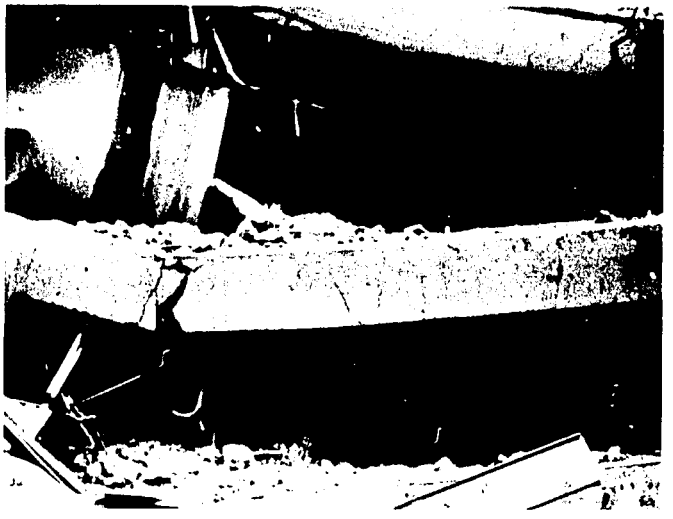
PD-ABD-470

International Cooperative Program For Earthquake Hazard Mitigation



NOTICE

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COVER PHOTOS

The two photos on the cover show the collapse of a 4-story reinforced concrete frame school building near Miravalles Plaza in Mexico City following the September 19, 1985, magnitude 8.1 Mexico earthquake. The lower photo shows that the concrete slabs are resting on the students' desks. None of the students enrolled in the school were in the building when the earthquake struck, at 7:18 a.m. local time. Clearly the death toll would have been high if the earthquake had occurred at, say, 10:00 a.m. (Photos by V. Bertero)

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INTERNATIONAL COOPERATIVE PROGRAM FOR EARTHQUAKE HAZARD MITIGATION

Prepared by
EERI Committee on Earthquake Hazard Mitigation

Roger E. Scholl, Chairman
Vitelmo V. Bertero
G. Wayne Clough
Robert D. Hanson
Walter W. Hays
Henry J. Lagorio
James L. Stratta
Anestis S. Veletsos

November 1986

Earthquake Engineering
Research Institute
El Cerrito, California

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EXECUTIVE SUMMARY

This report recommends carrying out a comprehensive International Cooperative Program for Earthquake Hazard Mitigation which, over the next 13 years (by the year 2000) will reduce property damage and life loss throughout the world from earthquakes.

This program will be accomplished through international cooperation involving dissemination and application of existing knowledge and new research findings, and fostering implementation of loss reduction measures worldwide. The primary effort needed for implementing the Program is to coordinate existing expertise and to exchange the information available among the earthquake-prone countries of the world. Although basic research must undergird the Program, the emphasis of this Program is on dissemination, application, and implementation of loss reduction measures.

The Program scope includes two research activities, five Technology Transfer activities, and two implementation activities. The research activities include: (1) research workshops and conferences held in the United States and in foreign countries for identifying research needs and exchanging knowledge, and (2) research project execution at facilities in the participating countries. The Technology Transfer activities include: (1) orientation seminars held in the United States for government policy makers and technical leaders, (2) technical seminars held abroad that are organized and conducted by U.S. earthquake specialists or organized by representatives of the country or region involved with U.S. assistance as requested, (3) in-depth technical seminars held in the United States for foreign earthquake specialists, (4) long-term advanced graduate education and training programs in the U.S. (including participation in a proposed Earthquake Engineering Education and Training Center), and (5) visits by distinguished foreign specialists to lecture at U.S. universities and at meetings of technical and professional societies. While technology implementation is crucial to the ultimate success of the Program, specific hazard mitigation actions must be tailored to the needs of the countries involved. Accordingly, the recommended implementation activities are: (1) development of Seismic Hazard and Risk Assessment Reports for each country participating in the Program and (2) ad-hoc implementation assistance abroad. The reports will characterize the seismic hazards and risks of the countries involved for the purpose of identifying fruitful hazard mitigation actions.

The need for the proposed Program stems from the devastating social and economic consequences of earthquakes that occur throughout the world every year. Every year about 10,000,000 earthquakes occur worldwide. Of these, about 50,000 are large enough to be felt without scientific instrumentation. During the past decade, starting with 1975, an average of about 40,000 people were killed each year by damaging earthquakes throughout the world. Because of the extraordinary pressures of urban growth and population increases in metropolitan areas throughout the world, postearthquake reconstruction costs have reached levels which require fiscal relief at international assistance levels through organizations such as the World Bank and the International Monetary Fund (IMF). Many countries are no longer able to finance total postearthquake reconstruction costs internally.

The need for the proposed Program was again reemphasized in the past two years with the occurrence of three major earthquakes (March 3, 1985 in Chile, September 19, 1985, in Mexico, and October 10, 1986, in El Salvador). These earthquakes typify the nature, complexity, and international character of the earthquake problem worldwide: they had a large economic impact, caused large loss of life and human suffering, demonstrated inadequacies in disaster response and recovery, and provided new technological insights to needed earthquake hazard mitigation measures. The proposed Program is designed to take full advantage of the lessons learned from these and other destructive earthquakes through an organized cooperative international exchange and implementation of earthquake hazard mitigation knowledge.

Among the anticipated benefits of this Program are: improvement of the economic benefits (cost-effectiveness) of investments in constructed facilities (buildings, infrastructure, dams, etc.) in earthquake-prone areas worldwide; minimization of life loss and property loss and reduction of suffering in countries stricken by earthquakes; establishment of individual country self-sufficiency in earthquake-prone regions of the world; maximizing international cooperation in earthquake engineering research, mitigation, and disaster response and recovery; and providing reciprocal benefits in research, mitigation, construction technology, cultural exchange, and quality of life.

The total capital cost for the proposed comprehensive worldwide Program is estimated to be about $32 million over the full 13-year planned schedule. Implementation of the Program is proposed in two phases as follows: Phase 1 -- Pilot Regional Application -- is a trial application involving limited implementation of the Program in one region of the world during the period of 1987-1989 with an estimated cost of about $3 million; Phase 2 -- Worldwide Application -- consists of complete implementation of all the proposed Program activities in all regions of the world during the period of 1990 to 2000 and is budgeted at about $29 million. This is regarded as an optimum Program that is clearly ambitious both in scope and budget. The Program is designed to be flexible and can be implemented in one or two of the worldwide regions identified, or various activities could be implemented independently in a single country. Representative budgets are prescribed for each activity and for Programs in a single country and in a single region.

A variety of options are available for managing the Program including taking advantage of already established organizations such as the National Science Foundation for managing the research element worldwide and the Organization of American States for managing the Technology Transfer and Implementation elements in Latin America.

In addition, a suggested management plan for the Program is given that consists of a private-sector Contractor having a substantial breadth of knowledge regarding earthquake hazards and procedures for mitigating earthquake hazards, and experience pertaining to the political processes involved in implementing earthquake hazard mitigation actions. Contractor staffing is highlighted by a Steering Committee, a Program Director, and Regional and Country Coordinators, with the number of Coordinators and their responsibilities tailored to the segments of the Program for which they are responsible.

ACKNOWLEDGMENTS

Several persons deserve recognition for their support of Program recommended herein. The EERI Committee on Earthquake Hazard Mitigation held two meetings with representatives of government and the private sector concerning activities relevant to the proposed Program.

In the first meeting, held in Washington, D.C., on January 28, 1985, several persons graciously gave of their time to provide the Committee with accounts of previously conducted and ongoing programs in international earthquake hazard mitigation and evaluations of the effectiveness of these programs. For this the Committee is grateful to: Drs. William A. Anderson, John B. Scalzi, K. Thirumalai, and Roger Doyon of the National Science Foundation; Ms. Gudrun Huden, Mr. Paul Krumpe, and Mr. Jack Snead of AID/OFDA of the Department of State; Professor Antonio Quesada E. of the Organization of American States (OAS); Dr. David Russ of the U.S. Geological Survey; Donald Geis of the AIA Research Foundation; Jean Parker of Intertect, Inc.; and Dr. Fredrick Krimgold of Virginia Polytechnic Institute.

The second meeting was held at the AID/OFDA offices in Washington, D.C., on March 7, 1985, for the primary purpose of assessing the perceived needs of the Program proposed herein from various AID/OFDA personnel who regularly deal with earthquake disasters in foreign countries. For their gracious contribution at this meeting, the Committee is grateful to: General Julius Becton, Wally Bowles, Denise Decker, Paul Krumpe, James Shill, Paul Thorn, Ralph Bird, Raymond Dionne, Mary Little, Jack Snead, Paul Vitale, and Frederick Cole -- all with AID/OFDA or AID.

In May 1985, several members of the Committee participated in a meeting in Puerto Rico that was also attended by several earthquake specialists from Latin America. On this occasion, a special six-hour evening meeting was held to discuss the attributes of various aspects of an international earthquake hazard mitigation program. Six experts from Latin America participated in this lively and active meeting. For their considered and substantive recommendations, the Committee is grateful to: Drs. Luis Garcia from Colombia, Hector Monzon from Guatemala, Daniel Torrealva from Peru, Mauricio Sarrazin from Chile, Jorge Gutierrez from Costa Rica, and Reginald Garcia from the Dominican Republic. The Committee is also grateful to Professor Antonio Quesada E., originally from Venezuela and presently with OAS in Washington, D.C., for attending this meeting and giving candid and constructive suggestions.

CHAPTER I
INTRODUCTION

STATEMENT OF PROBLEM

Every year about 10,000,000 earthquakes occur worldwide, of which about 50,000 are large enough to be felt without scientific instrumentation, and many are strong enough to cause property damage and life loss. During the past decade, an average of about 40,000 people a year were killed by damaging earthquakes. Most of the losses are due to poor performance of man-made structures, including buildings, dams, lifelines, and other critical operational facilities.

Clearly, the world is more vulnerable to major disasters now than in the past because of growing high-density metropolitan centers, rapidly expanding population in urban environments, greater interdependence of people, expanding interrelationships of national economies, and decreasing natural resources.

Social and financial losses due to major seismic events can seriously drain national economies and may threaten the financial viability of national fiscal budgets. In a given year, earthquake-induced losses may well reach $1 trillion. Many countries are no longer in a position to finance postearthquake reconstruction costs on their own and require fiscal relief at international assistance levels through organizations such as the World Bank and the International Monetary Fund. Yet the destructiveness of major earthquakes may be reduced significantly through improved design and construction practices and implementation of appropriate hazard preparedness programs.

PROGRAM DEFINITION, GOALS, AND OBJECTIVES

The objective of this document is to define a comprehensive earthquake hazard mitigation program that, when implemented, will significantly reduce property damage and life loss throughout the world by the year 2000. The objectives of this Program will be achieved through international cooperation involving dissemination and application of existing knowledge and new research results, and fostering implementation of loss-reduction measures in earthquake-prone countries worldwide.

The proposed Program is unique in that it emphasizes the cooperative transfer and implementation of existing knowledge and technology in addition to basic research. As defined herein, technology transfer encompasses a broad range of activities, including education of research and technical personnel, training of construction and inspection personnel, and fostering a process of implementing appropriate loss-reduction measures, all with appropriate reciprocal interactions and appropriate short- and long-term objectives. The primary effort needed to implement the Program involves the coordination of existing expertise and the development of appropriate mechanisms for transferring the requisite information and identification of appropriate research efforts between countries.

Basic research must undergird the Program; therefore cooperative research activities must be interrelated with dissemination, application, and implementation of loss-reduction measures. Figure 1 shows the key elements of the proposed Program and the interplay between them.

