physician fellowship training program in the world (Univ. Pgh., 1963-71), which led to new multidisciplinary subspecialty of Critical Care Medicine.
First Annual International Emergency and Critical Care Medicine Congresses (Pittsburgh) 1967-76.
Wolf Creek Conferences of Resuscitation Researchers (co-initiated and edited Wolf Creek Conference #1, 1975).
CPR research which led to change from manual to mouth-to-mouth artificial ventilation worldwide, CPR steps A and B (1950s). Co-initiation and co-development of CPR steps A-B-C, D-E-F, G-H-I (1960s). Animal models on dying and resuscitation, including first resuscitation studies on drowning (with Redding), lethal hemodilution (with Takaori), temperature extremes, etc. Development of first animal research ICU for long-term outcome studies (1970s-present). First multicenter randomized clinical study of cardiopulmonary-cerebral resuscitation (CPCR) (NIH NS15295) (1979-). First education research in CPR (1963-) which proved teachability of CPR-ABC to laymen. First American Heart Association CPR Instructors' Courses (1963-).
First EMS Community and State Councils, EMS organization guidelines (ASA), and pilot tests of national standards on ambulance design and equipment, and basic and advanced ambulance attendants training (with National Research Council/NAS and Freedom House Project, Pittsburgh 1968-75).

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Present Research (RRC): Principal Investigator of 4 research programs: (1) Cardiac Arrest (Post-Resuscitation Syndrome) Laboratory Studies. (2) Cardiac Arrest Multi-institutional Clinical Study. (3) Shock-Trauma Laboratory Studies. (4) Shock-Trauma patient oriented programs in Disaster Medicine. Research affiliations with 20 laboratory investigators of various disciplines in Pittsburgh; Max Planck Institute, Cologne, W. Germany; Univ. Uppsala, Sweden; and 20 clinical investigators of 7 countries.

Over 800 publications (incl. abstracts): 350 peer-reviewed scientific papers. First mouth-to-mouth and CPR manuals in the 1950s and 1960s. WFSA CPR Manual of 1968 (16 languages). WFSA CPCR book of 1981 (13 languages) and 1987 (Laerdal Publ., W.B. Saunders). First resuscitation and intensive care documentary and training films. Editor and author of 10 books, including one of the first 2 textbooks on Respiratory Therapy (1965, F.A. Davis); Public Health Considerations in Critical Care Medicine and Anesthesiology (1974, F.A. Davis); Advances in CPR, Wolf Creek Conference #1, 1975 (1977, Springer-Verlag); Principles and Practice of Emergency Medicine (1978, 1986; W.B. Saunders) with G. Schwartz, et al. (first textbook of Emergency Medicine); Brain Failure and Resusciatation, with Grenvik (1981, Churchill Livingston); and Disaster Resuscitology (1983).

Community Service. Helped initiate and develop at local, state, national and international levels -- care techniques, guidelines, teaching programs and services for: (1) anesthesiology; (2) resuscitation services; (3) the paramedical discipline of respiratory therapists; (4) the medical base discipline of emergency medicine; (5) the medical multi-disciplinary subspecialty of critical care (intensive care) medicine; (6) communitywide emergency medical services; and (7) disaster medicine.

Honors:

Honorary M.D., doctor honoris causa, Gutenberg University, Mainz, West Germany 1973.
Association of University Anesthetists (1959).
American Physiologic Society (1959).
German Society of Anesthesiologists (corresponding member) 1970s.
Peruvian Society of Anesthesiologists (corresponding member) 1970s.
Presbyterian-University Hospital (Pittsburgh) Hall of Fame 1970/71.
U.S. White House Committee on Emergency Medical Services 1974-76.
Vienna Gesellschaft der Arzte (Society of Medicine) 1978.
F.S. Cheever Professorship (Univ. Pittsburgh School of Medicine) 1978.
Magen David Adom Awards of Honors (Israel) 1978; (Pittsburgh) 1980.
American College of Emergency Physicians (Honorary Member) 1980.
University Association Emergency Medical Services (Honorary Member) 1980.
American Heart Association CPR Pioneer Award 1980 (Wash., DC) National H.A. (1985).
Western PA Heart Association Award 1980.
Pittsburgh Jaycees Man of the Year in Medicine Award 1980.
American Red Cross Magen David for Israel (supporting Magen David Adom, Israel's Red Cross): Award of Honor, 1980; Mission of Mercy Award, 1984.
Australian and New Zealand Intensive Care Society (corresponding member) 1981.
James Wattie Memorial Professor of New Zealand 1981.
Eliasberg Medal, Mt. Sinai Medical School, New York City, 1982.
Golden Tree Award New York Society of Respiratory Therapists 1982.
Austrian Academy of Sciences 1983.
Vice President, World Federation of Societies of Anesthesiologists 1984-.
Emergency Medicine Society, Jefferson Medical College, 2nd Annual Black and Blue Lecture Award, 1984.
Phoenix Award, Society of Critical Care Medicine Foundation, 1985.
British Association of Immediate Care (Honorary Member) 1985.

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Honors (continued)

Peter and Eva Safar Annual Lectureship in Medical Sciences and Humanities 1980-present (Bonica, 1980; Severinghaus, 1981; Greene, 1982; Bethe, 1983; Eckenhoff, 1984; Weisskopf, 1985; Mayrhofer, 1986; Grenvik, 1987)

Slovenian Academy of Sciences 1983.

University of Pittsburgh Affiliated Residency in Emergency Medicine: "Annual Safar Award for Emergency Medicine Research" 1984-present.

Pittsburgh Academy of Medicine: Man of the Year 1985.

Polish Society of Anesthesiology and Intensive Therapy 1986.

Centennial, Univ. of Pittsburgh School of Medicine (1986/87), invited Distinguished Lecturer (one of five) on "Past, Present and Future of Resuscitation Medicine".

Riverside Methodist Hospital, Columbus OH, Critical Care Humanitarian Award 1987.

Spanish Society of Intensive Medicine and Coronary Units (SEMIUC) Honory President of the National CPR Plan 1987.

German Academy of Natural Sciences Leopoldina. Invited lecturer 1985, elected member 1987.

Endowed Peter and Eva Safar Chair of Anesthesiology and Critical Care Medicine, University of Pittsburgh (first incumbent, Peter Winter, M.D.)

Invited speaker for keynote addresses or named lectureships, several each year since 1958. Rudolf Frey Memorial Lectures in Rotterdam (1982), Rome (1983), Bremen (1983) and Mainz (1987). In 1983: Department of Defense Symposium on Disaster Medicine, Monterey; Ridgeway Trimble Memorial Lecture Med. and Chi. Faculty of Maryland; Belgian Soc. Anes. Meeting; USSR Anes. and Reanimatology Congress in Riga; West German Disaster Medicine congress in Munich; Latin American Congress of Anesthesiologists in Lima, Peru. In 1984: NATO Advanced Research Workshop, Mauls/Sterzing, Suedtirol, Italy; the Twelfth General Meeting of Japanese Association for Acute Medicine, Hiroshima; Special lectures in Taiwan, Hong Kong, Indonesia, Kumanoto, Okayama, Kobe, Sapporo, Tokyo; 2nd International Congress in Israel on Disaster Management, Jerusalem. In 1985: German Academy of Natural Science Leopoldina, Halle, E. Germany; 4th World Congress Disaster Medicine (UK); Redding Memorial Lectures Las Vegas & Charleston (1985). In 1986: Ludwig Boltzmann Symposium on CPCR, Linz, Austria; 50 years of resuscitation research laboratory USSR Academy of Medical Sciences (V. Negovsky). In 1987: WAEDM Congress Rio; International Resuscitation Researchers Symposium on the Reversibility of Clinical Death, Pittsburgh; 25 years Dept. of Anesthesiology Gutenberg University Mainz.

Non-medical interests: Music (particularly piano); arts; skiing; mountaineering; water sports; photography; world peace.

Family: Wife Eva Safar (nee Kyzivat). Children: Elizabeth (died at age 12), Philip (age 27), Paul (age 18).