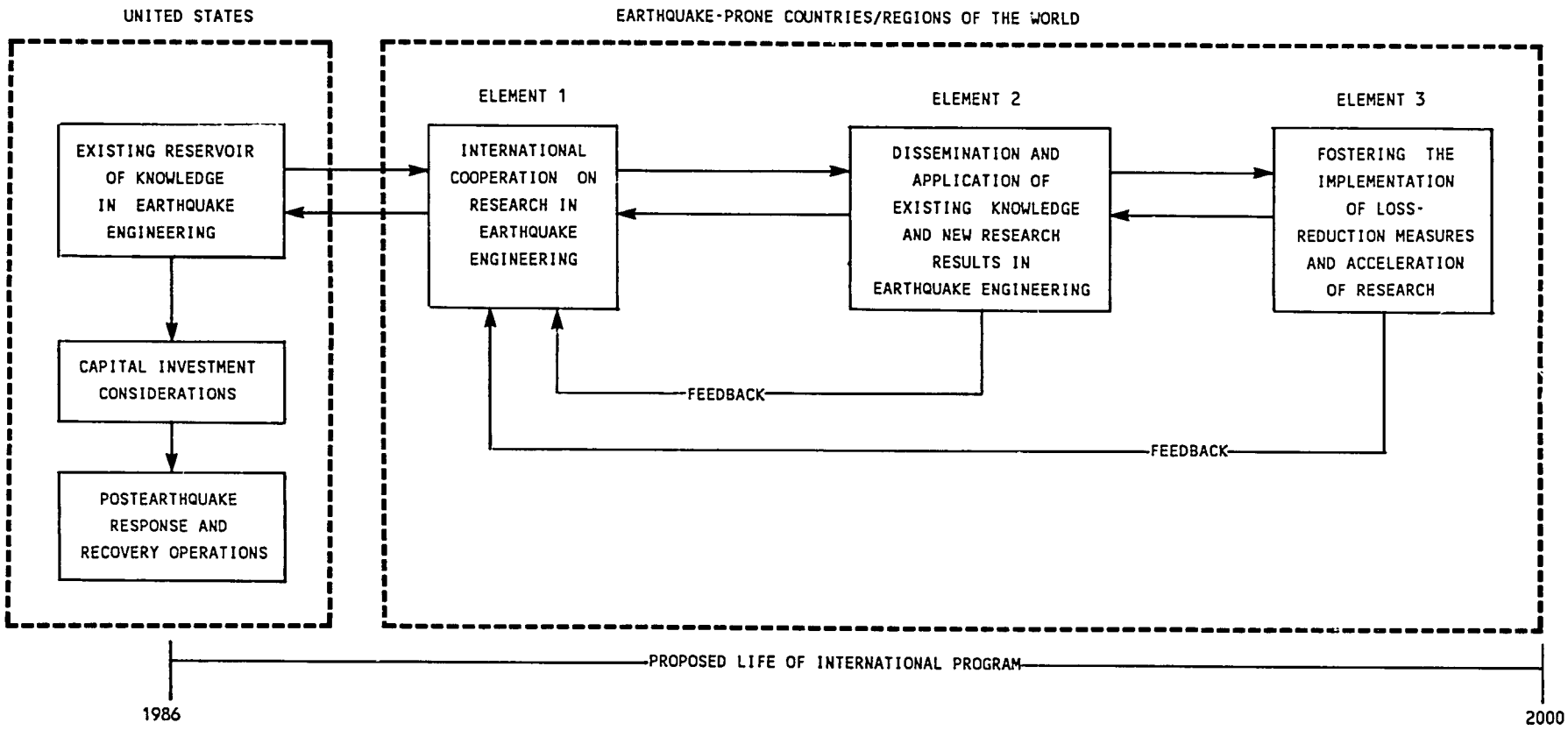


FIGURE 1. KEY ELEMENTS IN THE INTERNATIONAL COOPERATIVE PROGRAM FOR EARTHQUAKE HAZARD MITIGATION

Although the emphasis is on Elements 2 and 3, continuous basic and applied research must undergird the program. The program is expected to yield considerable reciprocal benefits. An effective worldwide program will require implementation over a period of 10 to 20 years.

Among the anticipated benefits of this Program are: improvement in the economic benefits (cost-effectiveness) of investments in constructed facilities (buildings, infrastructure, dams, etc.) in earthquake-prone areas worldwide; minimization of life loss and property loss and reduction of suffering in countries stricken by earthquakes; establishment of individual country self-sufficiency in earthquake-prone regions of the world; maximizing international cooperation in earthquake engineering research, mitigation, and disaster response and recovery; and providing reciprocal benefits in research, mitigation, construction technology, cultural exchange, and quality of life.

OBJECTIVES OF SPONSORING AGENCIES AT INTERNATIONAL LEVELS

The Office of Foreign Disaster Assistance (OFDA) is the lead U.S. government organization responding to disasters abroad as a manifestation of humanitarian objectives and economic assistance to the needs of regions overwhelmed by natural disasters. The objectives of this agency are to save lives and property and to reduce suffering in foreign countries stricken or threatened by disaster.

Three major goals identified in Chapter 9 of the Foreign Assistance Act of 1961 are of particular relevance to the proposed Program. They are:

1. To alleviate suffering by providing efficient, rapid, and appropriate responses to requests for emergency relief and enhance recovery through rehabilitation programs.

2. To foster self-reliance among disaster-prone nations by helping countries achieve adequate preparedness for disasters.

3. To save lives and property by introducing practical measures that can mitigate the effects of future disasters.

The United States presently has a highly developed, but still limited, earthquake engineering technology capability. Accordingly, activities undertaken in connection with the Program proposed herein will undoubtedly bring about reciprocal benefits to the United States and will result in future reductions of human suffering from earthquakes in the United States.

The National Science Foundation (NSF) Directorate for Engineering, under which research elements related to the Earthquake Hazard Mitigation Program are housed, supports research directed at achieving four major goals compatible with the goals of this Program:

1. Insure that the U.S. is at the leading edge of engineering research in all fields.

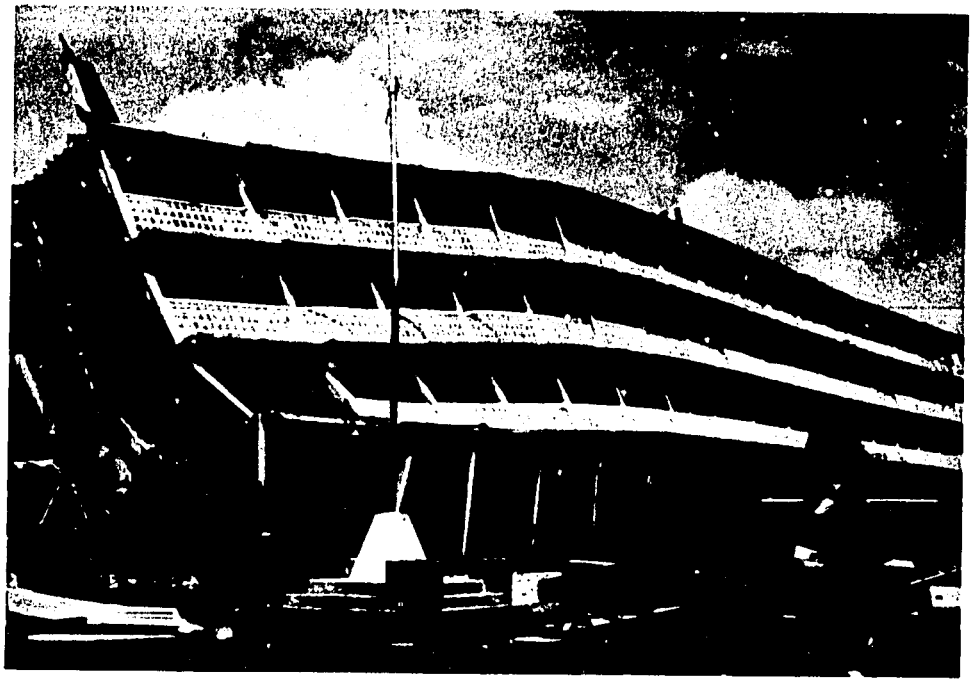
2. Assist U.S. engineering schools in producing the world's best engineers.

3. Find ways for the U.S. to benefit from the full research potential of universities, colleges, industry, and government resources.

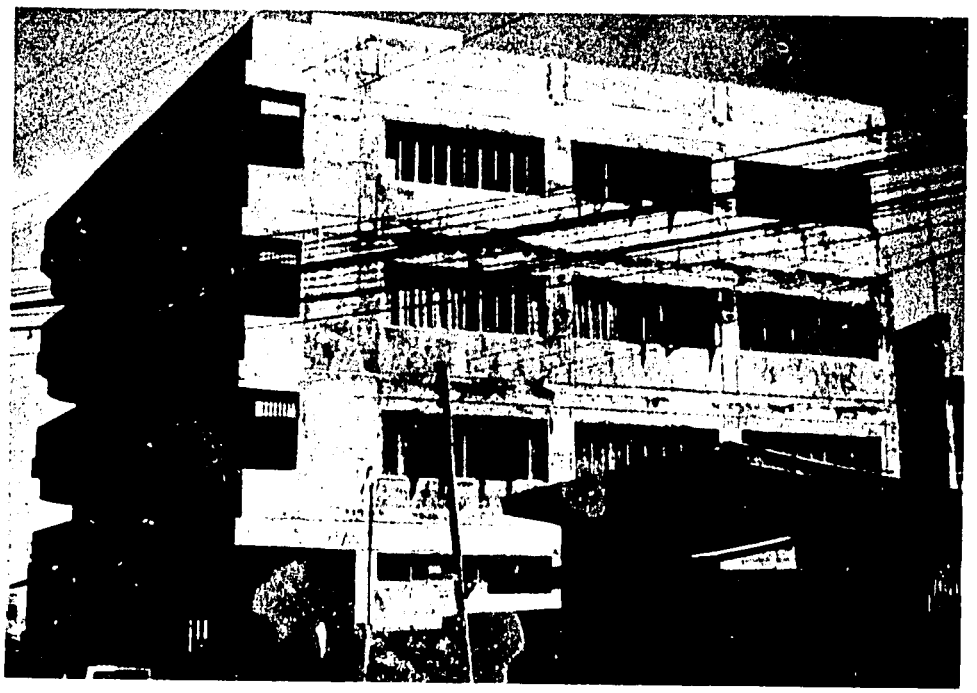
4. Insure that sufficient fundamental knowledge and expertise is available, along with cross-disciplinary activities, to stimulate advances in engineering in the private sector.

Under the Critical Engineering Systems Section of NSF, which administers the Earthquake Hazard Mitigation Program, critical areas for research study involve industrial and professional processes in which innovation may significantly alter: (a) international competitiveness, (b) environmental consequences of urban growth and industrial activity, and (c) problems related to maintaining the public and private capital investment that forms the physical basis for our modern industrial society. Of relevance to the activities to be developed in this International Program, the key words above are: "international competitiveness," "urban growth and industrial activity," and "maintaining the public and private capital investment."

Goals of the Earthquake Hazard Mitigation Program have a direct bearing on the viability of this International Program by ensuring that new research results which incorporate international and cooperative investigations will become available for application by design professionals for years to come. It is also clear that much of the new data derived from these research studies can be easily developed into educational material for information exchange with other countries and for utilization at international levels.



Harvardian College collapsed as did most other engineered buildings in Mindanao that were not designed with seismic considerations in mind.



The Tison Building, reportedly the only building in Mindanao designed in accordance with seismic considerations, was essentially undamaged.

Examples of good and poor earthquake performance of engineered buildings at Mindanao, Philippines, following the magnitude 8.0 earthquake that struck the islands on August 17, 1976, killing about 8,000 persons. While there are many alternatives available for reducing earthquake hazards, the implementation of earthquake-resistant design procedures and construction practices is perhaps the most important and effective earthquake hazard mitigation measure available. (Photos by J. L. Stratta)

CHAPTER 2
NATURE OF EARTHQUAKES AND HAZARD MITIGATION MEASURES

NATURE OF EARTHQUAKES

Depending on its size and location, an earthquake causes the physical phenomena of ground shaking, surface fault rupture, earthquake-induced ground failure (landslides, liquefaction, compaction, lurching, and foundation settlement), regional tectonic deformation, seiches, and (in some coastal locations) tsunamis. Each phenomenon can cause damage to structures and critical facilities, economic loss, injuries, loss of life, loss of function, and loss of confidence. Fires, landslides, and floods can also be triggered by these hazards. In addition, aftershocks may follow the main shock over a period of several months to several years and may cause additional damage, losses, and adverse psychological impacts. Compared with other natural hazards (e.g., hurricanes, floods, volcanic eruptions), an earthquake has the following four characteristics:

1. Pattern of Occurrence. Earthquakes occur mainly along the boundaries of tectonic plates throughout the world (providing partial proof of the theory of plate tectonics) and recur cyclically where they occurred in the past. Short-term prediction of the size, place, and time of future earthquakes, however, is still an emerging scientific field that cannot be depended upon to reduce losses independently of other mitigation activities.

2. Impact Time. The time between the first physical precursors, if any, of a major earthquake and its peak impact is short, on the order of a few hours or less, and no warning system is presently available to reduce potential losses. The duration of an earthquake is very short (a few seconds to several minutes) compared with the duration of many other natural hazards.