Biographical Sketch

LEE M. SANDERSON

PRESENT POSITION AND ADDRESS:

Chief, Acute and Natural Hazards Studies Section
Division of Environmental Hazards and Health Effects
Center for Environmental Health and Injury Control
Centers for Disease Control
1600 Clifton Road, NE
Atlanta, Georgia 30333
(404) 488-4682

EDUCATION:

Ph.D.	Epidemiology	Univ. of Texas School of Public Health
M.A.	Public Health	University of Texas Medical Branch
B.A.	Natural Science	Johns Hopkins University

BACKGROUND:

After completing my doctoral studies, I spent approximately five years working as an injury epidemiologist for the National Institute for Occupational Safety and Health (NIOSH). I was involved in initiating/analyzing state-based and national surveillance systems and conducting descriptive and analytical epidemiologic studies of fatal and nonfatal occupational injuries.

I left NIOSH in 1985 to join CDC's Center for Environmental Health and Injury Control (CEHIC) and became CEHIC's senior scientist for disaster epidemiology. Our activities have included epidemiologic field assessments and studies of floods, hurricanes, tornadoes, landslides, fires, and chemical releases. Particular areas of interest have included injury risk factors, preparedness and reaction of local populations, role of warning systems, efficacy of evacuation, mass health care issues, responder health and safety, etc. Surveillance activities have included collaborative work with the Environmental Protection Agency, the American Red Cross, and the National Weather Service in order to enhance available national data concerning health effects from acute and natural environmental hazards. Direct and consultative assistance with public health contingency planning for a catastrophic earthquake has been provided to the Public Health Service Regional Office (San Francisco) and various California departments.

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CHARLES SCAWTHORN

Charles Scawthorn is Vice President for Research and Development for EQE Engineering in San Francisco, CA. With 20 years experience in structural and earthquake engineering, Dr. Scawthorn has engaged in structural analysis and design and seismic risk mitigation on projects in the U.S., Europe, the Middle and Far East. His research has involved examination of loss reduction through land use planning and structural strengthening, and development of innovative methods for the estimation of losses due to five following earthquakes. A licensed enginecr in California and New York, Dr. Scawthorn was educated at the Cooper Union (N.Y.), Lehigh University (PA), and Kyoto University (Japan), and serves on the Scientific Advisory Committee of the National Center for Earthquake Engineering Research.

KEISHI SHIONO

Research Associate
Tokyo Metropolitan University

Dr. Keishi Shiono is a researcher at the Department of Civil Egineering and the Center for Urban Studies, Tokyo Metropolitan University. His present interest lies mainly in quantitative evaluation of disaster seriousness and computer modeling of various earthquake related events including human casualties.

He holds a bachelor and master degree in civil engineering from Tokyo Metropolitan University and a doctorate degree in earthquake engineering from Hokkaido University, Sappro, Japan.

He is a member of the Seismological Society of Japan, Japanese Society of Civil Engineers, and Earthquake Engineering Research Institute.

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Biographical Sketch – Gordon S. Smith

Gordon S. Smith, M.B.Ch.B., M.P.H., is an Assistant Professor of Health Policy and Management at The Johns Hopkins University School of Hygiene and Public Health. Dr. Smith has had extensive experience in the development of epidemiologic indicators useful for health planning purposes and is currently a consultant to the National Academy of Sciences BOSTID project to develop rapid epidemiologic assessment methodologies in developing countries. He is an experienced injury researcher and a member of the injury control group at Johns Hopkins where the abbreviated injury severity score widely used in many countries was developed and tested. He has had extensive experience in developing countries including working under very difficult field conditions.

WALLACE, Dr. Craig K.

December 4, 1928. Woodbury, New Jersey. Married, three children.

Education. A.B. (cum laude), Princeton University, 1950. University of Virginia, School of Law, 1951. M.D., New York Medical College, 1955.

Professional History. 1955-1960, Intern, Medical Resident and Chief Resident, Jefferson Medical College Hospital, Philadelphia, PA. 1960-1963, Clinical Investigator, Naval Medical Research Unit (NAMRU) No. 2, Taipei, Taiwan. 1964-1969, Assistant Professor of Medicine, The Johns Hopkins University (JHU) School of Medicine. 1964-1970, Assistant Professor of Pathobiology, JHU School of Hygiene and Public Health. 1964-1966, Resident Coordinator and Head, Medical Program, JHU Center for Medical Research and Training (JHUCMRT), Calcutta, India. 1966-1969, Assistant Physician, The Johns Hopkins Hospital. 1967-1972, Associate Director, JHUCMRT. 1969-1972, Associate Professor of Medicine, JHU School of Medicine. 1969-1972, Associate Professor of Pathobiology, JHU School of Hygiene and Public Health. 1972-1974, Head, Research Detachment, NAMRU-3, Addis Ababa, Ethiopia. 1974-1976, Commanding Officer, NAMRU-5, Addis Ababa, Ethiopia. 1976-1978, Program Manager, Infectious Diseases Research, Naval Medical Research and Development Command, Bethesda, MD. 1978-1981, Chief of Internal Medicine, Naval Regional Medical Center, Camp Pendleton, CA. 1981- 1982, Director of Clinical Services, Naval Regional Medical Center, Jacksonville, FL. 1982-1984, Commanding Officer, NAMRU-3, Cairo, Egypt. 1984-1987, Director, John E. Fogarty International Center for Advanced Study in the Health Sciences, National Institutes of Health (NIH), Bethesda, MD. 1984- Associate Director for International Research, NIH.

Professional Associations. Fellow of the American College of Physicians; Fellow of Infectious Diseases Society of America; Fellow of the Royal Society of Medicine; Fellow of the Royal Society of Tropical Medicine and Hygiene; American Association for World Health; American Medical Association; American Society for Microbiology; American Society of Tropical Medicine and Hygiene; Association of Military Surgeons of the United States; The National Foundation for Infectious Diseases; National Council for International Health; The Professional Association of the Commissioned Corps of the U.S. Public Health Service; The Society of Medical Consultants to the Armed Forces.

Awards. Armed Forces Reserve Medal, 1975. Meritorious Service Medal, with Gold Star in lieu of Second Award, 1976, 1984. Navy Commendation Medal, 1982.

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KARL A. WESTERN, MD, DTPH

1961 AB Georgetown University

1965 MD Georgetown University

1972 DTPH London University, Dissertation: "Epidemiology and Control of Natural Disasters"

1965-67 Internal Medicine, Bellevue (Cornell) Memorial Hospitals

1967–present Medical Officer, US Public Health Service

1969-1970 International Committee of the Red Cross Famine Relief–Nygeria

1970 State Department Mission to Biafra

1972-1974 State Epidemiologist, Virginia (included Manager of State EMS)

1972-1979 Consultant in Health for USAID Office of Foreign Disaster Assistance

1974-1979 Chief, Communicable Diseases Department, PAHO/WHO (Washington, DC)

1973 Pakistan Flood

1976 Guatemala Earthquake

1977 Mexico Dam Burst (Baja, California)

1977 Organization of PAHO Regional Program of Disaster Preparedness (including recruitment of Dr. Claude de Ville as Chief)

1979-present NIAID/NIH (Tropical Medical and International Research)

JOSE LUIS ZEBALLOS MD,MPH.
Pan American Health Organization
Disaster Preparedness and Relief Program
525,23 Rd. St. N.W.
Washington D.C. 20034. Tel.(202) 861 4324

Advisor on emergency preparedness and relief coordination in case of disasters. Dr. Zeballos joined PAHO in 1981. As a physician and epidemiologist, he has extensive experience working in Latin America in the areas of medical care, health management and epidemiology of communicable diseases.

His area of expertise covers disaster management with direct field experience, participation in damage assessment and health consequences, and coordination of the international response in most of the disasters affecting the Latin American region during the present decade. Dr. Zeballos also participated in various case studies and emergency cooperation activities promoted by PAHO/WHO.