3. Area Affected. A broad area of several hundred thousand square miles centered around the epicenter is affected in a major earthquake, with damage and losses generally decreasing with distance from the epicenter. However, as observed in the 1964 Prince William Sound, Alaska earthquake, tsunamis can be very destructive at locations thousands of miles from the epicenter, and ground shaking effects can cause collapse of buildings located 250 miles from the epicenter as in the 1985 Mexico earthquake. Hence, reduction of potential earthquake losses requires mitigation efforts on four scales (using conventional map scales as examples): (a) global (1:7,500,000 or larger), (b) regional (1:250,000 or larger), (c) urban (1:24,000 or smaller), and (d) engineering (1:5,000 or smaller).

4. Frequency. Compared to other natural hazards, a major earthquake occurs relatively infrequently, varying, on the average, from once every 30 years in high seismicity areas of the world to once every 500-1,000 years in low seismicity areas of the world. The infrequent annual occurrence of a major earthquake relative to other natural hazards like floods that occur annually tends to make loss-reduction measures evolve slowly and to limit progress mainly to the time immediately after the occurrence of a damaging earthquake.

Three recent major earthquakes (March 3, 1985 in Chile, September 19, 1985 in Mexico, and October 10, 1986 in El Salvador) reemphasized the nature, complexity, and international character of the problem which this document addresses. These earthquakes had a large economic impact, caused large loss of life and human suffering, demonstrated inadequacies in disaster response and recovery, and provided new technological insights into needed earthquake hazard mitigation measures. To take full advantage of the lessons that may be learned from these and future earthquakes will require a comprehensive multidisciplinary program. The goal would be to assess the consequences of such diverse factors as: ground motion characteristics, response of soils to ground shaking, response of man-made structures, effect of structural systems used, effect of codes on quality of design and construction practices, and emergency management processes.

DISTRIBUTION OF EARTHQUAKES AND CLASSIFICATION OF SEISMIC REGIONS

Figure 2 shows the major tectonic plates of the world and reveals the global threat of earthquakes. Table I lists major 20th century earthquakes and the number of deaths caused by those earthquakes.

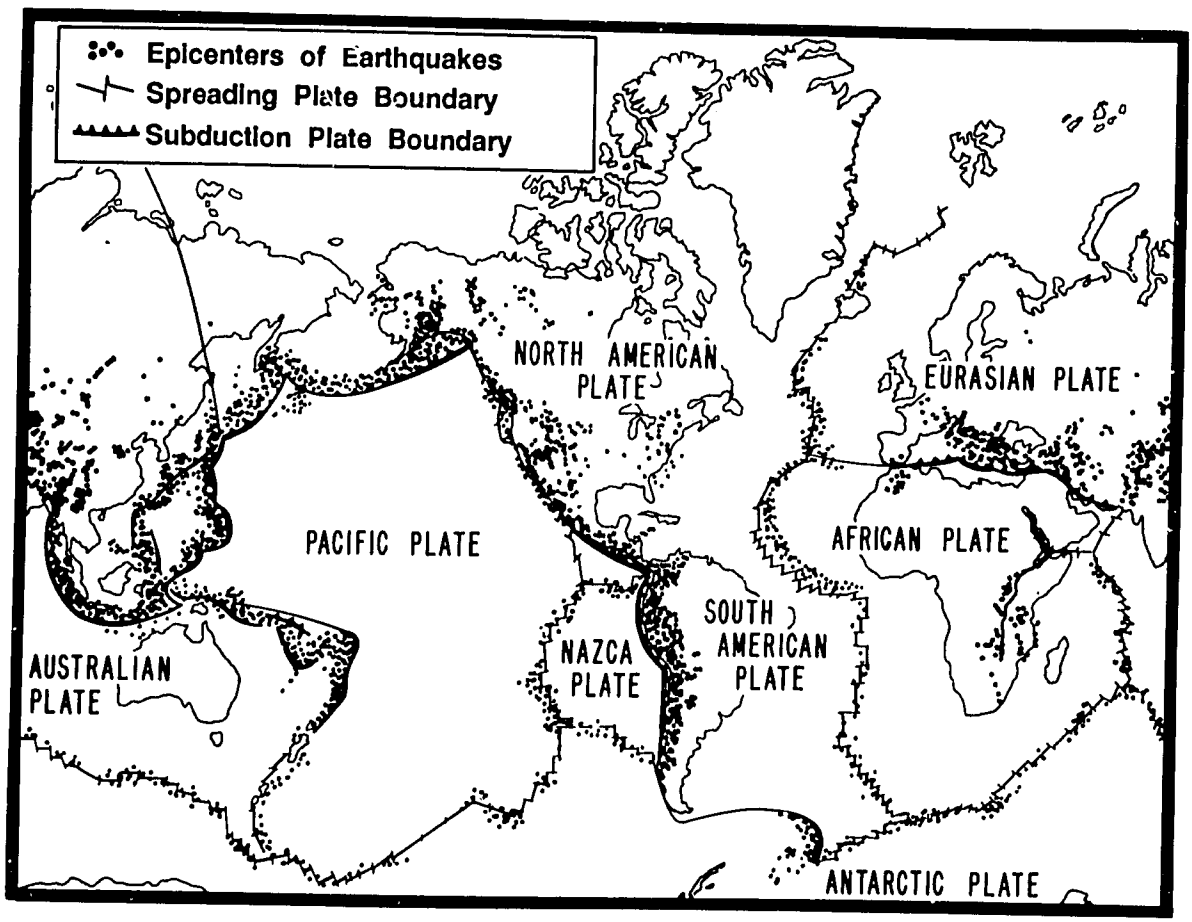


FIGURE 2. WORLD MAP SHOWING PRINCIPAL TECTONIC PLATES

TABLE I

MAJOR EARTHQUAKES OF THE 20TH CENTURY

DATE	PLACE	RICHTER MAGNITUDE	DEAD
September 19, 1985	Mexico	8.1	10,000
March 3, 1985	Chile	7.4	177
October 30, 1983	Turkey	7.1	1,300
December 13, 1982	North Yemen	6.0	2,800
November 23, 1980	Italy	7.2	4,800
October 10, 1980	Algeria	7.3	4,500
December 12, 1979	Colombia and Ecuador	7.9	800
September 16, 1978	Iran	7.7	25,000
March 4, 1977	Romania	7.5	1,541
November 24, 1976	Eastern Turkey	7.9	4,000
August 17, 1976	Philippines	7.8	8,000
July 28, 1976	Tangshan, China	8.2	242,000
May 6, 1976	Italy	6.5	946
February 4, 1976	Guatemala	7.5	22,778
September 6, 1975	Turkey	6.8	2,312
December 28, 1974	Pakistan	6.3	5,200
December 23, 1972	Nicaragua	6.2	5,000
April 10, 1972	Iran	6.9	5,057
February 9, 1971	United States	6.4	64
May 31, 1970	Peru	7.7	66,794
March 28, 1970	Turkey	7.4	1,086
August 31, 1968	Iran	7.4	12,000
August 19, 1966	Turkey	6.9	2,520
July 26, 1963	Yugoslavia	6.0	1,100
September 1, 1962	Iran	7.1	12,230
May 21-30, 1960	Chile	8.3	5,000
February 29, 1960	Morocco	5.8	12,000
August 17, 1959	United States	7.1	28
December 13, 1957	Iran	7.1	2,000
July 2, 1957	Iran	7.4	2,500
June 10-17, 1956	Afghanistan	7.7	2,000
March 18, 1953	Turkey	7.2	1,200
August 15, 1950	India	8.7	1,530
August 5, 1949	Ecuador	6.8	6,000
June 28, 1948	Japan	7.3	5,131
December 31, 1946	Japan	8.4	2,000
December 26, 1939	Turkey	7.9	30,000
January 24, 1939	Chile	8.3	28,000
May 31, 1935	India	7.5	30,000
January 15, 1934	India	8.4	10,700
March 2, 1933	Japan	8.9	2,990
December 26, 1932	China	7.6	70,000
May 22, 1927	China	8.3	200,000
September 1, 1923	Tokyo, Japan	8.3	99,330
December 16, 1920	China	8.6	100,000
January 13, 1915	Italy	7.5	29,980
December 28, 1908	Italy	7.5	83,000
August 16, 1906	Chile	8.6	20,000
April 18-19, 1906	San Francisco	8.3	452

For the purpose of this International Program, high-risk seismic regions of the world and the countries that may be affected by the proposed program are classified into three regions, as shown in Table 2.

TABLE 2
GEOGRAPHIC DIVISION OF THE WORLD IN THREE SEISMIC REGIONS

Region I America	Region II Asia & Pacific	Region III Africa & Europe
Argentina	Australia	Algeria
Bolivia	China	Bulgaria
Brazil	India	Greece
Canada	Indonesia	Iran
Chile	Japan	Italy
Colombia	Korea	Morocco
Costa Rica	Nepal	Portugal
Ecuador	New Zealand	Romania
El Salvador	Pakistan	South Africa
Guatemala	Philippines	Spain
Honduras	Taiwan	Turkey
Jamaica		Yugoslavia
Mexico		
Nicaragua		
Panama		
Peru		
United States		
Venezuela		

EARTHQUAKE VULNERABILITY OF STRUCTURES AND EARTHQUAKE-RESISTANT DESIGN

In the past two decades, dramatic technological advances have been made in earthquake engineering in the United States--largely resulting from the infusion of research funding and response to the need to ensure seismic safety for nuclear power plant construction. In addition, important lessons on the seismic performance of structures have been learned by studying, in cooperation with other countries, the effects of earthquakes in countries other than the United States.

Following the 1933 Long Beach, California, earthquake, the California legislature enacted the Field Act, requiring that all elementary and secondary public school buildings be designed and constructed to resist severe earthquakes. While this advanced attitude toward the feasibility of earthquake-resistant construction presently prevails in the United States, it does not exist worldwide. As recently as 1976, the entire city of Tangshan, China, having a population of 1,000,000 persons, was totally demolished. Since 1976, China has implemented a major earthquake countermeasures program, but there are many earthquake-prone countries of the world that have not yet adopted the attitude that earthquake-resistant construction is feasible.

Recent postearthquake observations of the performance of engineered works in the United States have revealed both successes and failures. For example, new California elementary and secondary public school buildings have been observed to perform well, but some nonstructural component detailing has been inadequate.

Severe damage to engineered buildings has been observed in earthquakes that were not expected to induce such damage. Although the earthquake problem has not yet been solved, the United States currently holds a strong technological leadership role in earthquake engineering.

Active involvement on the part of the United States in an international earthquake hazard mitigation program is beneficial from two perspectives: (1) the advanced earthquake engineering technology that exists in the United States can be productively shared worldwide for humanitarian reasons as well as to protect United States investments abroad, and (2) recognizing that the earthquake problem has not yet been solved and that devastating earthquakes occur in several parts of the world, enhanced cooperation with selected countries will be technologically beneficial to both the United States and the other countries involved.

OVERVIEW OF THE HAZARD MITIGATION PROCESS

Mitigation is the process of reducing the vulnerability of lives, property, and resources to the effects of earthquakes. The diversity and complexity of earthquake hazards make their mitigation extraordinarily difficult. An integrated, multidisciplinary plan of attack incorporating the efforts of many individuals and the knowledge, skills, and techniques of several professional disciplines is required. Figure 3 is a schematic representation of the primary factors and processes involved in first making an Assessment of Risk for a specific structure or class of structures, and then Implementation of Loss Reduction Measures. Contributions from the following groups of people are needed: (1) elected and appointed public officials and political leaders; (2) earth scientists, social scientists, architects, geotechnical engineers, structural engineers, and construction engineers from both the academic community and the private sector; (3) urban planners; (4) building officials; and (5) individual and professional builders, including representatives of the building materials and crafts industries.

Contributing to the difficulty of earthquake hazard mitigation is the fact that different countries have their own unique problems, social structures, economic programs, environmental interests, and characteristic strengths in addressing the mitigation of natural hazards. To be effective, international assistance and cooperative programs must give due attention to these matters and must be individually tailored.

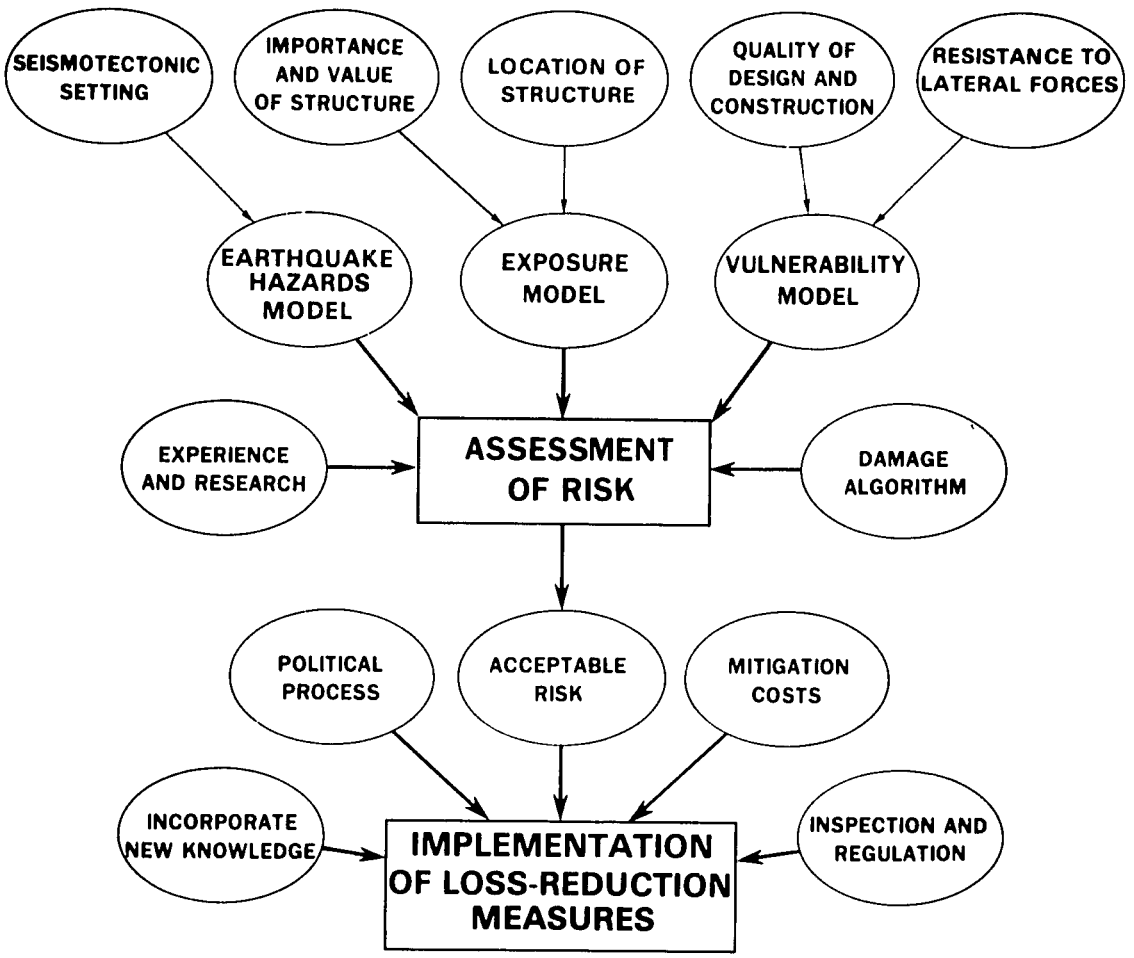


FIGURE 3. SCHEMATIC OF EARTHQUAKE HAZARDS AND MITIGATION PROCESSES

Illustration shows the relationship between the earthquake hazards model, the exposure model, and the vulnerability model and the various factors that must be considered in assessing earthquake hazards and devising loss-reduction measures.

CHAPTER 3

BASIC CONSIDERATIONS FOR DEVELOPING AN EFFECTIVE PROGRAM

An effective earthquake hazard mitigation program requires a balanced combination of research, dissemination, and implementation efforts at the international level. Before presenting a plan for responding to this challenge, it is desirable to identify the audiences involved in earthquake hazard mitigation and the professional disciplines from which expertise must be drawn and to review strategies for effective communication.

AUDIENCES INVOLVED

Strictly speaking, the success or failure of an earthquake hazard mitigation program depends on all segments of society. The range of perspectives of the people involved is broad, and each group plays a different role. The audiences involved include:

- Political leaders
- Educators
- Earthquake scientists
- Earthquake practicing professionals
- Social scientists
- Building officials
- Individual builders
- Community representatives

Not only is the role of each group different, but each group responds to different stimuli. Accordingly, an effective earthquake hazard mitigation program must be responsive to the needs and interests of all groups involved.

Differences in perspective are the main reason that an earthquake hazard mitigation program of a country (region, city, agency, or institution) must have well-coordinated short- and long-term objectives and must involve both the scientific/technical community and decision makers in a way that minimizes the differences in their perspectives. Similar attention must be given to the other audiences to ensure the effectiveness of the program.

PROFESSIONAL DISCIPLINES INVOLVED

For the mitigation of the earthquake hazard, expertise needs to be drawn from the fields of earth science, urban planning, design engineering, construction technology, architecture, public policy, education, and social science. Integration of the information from these areas allows:

1. Active fault zones to be identified and potential effects of earthquakes to be quantified.

2. Structures, major utilities, and habitations to be located in areas less likely to be subject to major ground dislocations.

3. Areas of potential disruption of lifelines to be identified and plans to be defined for dealing with the losses that inevitably occur.

4. Structures, major utilities, and habitations to be designed for reasonable levels of earthquake motions.

5. Proper types of construction, construction codes, and construction inspection to minimize earthquake damage.

In the following paragraphs, brief descriptions are given of the principal disciplines involved.

Geology

Geology serves to provide the information about the structure of the earth and the causes of earthquakes. The geologist identifies and locates earthquake faults, determines the type of fault, and determines the frequency of the fault movement. Also, information pertaining to the potential length of fault break is generated, a parameter that is important in determining the potential magnitude of future seismic events.

Seismology

The science of seismology is concerned with the types of earthquake waves and how these waves are transmitted through the earth. The seismologist plays a key role in sorting out the distance at which an earthquake will be felt and the likely maximum acceleration that will exist at a site for various possible fault breaks. Recently, considerable work has been done by seismologists on the issue of prediction of earthquakes.

Geotechnical Engineering

The responsibility of the geotechnical engineer lies with the response of the ground. The geotechnical engineer is also concerned with the possible influence of the soil conditions on the earthquake-induced motions, and he generally participates with the structural engineer and seismologist in the choice of a design loading for a site. Particular issues of interest to this specialty include earthquake-induced landslides, liquefaction of saturated sands, settlement and subsidence, the interaction of soils and structures, and the behavior of dams, levees, and embankments.

Lifeline Engineering

Lifelines are those facilities that supply modern culture with communications, power, water, sewage handling, and transportation. It is characteristic of these systems that they are networks and cover large distances. Because of the extent of lifelines, it is almost impossible to expect that no failures will occur in a major seismic event. The task of the lifeline engineer is to minimize the failures that do occur and to provide for alternative means of service when certain elements of the system fail.

Architecture

The architect is commonly the lead in the design of the overall function and mass of a building. As such, he is concerned with how the building will serve to fulfill

its role during and after an earthquake. The architect should be aware of how the shape of a building impacts its performance during an earthquake and how to modify concepts based on visual appearance, program constraints, and fiscal limits. In addition, the architect must serve as the central agent in integrating the earthquake design inputs from other design professionals such as electrical, mechanical, geotechnical, and structural engineers.

Structural Engineering

The information from the geologist and the seismologist is used by the structural engineer to help select the proper level of seismic loading that should be used to design buildings and other structures. The job of the structural engineer is to then ensure that a building has enough strength and that all the necessary connections and load transfer mechanisms are included to resist the most likely earthquake load expected in the life of the building. This design responsibility, in consultation with the geologist and seismologist, also includes consideration of location of structures so as to avoid faults if possible and allowance for the effects of differing subsurface conditions on the general motions predicted by the seismologist.

Mechanical and Electrical Engineering

Mechanical and electrical engineers are concerned about the stability and consequences of failure of the machines and electrical systems in buildings and structures. They must also deal with the maintenance and supply of power and other services following an earthquake.

Construction

Following the design of a structure or system by the engineers and architects, it must be constructed according to the plans and codes. This will involve both the actual construction and the inspection to enforce the intent of the plans and codes. Without proper construction and inspection, facilities all too often are unable to fulfill their function during an earthquake. The construction engineers, building officials, and inspectors are the personnel who serve to achieve the goals of the designers if the structural engineer does not perform this function.

Urban and Emergency Response Planning

Planning is the essential element in determining how well prepared a society is to respond to the effects of a seismic event. The urban planners and emergency planners are responsible for designing the schemes for providing emergency services; keeping access open to medical units; making sure that enough doctors, fire-fighting units, police units, and rescue units are available; coordinating agencies that are trying to provide services; and maintaining civilian morale. The planner's task is sometimes made difficult because of the infrequency of damaging earthquakes, and this calls for careful attention to the process of educating the public about the dangers and hazards involved.

Education

This Program deals with education of the professional who in turn will educate the public. Clearly, education of the public is essential for comprehensive earthquake mitigation, but this is beyond the scope of this Program.

Politics and Policy Development

For all of the advances in our ability to technically deal with earthquake hazard mitigation, very little will actually happen unless the proper policy is developed to enforce the needed safeguards. This comes in the form of codes, zoning ordinances, and political structures that can guarantee government agency coordination in the days following an earthquake. Politicians and public employees are the key ingredients in this aspect of the earthquake hazard problem.

The provision of protection to life and property against earthquakes is clearly not the job of one discipline or one group of people. This requires the interaction of many elements in our society if an effective and fair system is to be obtained.

STRATEGIES FOR EFFECTIVE COMMUNICATION

Following is a listing of communication mechanisms envisioned as pertinent to this program.

- Conferences
- Seminars
- Continuing education courses
- Formal education
- Guest lecturers

Irrespective of which of these communication methods is employed, it is important that certain strategies be adhered to in order to affect earthquake hazard mitigation policies and procedures in a country or community. These strategies include:

1. Give key persons a role in the process, asking them to take part in the planning through steering committees, counterpart organizations, review boards, etc. This involvement gives them a target for their influence.

2. Take advantage of recent occurrences of earthquakes or other natural hazards in the country, disasters in other parts of the world whose lessons are transferrable, or dates of the anniversaries of past (but not forgotten) major earthquakes. Use them to gain attention and to add reality.

3. Build on existing programs, seeking to strengthen and integrate them and to accelerate their progress whenever possible.

4. Coordinate planning with other national activities such as major meetings of professional societies and regional or world conferences.

5. Make a concerted effort to identify all of the constraints that hinder implementation of mitigation strategies in the country (region, city, agency, institution) and identify ways to eliminate or minimize their impact.

6. Involve selected local experts in the training process so that the students can become the "future teachers." Give them the visual aids.

7. Give lecture notes to the participants as a permanent record.

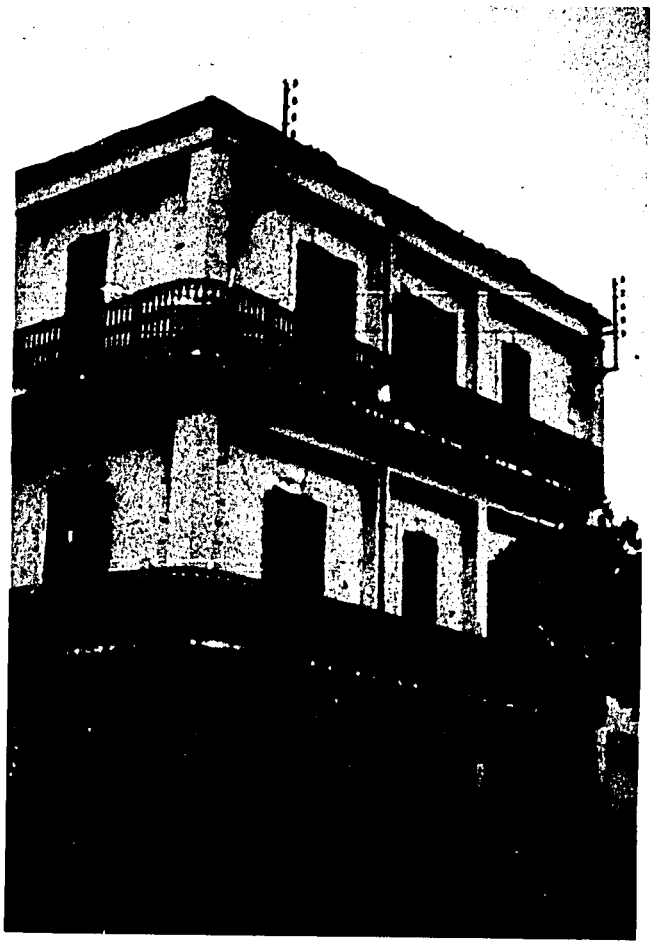
8. Provide a glossary of technical terms to facilitate communication.