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APPENDIX D:
SCHEDULE FOR BREAKOUT GROUPS

WORKSHOP SCHEDULE:

Monday, July 10

Arellano Theatre, Levering Hall

8:30 a.m.	– 9:00 a.m.	Introduction
		Welcomes (Muller, VandeLinde)
9:00 a.m.	– 10:00 a.m.	Keynote (Lechat)
10:00 a.m.	– 10:15 a.m.	—Break—
10:15 a.m.	– 12:00 p.m.	Presentations 1: 4 papers 25min
12:00 p.m.	– 1:15 p.m.	—Lunch (Hopkins Club)—
1:15 p.m.	– 2:45 p.m.	Presentations 2: 4 papers 15min, 30 min discussion
2:45 p.m.	– 3:00 p.m.	—Break—
3:00 p.m.	– 4:30 p.m.	Presentations 3: 4 papers 15min, 30 min discussion
4:30 p.m.	– 6:00 p.m.	Presentations 4: 4 papers 15min, 30 min discussion
6:00 p.m.	– 7:30 p.m.	Cocktail reception (Hopkins Club)
7:30 p.m.	– ?	Dinner on your own

Tuesday, July 11

Arellano Theatre, Levering Hall

8:30 a.m.	– 10:00 a.m.	Presentations 5: 4 papers 15min, 30 min discussion
10:00 a.m.	– 10:15 a.m.	—Break—
10:15 a.m.	– 12:00 p.m.	Presentations 6: 5 papers 15min, 30 min discussion
12:00 p.m.	– 1:15 p.m.	—Lunch (Hopkins Club)—

Breakout Session Rooms – See Assignments

1:15 p.m.	– 3:00 p.m.	Breakout session 1
3:00 p.m.	– 3:15 p.m.	—Break—
3:15 p.m.	– 5:00 p.m.	Breakout session 2
5:00 p.m.	– 6:00 p.m.	Free
6:00 p.m.	– 8:30 p.m.	Dinner (Hopkins Club)

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Wednesday, July 12

Arellano Theatre, Levering Hall

8:30 a.m. – 9:00 a.m. General Session - recap on Tues sessions

Breakout Session Rooms – See Assignments

9:00 a.m. – 10:15 a.m. Breakout session 3
10:15 a.m. – 10:30 p.m. —Break—
10:30 a.m. – 12:00 p.m. Breakout session 4
12:00 p.m. – 1:15 p.m. —Lunch (Hopkins Club)—
1:15 p.m. - 3:00 p.m. Breakout session 5
3:00 p.m. - 3:15 p.m. —Break—

Arellano Theatre, Levering Hall

3:15 p.m. – 5:00 p.m. Wrap up, summary, conclusions.

- 1193'

INTERNATIONAL WORKSHOP ON EARTHQUAKE INJURY EPIDEMIOLOGY FOR MITIGATION AND RESPONSE

will be held at

The Johns Hopkins University
Baltimore, Maryland, U.S.A.

July 10 – 12, 1989.

Session Assignments

Breakout Session 1: Tuesday 11 July: 1:15 p.m. – 3:00 p.m.

Topic: Comprehensive Reference to Existing Data

Group A	Group B	Group C	Group D
Gordon Smith	Eric Noji	Fred Krimgold	Nick Jones
Conf Room A	Conf Room B	Latrobe 106	Latrobe 107
Abrams	Anderson	Alexander	Andrews
Armenian	Cheu	Aroni	Davidson
Briese	Coburn	Buckle	Freeman
Brismar	Klain	Charchoglyan	Ho
Chung	Kunkle	Coulson	Kvetan
Comfort	Lagorio	Gray	Meli
de la Garza	Lechat	Hays	Rojahn
Durkin	Mochizuki	Holland	Scawthorn
Hammond	Olson	McClure	Shiono
Lescarboura	Pantelic	Quarantelli	Tiedemann
Mahoney	Ricci	Sanderson	Wenger
Safar	Rouhban	Steinbrugge	Western
Zensinger	Wallace	Yamamoto	Zeballos

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Breakout Session 2: Tuesday 11 July: 3:15 p.m. – 5:00 p.m.