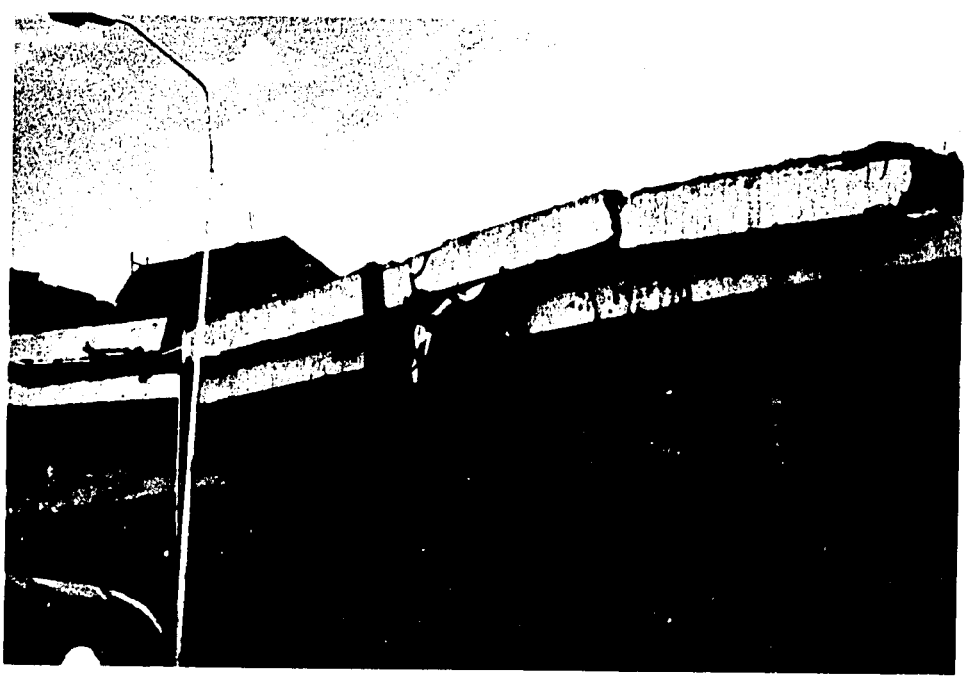
9. Perform a critical evaluation of what happened. Use non-threatening procedures to obtain feedback.

10. Incorporate the results of the critical evaluation in future seminars so that strong points are always being improved and the weak points are avoided.

The upper photo shows a 3-story building that was damaged during an earlier earthquake at El Asnam in 1954 and subsequently repaired and strengthened by constructing pilasters and bond beams on its exterior and then running tie rods through it at floor and roof levels to tie the existing walls and the new concrete frames together. This building was essentially undamaged during the 1980 earthquake. (Photo credit: N. Forell)

The lower photo shows the remains of the modern 3-story, reinforced-concrete, moment-resisting-frame Cite An Nasar Market complex that collapsed during the 1980 earthquake. The collapse of this huge shopping mall and apartment complex initially trapped some 3,000 persons, and the final tally included several hundred deaths. The structural design included heavy waffle floor slabs supported on columns that did not have sufficient moment capacity to resist the ground motion, as the photo clearly shows. (Photo credit: H. Shah)





EXAMPLES OF GOOD AND POOR PERFORMANCE OF BUILDINGS IN EL ASNAM, ALGERIA, FOLLOWING THE MAGNITUDE 7.3 EARTHQUAKE THAT DESTROYED EL ASNAM ON OCTOBER 19, 1980. APPROXIMATELY 4,000 PERSONS WERE KILLED BY THIS EARTHQUAKE.

CHAPTER 4

MAJOR ELEMENTS OF THE PROGRAM

The activities deemed to be necessary for an effective United States role in an international earthquake hazard mitigation program are discussed under three headings, as follows:

1. Recommended Cooperative Research Activities
2. Recommended Technology Transfer Activities
3. Recommended Implementation Activities

RECOMMENDED COOPERATIVE RESEARCH ACTIVITIES

Almost every basic and applied research activity in earthquake engineering appropriate for the United States has a companion cooperative research element which would enhance the value of the results and speed the dissemination of the information internationally. Only mutually beneficial research activities which will contribute directly to the proposed Program are recommended. A list of research topics that would benefit from international cooperation include:

1. Ground motion studies.
2. Instrumentation of structures in seismically active regions and analysis of resulting data.
3. Retrofit and repair of structures.
4. Performance of lifelines.
5. Postearthquake observations and studies (investigations of effects of actual earthquakes).
6. Large-scale testing programs that may be too expensive for one country to undertake.
7. Postearthquake reconstruction and development.
8. Development of International Test Sites.

A discussion of these activities, describing how they would contribute to the proposed Program, is given in Appendix A.

As indicated above, there is a broad range of research that can be fruitfully conducted in connection with the proposed Program. Research conducted should focus on three important objective: (1) to resolve technological and scientific issues needed for earthquake hazard mitigation in the countries or regions involved, (2) to stimulate the interest in the Program of the leading scientists and engineers of the countries involved, and (3) to resolve technological and scientific issues that will benefit earthquake hazard mitigation measures.

Research Workshops and Conferences - Activity R1

These workshops and conferences are proposed for leading researchers (from the participating countries), governmental officials responsible for financial resource allocations, and leading practitioners in the building design and construction fields.

The objectives of the workshops and conferences are:

1. To provide the participants with an overview of current research activities, research personnel, and facility capabilities available for cooperative research activities.

2. To identify and prioritize research needed to reduce the earthquake hazard in the participating countries quickly and economically.

3. To initiate cooperative research programs and provide mechanisms for planning additional cooperative research as funds, personnel, and facilities become available.

While these cooperative research workshops and conferences must consider both analytical and experimental activities, the emphasis will be on experimental studies needed to provide appropriate analytical models for the type of construction and structures being considered. Mutual benefits of the research activities must be in focus.

This activity would generally be limited to about 2 to 4 days and would involve representatives from four to five different countries from the same geographic region. Conferences may involve a broader audience, however.

Research Performance - Activity R2

The benefits of cooperative research activities include the opportunity to discuss research techniques, procedures, and results with knowledgeable counterparts with different perspectives. Thus, the knowledge gained and growth experienced by the participants is expected to produce substantial reciprocal benefit to the countries involved.

The objectives of the cooperative research activities are:

1. To generate information necessary for earthquake hazard reduction in construction.

2. To develop research capabilities and expertise in personnel of all participating countries.

3. To develop independent research capabilities in all participating countries to pursue research topics of local importance but not of mutual benefit for cooperative research.

These objectives can be met by full exchange of participating personnel and involvement of these individuals in research project planning, execution, evaluation, and interpretation. This will require on-site participation for at least six months or, for larger research efforts, up to two years. Participation in this research program can be strengthened by including these individuals in the Long Term Education and

Training Programs - Activity T4 discussed in the next section. The number of participants, their activities, etc., depend upon the scope and complexity of the specific research project implemented.

RECOMMENDED TECHNOLOGY TRANSFER ACTIVITIES

Five types of activities are proposed for transferring earthquake engineering technology to the various earthquake-prone countries of the world listed in Table 2 and for benefiting from developments in those countries.

T1. Orientation seminars held in the United States for government policy makers and technical leaders.

T2. Technical courses held abroad, organized by representatives of the country or region involved, with appropriate U.S. assistance as requested.

T3. In-depth technical seminars held in the U.S. on a variety of earthquake engineering topics for appropriate foreign experts.

T4. Long-term education and training programs in the U.S. for foreign nationals, including:

1. Participation in degree-granting programs at universities.

2. Participation in a proposed Earthquake Engineering Education and Training Center.

T5. Visits by distinguished foreign specialists to lecture at U.S. universities and at meetings of technical and professional societies.

Brief descriptions follow of the objectives and scope of these activities.

Orientation Seminars - Activity T1

Audience. These seminars are proposed for highly placed government officials (both foreign and U.S.), along with leading foreign technical people and associated AID program managers. The joint representation of all three groups is considered beneficial to the success of the program.

Objectives. The objectives of these seminars will be:

1. To provide the participants with an overview of the nature and scope of the earthquake hazard and of possible measures for mitigating the potentially disastrous effects of earthquakes. The principles of sound earthquake-resistant design and construction and the cost-effectiveness of such practices would be highlighted.

2. To review the seismicity of the countries represented at the meeting and to identify the earthquake engineering programs that are active or are being planned in these countries and the organizations responsible for these activities.

3. To inform the participants of the objectives and scope of the proposed International Earthquake Hazard Mitigation Program and to identify the type of activities and the individuals that would be most effective in promoting individual national efforts to mitigate the earthquake hazard. An added objective would be the establishment of the mechanism(s) for developing the Country Hazard and Risk Assessment documents referred to later in this report.

Scope. The presentations for Item 1 should be made by our most distinguished experts in the field; those for Item 2 should be made by the foreign participants, because of their greater familiarity with the issues involved and in order to emphasize the cooperative nature of this undertaking.

In addition to the formal presentation, there should be round-table discussions among the foreign delegates and the Steering Committee for the proposed Program, as well as meetings with appropriate U.S. government agency officials in Washington.

This activity would be limited to about one week but may be expanded to include a complementary short course of 3 to 5 days' duration for the technical people in the group. From four to five different countries from the same geographic region would be represented in addition to the U.S. in these seminars. A sample program for this activity is given in Appendix B.

Technical Courses Abroad - Activity T2

Three types of courses are proposed under this activity, all three of which are to be organized by representatives of the country involved, as follows:

1. A relatively short-duration course (2 to 4 days) by U.S. specialists with appropriate input by local representatives,

2. More detailed, longer-term offerings by local specialists, with such assistance from U.S. specialists as they may deem appropriate, and

3. Visiting appointments at foreign universities of varying durations for U.S. faculty members and/or practicing engineers.

The primary focus of these activities is implementation of earthquake hazard mitigation measures in the various foreign countries. This Program activity will be providing support for the earthquake hazard mitigation initiatives taken by the local country organizer. The objective would be to assist in stimulating interest in earthquake hazard mitigation, to demonstrate our interest and concern, and to assure our hosts of our readiness to cooperate and to be of help. Because the activities are being held in the foreign country or region, a much more extensive audience can be reached than that which would be feasible if the activity were held in the U.S.

The courses contemplated under Item 1 are envisioned as high-level technical seminars that may be offered sequentially in several countries in a given region. These courses could be much the same as the Seminars on Earthquake Fundamentals that EERI has conducted throughout the U.S. for the past decade. The program for such a seminar would be similar to that illustrated in Appendix B, but tailored for a totally technical audience.

Items 2 and 3 under Activity T2 do not require elaboration other than to point out that the role of this Program will be to provide assistance with the planning and

execution of the activity as requested by the organizer in a given country or region. It is likely that these organizers will have been participants in one of the other Program activities.

In-Depth Technical Seminars - Activity T3

Audience. These seminars would be held for practicing design professionals and other technical leaders from various countries who are responsible for the implementation of earthquake hazard mitigation measures.

Objectives. The primary purpose for these seminars would be to provide the participants with a comprehensive technical overview of earthquake hazards and all types of hazard mitigation procedures. The depth of coverage would be sufficient to leave the participants with a conversational knowledge of all aspects of the earthquake problem (e.g., seismology, geotechnical engineering, earthquake-resistant design, and preparedness) and with a working knowledge in a specific topical area.

Scope. As presently conceived, these seminars will be held in the U.S., will be of 6 to 8 weeks' duration, and will have about 15 to 20 participants. Lecturers will be recognized earthquake experts from the U.S. selected from universities, research institutions (government and private), and private practice. Field trips will be scheduled to: observe faulting and seismically notable geotechnical sites, visit well-designed buildings under construction, observe shake table tests, and visit professional engineering offices and university research facilities.

A variety of such courses would be developed depending on the background and interests of the participants. The detailed scope of these seminars should be developed by a broadly based advisory committee in consultation with the individuals who will serve as lecturers. A secondary but important objective of this activity would be the training of individuals to plan and manage similar offerings in their respective countries.

A possible program for such a seminar for building designers is given in Appendix C.

Long-Term Education and Training Programs - Activity T4

Two distinct activities fall under this category:

1. Participation by foreign nationals in degree-granting programs at universities in the U.S.

2. Participation by foreign nationals in an Earthquake Engineering Education and Training Center.

Participants in the degree-granting university programs would typically be a small group of individuals of high academic credentials and leadership potential. The program would be that normally offered at selected universities with a major in one or more of the earthquake-engineering-related fields, and it will be of 1 to 4 years' duration.

Detailed discussion of the Earthquake Engineering Education and Training Center follows.

Audience. The participants in the program would be primarily younger (postgraduate) aspiring engineers and architects, including both design professionals and scientists from the U.S. and other countries who are likely to play an important role in the future in the earthquake hazard mitigation activities of their home countries.

Objectives. The objective of this activity is to rapidly generate a large cadre of engineers, design professionals, and scientists who have a sound technical working knowledge of the extent of earthquake hazards and earthquake hazard mitigation procedures and options. It is planned that about 25 students be involved in this activity each year.

Another important objective for creating this program is to afford students the opportunity to become educated in all aspects of the earthquake problem, e.g., geology, seismology, geotechnical engineering, earthquake-resistant design, architecture, urban planning, and preparedness. Presently, there is no university program that affords students this breadth of coverage in a reasonable length of time. The lack of understanding of all aspects of the earthquake problem and the priority of communication between the various disciplines is perceived as a serious present-day impediment to comprehensive earthquake hazard mitigation action.

Scope. Each session of the program will be 11 months in duration. The curriculum will include formal courses of study on all of the major topics of the earthquake problem, e.g., seismology, earthquake-resistant design, etc. Students will be afforded the opportunity to select a major area of focus for which more detailed offerings will be made available.

Irrespective of the student's major, however, the primary focus of the program will be design. For 2 months of the 11-month program, the students will work, without pay, in a typical consulting office (e.g., engineering, architecture, planning) that specializes in earthquake-related work. This will allow students to become familiar with professional practices in the U.S. and to get some work experience before returning to their home countries.

The courses for the program will be developed along the lines of typical university programs but with a much greater emphasis on applied (practical) experimental and analytical laboratory work. The purpose for this is to leave the student with as much hands-on working experience as possible. The detailed curriculum for the program will have to be developed by a well-coordinated committee of earthquake engineering specialists representing all the major disciplines in the earthquake problem and representing both the academic community and private practice.

Visits of Foreign Experts - Activity T5

To take advantage of earthquake engineering developments abroad, it is recommended that distinguished earthquake engineering experts from other countries be invited periodically to visit the United States for the following purposes:

1. To lecture at universities and at meetings of major professional societies.

2. To participate in special courses, colloquia, and workshops.

3. To discuss with appropriate groups means of enhancing the effectiveness of international earthquake hazard mitigation actions.

Possible topics of presentation include results of major recent research, descriptions of projects in which the earthquake problem was a major consideration, and experience with and lessons learned from recent destructive earthquakes. The length of stay for such visitors may range from a week to several months.

RECOMMENDED IMPLEMENTATION ACTIVITIES

The benefits of any earthquake hazard mitigation concept can be realized only through local implementation of that concept. Thus, an important element of the proposed Program involves fostering implementation of effective loss-reduction measures.

Specific regional or local country activities that would be beneficial to the earthquake hazard mitigation effort include: (1) development or improvement of design codes for earthquake-resistant construction in the countries involved, (2) development of strong-motion instrumentation networks and of experimental testing facilities to satisfy the special research needs of the region or country, and (3) development of suitable community earthquake hazard preparedness programs.

While technology implementation is crucial to the success of the proposed Program, specific hazard mitigation actions must be tailored to the needs of the countries involved. Accordingly, two implementation activities are recommended as follows:

1. Development of seismic hazard and risk assessment reports.

2. Ad-hoc implementation assistance abroad.

Seismic Hazard and Risk Assessment Reports - Activity 11

It is recommended that a Seismic Hazard and Risk Assessment Report be prepared for each county participating in the Program. The report will characterize the seismic hazard of the country, the principal types of construction involved, the seismic design and construction practices and associated building codes, the emergency response capabilities, and a summary evaluation of the seismic risk. Additionally, it will highlight any special issues that may affect the development of an effective mitigation program in the country. In some cases, one report may address conditions of several countries in a region. Following is a sample of the report contents:

1. Description of seismicity.

2. Discussion of unique soil characteristics.

3. Characterization of typical construction.
   -- Metropolitan and urban
   -- Commercial, residential, and industrial

4. Discussion and critique of codes and seismic-resistant design and construction practices.

5. Status of earthquake hazard preparedness activities.

These reports will serve two important purposes: (1) they will identify the most fruitful activities that should be undertaken to mitigate earthquake hazards and risk in the country, and (2) they will identify seismic risk concerning future U.S. investments in the country and will highlight immediate steps that could be undertaken to minimize the vulnerability of these investments.

Ad-Hoc Implementation Assistance Abroad -- Activity 12

Because of the broad spectrum of needs worldwide in connection with implementing earthquake hazard mitigation measures, it is impractical to list specific assistance that may be needed in any given country. However, a comprehensive Program such as that proposed here must provide for such needed assistance. The objective of this activity is to provide foreign technical and political leaders with implementation assistance, as requested and as is programmatically feasible in connection with implementing earthquake hazard mitigation procedures.

A summary of these various program activities is given in Appendix D.

PROGRAM DURATION AND INTERNATIONAL DECADE OF HAZARD REDUCTION

Recognizing the complexities of earthquake hazard mitigation and the diplomacy required to establish a fruitful international program of the type proposed herein, it is recommended that the Program cover a 13-year period, through the year 2000. The overall schedule includes a 3-year Pilot Program during the period of 1987-1989, in which the most basic Program activities are implemented in one region and involve only a few countries. This is followed by a 10-year period (1990-2000) in which all activities are implemented in all regions of the world.

This schedule is designed to overlap with the International Decade of Hazard Reduction (IDHR) proposed for the period of 1990-2000 by Dr. Frank Press, President of the National Academy of Sciences, at his keynote speech during the Eighth World Conference on Earthquake Engineering in July 1984 in San Francisco. The conference was sponsored by the International Association of Earthquake Engineering (IAEE) in cooperation with EERI. Specifically, Dr. Press noted that "natural hazards know no national boundaries except the world itself, that there is already a history of cooperation in earthquake engineering between nations, some of which are being reported on at this very conference," and importantly pointed out that:

> "An IDHR would exploit many of the scientific and engineering advances of recent years. Research on natural hazards, particularly earthquake hazards, is moving to a new era characterized by theoretical advances, large-scale field experiments, expensive experimental testing facilities, use of supercomputers, access to global monitoring, and communication facilities. At the same time, hazards research in many countries is funded below the level that is really needed to fully utilize these new opportunities."

Since the technical means to minimize the destructiveness of damaging earthquakes is available now, the International Cooperative Program for Earthquake Hazard Mitigation as proposed herein, fits in very well with the concepts and goals of the IDHR expressed by Dr. Press.

CHAPTER 5
MANAGEMENT OF THE PROPOSED PROGRAM

A variety of options are available for managing the proposed program, and there are presently in existence several organizations capable of implementing various aspects of the program. The National Science Foundation, for example, could undertake implementation of the research element of the program worldwide. The Organization of American States has in the past 15 years been involved in earthquake hazard mitigation and could manage the dissemination and implementation elements of the program in Central and South America.

Irrespective of the management plan adopted, this International Program will require coordinated interaction between many individuals and private and governmental organizations within the U.S. and with similar individuals and organizations in the other participating countries.

An example organizational structure to achieve successful implementation of this Program is outlined in Figure 4. It consists of the Contractor, a Steering Committee, a Program Director, and Regional and Country Coordinators. The number of Coordinators and their responsibilities must be tailored to the segments of the Program for which they are responsible. It should be recognized that this organizational structure will be sparsely populated during the early stages of its development. The responsibilities and requisite qualifications of the various individuals and groups are described below.

CONTRACTOR

The Contractor, who has the ultimate responsibility for the implementation of the Program, must have a substantial breadth of knowledge regarding earthquake hazards, effective procedures for mitigating earthquake hazards, and experience pertaining to the political processes involved in implementing earthquake hazard mitigation actions. State-of-the-art knowledge in all aspects of the earthquake problem is essential. Experience with communicating this knowledge is also an essential attribute that the Contractor should possess. Finally, the Contractor must have the creative leadership capability to develop new techniques for solving earthquake hazard problems in other countries, using U.S. technology and applying it to the materials and procedures available to the other countries.

STEERING COMMITTEE

The Steering Committee, which will be appointed by the Contractor to provide the most knowledgeable, active perspective on international earthquake hazard mitigation activities, will be responsible for major policy decisions regarding implementation of all three elements of the Program. Its members should be selected for their breadth of experience and responsibilities and their familiarity with international earthquake engineering issues. The broad Program goals, encompassing research, dissemination, and implementation, will require a balanced perspective on the importance of these three modes of interaction and appropriate allocation of resources in these three areas. It is recommended that the Committee consist of seven members who will serve for staggered three-year terms.

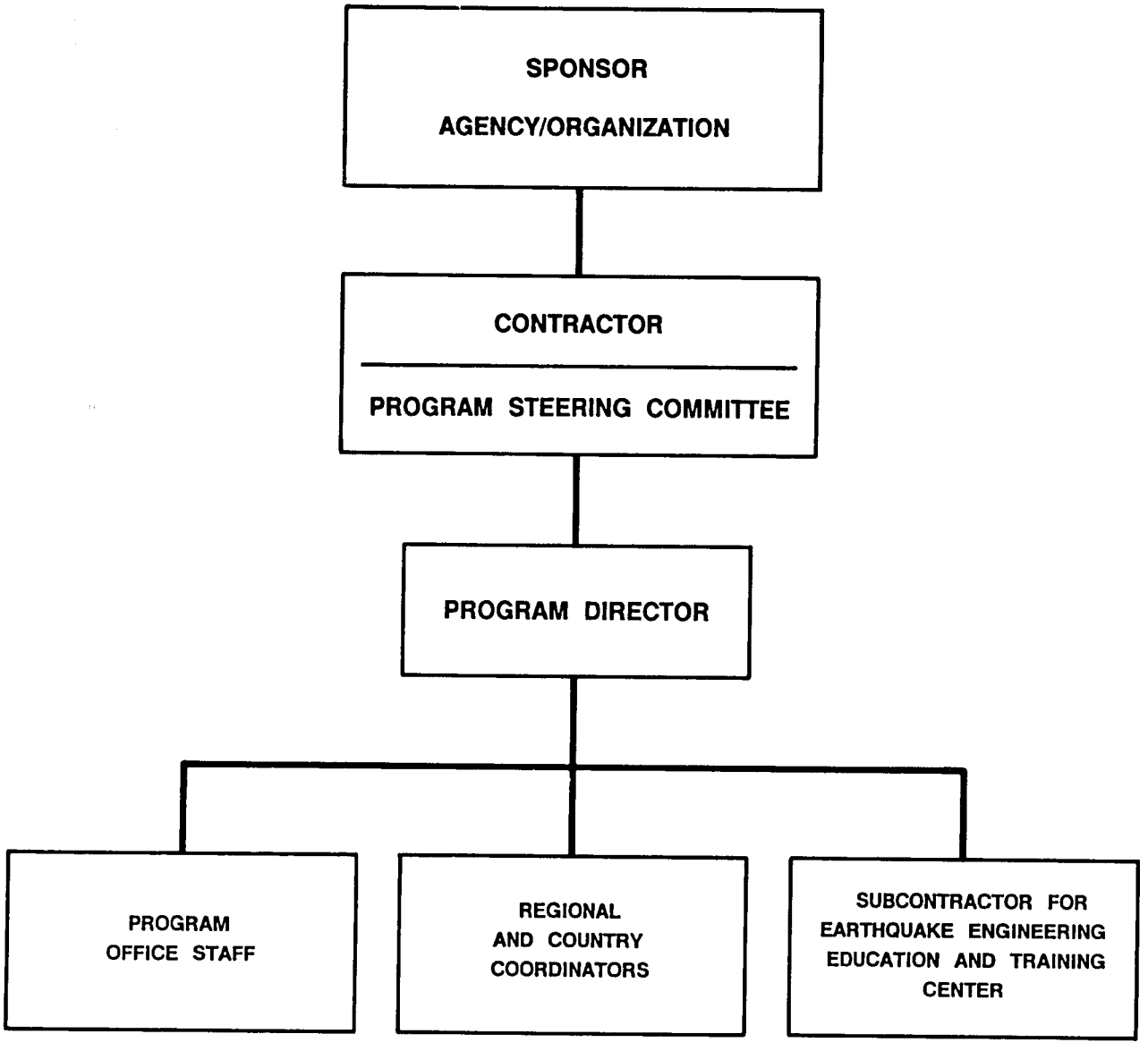


FIGURE 4. ORGANIZATION CHART FOR PROGRAM MANAGEMENT

PROGRAM DIRECTOR

The Director, who will be responsible for coordinating the activities of the many participants, is probably the most important element of the proposed organizational structure. Only through this individual can the many simultaneous program activities provide fully the synergistic interactions necessary for maximum effectiveness. The Director will be responsible to the funding agencies for all operational aspects of the Program.