Topic: Consensus on Field Research Protocol and Implementation

Group A	Group B	Group C	Group D
Gordon Smith	Eric Noji	Fred Krimgold	Nick Jones
Conf Room A	Conf Room B	Latrobe 106	Latrobe 107
Alexander	Abrams	Armenian	Andrews
Anderson	Brismar	Briese	Aroni
Chung	Coulson	Buckle	Coburn
de la Garza	Davidson	Charchoglyan	Comfort
Durkin	Lescarboura	Cheu	Gray
Kunkle	Mahoney	Freeman	Hammond
Lagorio	Mochizuki	Ho	Hays
Lechat	Scawthorn	Holland	Klain
Ricci	Shiono	McClure	Kvetan
Rojahn	Tiedemann	Meli	Olson
Rouhban	Wenger	Pantelic	Quarantelli
Wallace	Yamamoto	Steinbrugge	Safar
Zensinger	Zeballos	Western	Sanderson

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Breakout Session 3: Wednesday 12 July: 9:00 a.m. – 10:15 a.m.

Topic: Research Applications/Implementation/Dissemination

Group A	Group B	Group C	Group D
Gordon Smith	Eric Noji	Fred Krimgold	Nick Jones
Conf Room A	Conf Room B	Latrobe 106	Latrobe 107
Alexander	Cheu	Anderson	Abrams
Andrews	Chung	Armenian	Aroni
Brismar	Comfort	de la Garza	Briese
Buckle	Davidson	Hammond	Coulson
Charchoglyan	Durkin	Kunkle	Freeman
Coburn	Gray	Kvetan	Holland
Lescarboura	Hays	Lagorio	Quarantelli
McClure	Ho	Lechat	Safar
Rouhban	Klain	Mahoney	Sanderson
Scawthorn	Mochizuki	Meli	Shiono
Tiedemann	Pantelic	Olson	Wallace
Western	Ricci	Steinbrugge	Wenger
Zeballos	Rojahn	Zensinger	Yamamoto

Breakout Session 4: Wednesday 12 July: 10:30 – 12:00 p.m.

Topic: Research Needs and Agenda: Multidisciplinary

Group A	Group B	Group C	Group D
Gordon Smith	Eric Noji	Fred Krimgold	Nick Jones
Conf Room A	Conf Room B	Latrobe 106	Latrobe 107
Brismar	Aroni	Anderson	Abrams
Chung	Comfort	Andrews	Alexander
Kvetan	Davidson	Buckle	Armenian
Lechat	de la Garza	Cheu	Briese
Lescarboura	Freeman	Coburn	Charchoglyan
Mahoney	Gray	Coulson	Durkin
Mochizuki	Hays	Klain	Hammond
Olson	Ho	McClure	Holland
Rojahn	Lagorio	Pantelic	Kunkle
Safar	Meli	Sanderson	Ricci
Shiono	Quarantelli	Scawthorn	Rouhban
Wallace	Wenger	Steinbrugge	Tiedemann
Zensinger	Yamamoto	Zeballos	Western

Breakout Session 5: Wednesday 12 July: 1:15 p.m. – 3:00 p.m.

Topic: Research Needs and Agenda: Intradisciplinary

Group A	Group B	Group C	Group D
Gordon Smith	Eric Noji	Fred Krimgold	Nick Jones
Conf Room A	Conf Room B	Latrobe 106	Latrobe 107
Alexander	Brismar	Anderson	Abrams
Armenian	Charchoglyan	Andrews	Aroni
Comfort	Cheu	Briese	Buckle
Coulson	de la Garza	Chung	Coburn
Freeman	Ho	Davidson	Durkin
Gray	Klain	Hays	Hammond
Lechat	Kunkle	Holland	Lagorio
Mahoney	Kvetan	Lescarboura	McClure
Ricci	Safar	Olson	Meli
Sanderson	Yamamoto	Pantelic	Mochizuki
Wallace		Quarantelli	Rojahn
Western		Rouhban	Scawthorn
Zeballos		Steinbrugge	Shiono
		Tiedemann	
		Wenger	
		Zensinger	

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