REGIONAL COORDINATORS

Coordinators for each of the three geographical regions of Latin America, Asia and Pacific, and Africa and Europe (see Table 2) would be needed for this Program. These positions will not be filled until the project activities within a region require more attention than can be satisfactorily given by the Director's office. Their responsibilities would include the development of useful earthquake hazard mitigation projects in conjunction with leaders in the countries of their region. The proposed projects would be presented to the Director, the assembly of Regional Coordinators, and the Steering Committee for review and funding by the Program. When funding is granted for a specific subprogram, it will be the responsibility of the relevant Regional and local Country Coordinators to ensure that the tasks are pursued and objectives achieved in accordance with the approved proposal. They will be responsible for preparing reports on all projects in their region for use by the Director and the Steering Committee. A major activity will be to identify significant reductions in earthquake hazards achieved through their programs and to suggest means by which this information can be applied to other regions of the world.

COUNTRY COORDINATORS

For more than two or three projects in a country, it may be advisable to establish a Country Coordinator to assist in local project management and coordination. The Country Coordinators will be responsible for arranging technological exchanges among the active participants in their country and sharing the results from other countries relating to their problems. One of the strengths of the International Program is the cooperative exchange of information, technology, and techniques. To maximize this interchange, it is important for an individual in each country to participate with counterparts from other countries on a regular basis, especially within a region. Thus, they will be able to utilize the experiences of others to assist their country's earthquake hazard mitigation program.

PROGRAM PARTICIPANTS

U.S. Participants

The Director and the members of the Steering Committee, university researchers and educators, laboratory researchers, professional engineers, structural engineers, scientists, technology educators, and trades personnel would be active participants in this Program. Their roles in each of the various Program activities are self-evident and will not be described here. Specific individuals and organizations can be identified to provide specific contributions to the Program.

Regional Participants

Qualified scientific and technical experts would be active participants in the research, dissemination, and implementation aspects of the Program. The Regional Coordinators need to be highly respected individuals in their region with an interest in and ability to promote the comprehensive approach to earthquake hazard mitigation activities.

These individuals will be identified on the basis of the program objective in that country and will be selected on a competitive basis. Depending upon which of the Program activities is under consideration, the selection process could vary from a primarily local decision for in-country projects to a primarily remote decision for applications to U.S. graduate degree programs.

CHAPTER 6
PROGRAM PLAN, BUDGET, AND SCHEDULE

PROGRAM PLAN

Developing and conducting the proposed Program on a worldwide basis represents a major undertaking and capital investment. It is highly desirable that all the proposed activities in the three major elements of the program -- Research, Dissemination (Technology Transfer), and Implementation -- be developed and conducted systematically. The Program Plan that follows represents an optimum implementation plan and is based on the assumption that all the proposed activities are implemented. Limited success can be expected, however, even if some of the activities are deleted. Accordingly, representative budgets are prescribed for both an optimum program and for individual activities.

To maximize the benefits from initial investments in the program and to enhance its ultimate success, it is proposed that the program be implemented in two phases as follows:

Phase 1 - Pilot Regional Application

Phase 2 - Worldwide Application

Phase 1 is planned for the period 1987 through 1989, and Phase 2 is planned for the period 1990-2000.

Phase 1 - Pilot Regional Application

This phase would involve the application of the program in a single region of the world. It will include of some of the activities described in Chapter 4 along with establishment of a limited staff to implement the program. An important feature of this phase is that a report, summarizing and critiquing the experiences gained in the pilot application of the program, will be prepared to facilitate decision making in connection with the wider application of the program and any requisite changes.

Phase 2 - Worldwide Application

Phase 2 involves complete worldwide implementation of the program, including carrying out all of the activities described in Chapter 4 and establishment of the full complement of organizational staffing described in Chapter 5.

Program Tasks

Complete implementation of the program would involve the 12 tasks listed below. A description of these tasks is given with proper distinction between activities planned for Phase 1 and Phase 2.

Task 1 Contractor Staffing

Task 2 Identify Regions and Countries Involved in Program

Task 3	Establish and Maintain Region and Country Technical and Political Contacts
Task 4	Conduct Orientation Seminars
Task 5	Develop Country Seismic Hazard and Risk Assessments
Task 6	Support Technical Courses Held Abroad
Task 7	Conduct In-Depth Technical Seminars
Task 8	Establish and Manage Earthquake Engineering Education and Training Center in the U.S.
Task 9	Manage Degree-Granting Activity
Task 10	Support Visits by Foreign Specialists
Task 11	Provide Ad-Hoc Technology Implementation Assistance Abroad
Task 12	Reports Summarizing and Critiquing Program Experiences

The 12 tasks listed above represent a structured plan for conducting the technology transfer and implementation activities of the Program described in Chapter 4. The two research activities described in Chapter 4 are not included in the above list of tasks because it is presumed that these activities would be managed directly by the Sponsoring Agency. The research activities are included in the Program budgets, however, for planning purposes. While the research element could be beneficially conducted separately from the technology transfer and implementation elements, a significant reciprocal benefit would result from coordinating the execution of all the various activities.

Task 1 - Contractor Staffing. Upon execution of a contract with the Sponsoring Agency or Agencies, the Contractor will appoint the Program Steering Committee and Program Director. Subsequent appointments, including those of the Regional Coordinators, Country Coordinators, and support staff will be made as needed by the Program Director with the concurrence of the Program Steering Committee.

The Phase 1 staff would be limited to the Steering Committee, the Program Director, one Regional Coordinator, Country Coordinators as needed, and minimal support staff. In Phase 2, two additional Regional Coordinators are anticipated, along with appropriate increases in the number of Country Coordinators and support staff.

Task 2 - Identify Regions and Countries Involved in Program. In cooperation with the Sponsoring Agency or Agencies, the Steering Committee and Program Director will identify the geographic region and countries to be involved in the program. The Phase 1 effort will probably be limited to a maximum of five countries, while Phase 2 may involve up to 20 countries from the three geographic regions.

Task 3 - Establish and Maintain Region and Country Technical and Political Contacts. In consultation with the Sponsoring Agency, the Steering Committee, and others, the Program Director will establish appropriate technical and political contacts in each of the countries involved. The technical contacts must be familiar with the earthquake problem and must be esteemed leaders in the country. The

political contacts must be generally aware of the earthquake hazards problem, be willing to support governmental action to implement earthquake hazard mitigation measures, and be sufficiently astute to implement hazard mitigation measures.

In Phase 1, this task will represent a modest effort because of the small number of countries involved. In Phase 2, with up to 20 countries involved in the Program, this task will require a major effort.

Task 4 - Conduct Orientation Seminars. Orientation Seminars (Activity T1 in Chapter 4) will be held in the United States for highly placed government officials (both foreign and U.S.), along with leading foreign technical people and associated Sponsoring Agency representatives. The Program Director, along with the Program Steering Committee, will be responsible for developing the curriculum and agenda and for selecting the participants. The Program Director will be responsible for the detailed conduct of the seminars. From 15 to 20 persons would attend the seminars, with representatives from 2 to 4 countries, including the U.S. participants.

One or two Orientation Seminars are proposed for Phase 1, and six to eight are proposed for Phase 2.

Task 5 - Develop Seismic Hazard and Risk Assessment Reports. These reports, which are described in Chapter 4, will be prepared for each country involved in the Program. The Program Director, appropriate Regional Coordinator, and Program Steering Committee will be responsible for establishing the generic outline for the reports. These reports will be prepared by regional or foreign country Subcontractors who will be responsible to either the Program Director or the Regional Coordinator.

Four or five reports are proposed for completion in Phase 1, with about an additional 15 reports planned for Phase 2.

Task 6 - Support Technical Courses Held Abroad. In Phase 1, one short-duration technical course will be held in each of the several countries in the region selected. In addition, technical assistance will be provided as needed to facilitate organizing and holding various longer-term offerings by local specialists. In Phase 2, up to four short-duration technical courses will be offered abroad, and assistance for organizing and holding the longer-term offerings by local specialists would be expanded to the added regions and countries. In addition, the possibility of having visiting appointments by U.S. professors at foreign universities will be explored.

Task 7 - Conduct In-Depth Technical Seminars. As indicated in the discussion of this activity (Activity T2) in Chapter 4, the curriculum can be varied to provide focus on various aspects of the earthquake problem. With this in mind, there are seven major work items associated with holding these seminars:

1. Manage the Subcontractor responsible for arrangements and facilities.

2. Establish the curriculum and lecturers.

3. Prepare the student handout material.

4. Establish the student selection criteria.

5. Advertise the activity through the foreign country contacts established in Task 3.

6. Select and invite the students.

7. Ensure student well-being while in the U.S.

These work items will be performed by the Program Director, with concurrence from the Program Steering Committee.

Two alternatives may be considered for the location for holding these In-Depth Technical Seminars. There are several universities throughout the U.S. that have expertise in earthquake engineering, with each having slightly differing areas of specialization. Thus, one alternative would be to hold these seminars at various universities throughout the country, depending on the technical emphasis (e.g., structural design, geotechnical engineering) of a particular seminar. In this case, the arrangements and facilities Subcontractor could be the Continuing Education division at the particular university involved. A second option would be to establish the Earthquake Engineering Education and Training Center (Activity T4 in Chapter 4 and Task 8 below) and hold these seminars at the same location.

One six-week In-Depth Technical Seminar involving 15 to 20 participants is planned for Phase I of the program. In Phase 2, one or two six-week seminars involving about 25 participants each will be held every year.

Task 8 - Establish and Manage Earthquake Engineering Education and Training Center. The detailed scope and objectives of the Earthquake Engineering Education and Training Center activity are discussed under Activity T4 in Chapter 4. Because the activity involves an academic schedule having a duration of 11 months, with about 25 students participating, a Subcontractor will have to be identified to organize and manage the physical arrangements including student housing, food service, and classrooms. The Program Director in cooperation with the Program Steering Committee will recommend an appropriate Subcontractor to the Contractor for approval.

The Subcontractor will be responsible for all student arrangements from the time of selection to coordinate their arrival in the U.S. and will also be responsible for the students' well-being, including housing, until the students depart the U.S. for their home countries.

The major work items in this task are the same as those in Task 7 above and therefore will not be repeated here.

The Phase I effort in connection with this task would involve only developing detailed plans for creating the Earthquake Engineering Education and Training Center. Implementation would begin in Phase 2, and one 11-month program involving about 25 students would be held each year.

Task 9 - Manage Degree-Granting Activity. Selection criteria will be prepared by the Program Director (PD) and Program Steering Committee (PSC) in cooperation with the universities interested in participating in this activity. In addition, the PD and PSC will establish guidelines delineating specific student expenses that will be covered under the program. These criteria and guidelines and the list of participating universities will be transmitted to appropriate regional and foreign country contacts established in Task 3 for their use in recommending candidates. Students will be selected on the basis of duly submitted applications.

An important objective in this Program is to establish a broader based network of highly trained individuals wirh which the Program can work to enhance earthquake

hazard mitigation in various countries. To ensure maximum effectiveness in this regard, regular contact and/or communication will be made with the persons involved in this degree-granting activity following the completion of their studies.

The Phase I effort in connection with the Degree Granting activity would also be limited to developing detailed plans for implementation. In Phase 2, it is planned that there will be up to five students participating in the program each year.

Task 10 - Support Visits by Foreign Experts. This task represents a very important activity in the proposed program because it provides for an interactive exchange between the experts in foreign countries and experts in the U.S. Accordingly, this activity will be actively implemented in both Phase I and Phase 2 of the program. Up to three visits each year from each country involved in the Program are planned.

Implementation of this activity will involve the PSC, PD, and Regional and Country Coordinators as appropriate. A list of candidates from each country will be developed based on recommendations from the technical and political contacts established in Task 3, and, based on Program Staff awareness of exchange opportunities, experts from foreign countries would be invited to participate in various activities in the U.S.

Task 11 - Provide Ad-Hoc Implementation Assistance Abroad. Implementation of hazard mitigation procedures and practices in various countries is the final essential step to ensuring that earthquake hazards are, in fact, mitigated. There are a variety of needs for assistance that will likely arise in connection with implementation, depending on the particular country. For example, assistance may be desired for developing and/or improving design codes. Another example would be to provide assistance in connection with developing earthquake disaster preparedness plans for various countries.

In this task, the Program Director will prepare an informal brochure which identifies implementation actions that would ensure an effective hazard mitigation effect and describes the types of assistance that the Program can provide on request. The Phase I effort in this task will be limited to the preparation of the brochure, listing and describing various implementation actions. In Phase 2, active support of implementation actions will be offered and made.

Task 12 - Reports Summarizing and Critiquing Program Experiences. In the third year of the Program, which is planned as the concluding year of Phase I, a detailed report will be prepared that summarizes the experiences gained in Phase I, identifies any changes that should be considered in future activities, and presents detailed plans for the Earthquake Engineering Education and Training Center and the Phase 2 activities. To summarize and critique the activities in the entire Program, a second report is planned for completion in the tenth year of Phase 2.

PROGRAM BUDGET

The budgets for the comprehensive worldwide Program, including management staff, and for carrying out the various tasks described in the Program Plan, are given in Table 3 for both Phases I and 2. The combination of Phases I and 2 is an optimum Program that is clearly ambitious in both scope and budget.

The Program is designed to be flexible and can be implemented in one or two of the worldwide regions identified, or various activities could be implemented

TABLE 3

BUDGET FOR COMPREHENSIVE PROGRAM*

		Phase 1 Pilot Regional Application				Phase 2 Worldwide Application											Total
		1987	1988	1989	Phase 1 Total	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	Phase 2 Total	
Task 1	Contractor Staffing	150	250	250	650	350	450	500	500	500	500	500	500	500	500	4,800	5,450
Task 2	Identify Regions and Countries Involved in Program	50	--	--	50	50	50	50	--	--	--	--	--	--	--	150	200
Task 3	Establish and Maintain Region and Country Technical and Political Contacts	100	50	--	150	50	100	100	100	100	50	50	50	50	50	700	850
Task 4	Conduct Orientation Seminars	50	100	100	250	100	100	100	100	100	100	100	100	--	--	800	1,050
Task 5	Develop Country Seismic Hazard & Risk Assessments	100	200	200	500	100	200	200	200	200	200	200	--	--	--	1,300	1,800
Task 6	Support Technical Courses Held Abroad	--	50	100	150	100	200	200	200	200	200	200	300	300	200	2,100	2,250
Task 7	Conduct In-Depth Technical Seminars	--	100	250	350	300	400	400	400	400	400	400	400	400	400	3,900	4,250
Task 8	Establish and Manage Earthquake Engineering Education and Training Center in the U.S.	--	50	50	100	200	500	500	500	500	500	500	500	500	500	4,700	4,800
Task 9	Manage Degree-Granting Activity	--	--	50	50	100	300	300	300	300	300	300	300	300	300	2,800	2,850
Task 10	Support Visits by Foreign Experts	--	50	50	100	50	100	100	100	100	100	100	100	100	100	950	1,050
Task 11	Provide Ad-Hoc Implementation Assistance Abroad	--	50	50	100	50	50	50	100	100	150	150	150	150	150	1,100	1,200
Task 12	Reports Summarizing and Critiquing Program Experiences	--	--	50	50	--	--	--	--	--	--	--	--	50	150	200	250
	SUBTOTAL	450	900	1,150	2,500	1,450	2,450	2,500	2,500	2,500	2,500	2,500	2,400	2,350	2,350	23,500	26,000
	Research Workshops	--	50	100	150	100	100	100	100	100	50	50	50	--	--	650	800
	Conduct Research Projects	--	--	150	150	300	500	500	500	500	500	500	500	500	500	4,800	4,950
	TOTAL	450	950	1,400	2,800	1,850	3,050	3,100	3,100	3,100	3,050	3,050	2,950	2,850	2,850	28,950	31,750

*Budget in thousands of 1986 dollars.

independently. Table 4 gives representative budgets for individual activities and for Programs in a single country and in a single region. These budget figures are necessarily only approximate because of the wide variation in travel cost, depending on the specific country involved. Note that establishing the Earthquake Engineering Education and Training Center is not practical for Program implementation in a single country and is only marginally practical for Program implementation in a single region.

PROGRAM SCHEDULE

The schedule for conducting the various Phase I and Phase 2 tasks described in the Work and Management Plan is largely revealed in the Program Budget given in Table 3.

TABLE 4

BUDGET FOR ACTIVITY-FOCUSED PROGRAM*

		Individual Country Implementation		Individual Region Implementation	
Activity	Unit Cost	Planned Number of Years or Activities	Total Cost	Planned Number of Years or Activities	Total Cost
R1	$100	1	$100	5	$ 500
R2	250	2	500	10	2,500
T1	100	1	100	3	300
T2	75	2	150	10	750
T3	500	--	--	5	2,500
T4**	25	4	100	30	750
T5	50	2	100	8	400
I1	150	1	150	5	750
I2	100	2	200	8	800

*Budget in thousands of 1986 dollars.

**Degree-granting portion of activity only.

APPENDIX A

Cooperative Research Topics Beneficial to the Proposed Program

Following is an expanded discussion of the nine topical areas identified in Chapter 4 in which cooperative research involving the various participating countries would be beneficial to the proposed Program.

1. GROUND MOTION STUDIES

One of the most important but uncertain factors controlling the design of earthquake-resistant structures is the expected level of ground motion to be resisted and the characteristics of that ground motion. The 1985 experience in Mexico has demonstrated the importance of properly characterizing the expected ground motion at the building site. This is truly an international need from which all can benefit from data gathered worldwide.

2. INSTRUMENTATION OF STRUCTURES IN SEISMICALLY ACTIVE REGIONS AND ANALYSIS OF RESULTING DATA

Earthquakes large enough to cause significant structural damage occur infrequently at the same location in the world. Thus, in order to obtain full-scale actual earthquake data on the performance of structures in damage-level earthquakes requires the instrumentation of structures at many locations worldwide. To maximize the value of the data, the selected structures should have "predicted" characteristics which can be checked against those obtained during and after the earthquake.

3. RETROFIT AND REPAIR OF STRUCTURES

There are many buildings throughout the world that are known to be hazardous to life-safety during earthquakes. Development of effective, economical techniques and procedures for incorporating life-safety countermeasures in these structures either before or following an earthquake is essential. Although many techniques may be technology dominated, others can be transferred from one country to another easily.

4. PERFORMANCE OF LIFELINES

Although lifelines become more sophisticated in industrial countries, the basic lifeline systems are similar worldwide. Knowledge gained in one country can be directly translated to practice in another country with appropriate modifications. The ease of interchange provides extra incentive to perform cooperative research in these fields.

5. POSTEARTHQUAKE OBSERVATIONS AND STUDIES (INVESTIGATIONS OF EFFECTS OF ACTUAL EARTHQUAKES)

Because the cost of experimental studies of the dynamic response of structures is prohibitive, it is important to obtain as much information as possible about damage-level and failure-level structural behavior from real earthquake experiences. Although instrumented buildings can provide essential data for major contributions to understanding, much can be learned by detailed studies of damaged structures which did not have instruments in them.

6. LARGE-SCALE TESTING PROGRAMS THAT MAY BE TOO EXPENSIVE FOR ONE COUNTRY TO UNDERTAKE

Unique experimental facilities capable of full-scale testing programs are extremely expensive to construct and operate. Test specimens are also very expensive to construct, instrument, and analyze. A cooperative research program which can utilize unique facilities has benefits for all participants because of the mutual exchange of ideas and information and the sharing of research expenses. The USA/Japan Large-Scale Research Program is an example of a successful cooperative program of this type.

7. POSTEARTHQUAKE RECONSTRUCTION AND DEVELOPMENT

Worldwide experience has shown that most structures are rebuilt after an earthquake in the same manner that they were built before the earthquake. The reasons are many, but the most important are economic and local availability of materials. It is important to recognize that this poor practice can be eliminated only if plans are made before the earthquake for postearthquake reconstruction and development. For example, the reconstruction plans for Tangshan are well developed and are being implemented. (Because of the massive destruction caused by the Tangshan earthquake, there was time to develop the reconstruction plans after the earthquake.) Their experiences could provide valuable input to other countries for postearthquake reconstruction and development planning.

8. DEVELOPMENT OF INTERNATIONAL TEST SITES

Much is yet to be learned about the response of the ground under earthquake loading in the natural environment. Numerous questions remain about the issues of site amplification, liquefaction, and slope movements that can only be addressed through instrumented field sites. Such sites may also serve as locations for testing of in situ soil and rock investigation tools. Development of sites in countries where seismic activity is high can be beneficial to a far greater audience than just the host country. By pooling the resources of a group of cooperative countries, and instrumenting and testing sites with different characteristics in different countries, a broad base of information can be obtained, and international cooperation can be fostered.

APPENDIX B

Sample Program for
Orientation Seminar

PROGRAM
FOR
ORIENTATION SEMINAR

(2-Day Technical Portion of Activity T1 Described in Chapter 4)

Session	Topic
1	Overview of Earthquake Effects on Man and Man-Made Works • Types of Earthquake Losses • Causes of Earthquake Losses • Examples of Failures and Successes
2	Regional Seismicity (Region and/or Country Specific) • Geology • Seismology • Ground Motion
3	Geotechnical Engineering • Soil Foundations • Landslides • Liquefaction • Site Amplification
4	Architectural Considerations in Earthquake-Resistant Design • Building Configuration • Nonstructural Components • Equipment and Contents
5	Earthquake-Resistant Design of Buildings • Structural Systems • Connection Details • Procedures for Damage Control • Codes
6	Earthquake-Resistant Design of Lifelines • Define Lifelines • Procedures for Damage Control
7	Urban Planning for Earthquake Hazard Mitigation • Siting • Reconstruction • Emergency Traffic Flow
8	Urban Earthquake Hazard Preparedness Planning

APPENDIX C

Example Program for
In-Depth Technical Seminar
for Building Designers

EXAMPLE PROGRAM FOR
IN-DEPTH TECHNICAL SEMINAR
FOR BUILDING DESIGNERS

(Six-Week Course)

WEEK	SESSION	MATERIAL TO BE COVERED
1	1	INTRODUCTION TO COURSE. 4 Hours a. What the course will cover. Outline. Handout. b. Earthquake engineering: Importance of earthquake-resistant design and construction of civil engineering structures in earthquake engineering. c. Past earthquake losses (life, damage, etc.). Slide presentation. A copy of 50 of the most expressive slides with a short description of what each slide illustrates could be presented to each participant.
	2	ELEMENTARY ENGINEERING SEISMOLOGY AND GEOLOGY, AND GEOTECHNICAL ENGINEERING. 8 Hours a. The causes of earthquakes. Plate tectonics. b. Measuring earthquakes. c. Size of an earthquake: Intensity (subjective scale and instrumental); magnitude; and energy.
	3	EFFECTS OF EARTHQUAKE GROUND MOTIONS ON SOILS AND STRUCTURES (DIRECT AND INDIRECT DAMAGE). 4 Hours a. Fault rupture; soil failures, liquefaction, landslides, etc. Importance of site suitability analysis. b. Effects of ground motions on structures.
	4	STRUCTURAL DYNAMICS. 16 Hours a. Dynamics of simple structures. (Emphasis on dynamic effects of earthquake ground motions.) b. Linear and nonlinear (inelastic) response to harmonic excitations c. Linear and nonlinear (inelastic) response to impulsive excitations. d. Linear and nonlinear response to earthquake ground motions: response history and response spectrum (elastic and inelastic). e. Dynamics of multistory buildings: Modal analysis of earthquake response.
	5	EARTHQUAKE-RESISTANT DESIGN OF STRUCTURES. 4 Hours a. Code procedures vs. use of dynamic analysis.

WEEK	SESSION	MATERIAL TO BE COVERED
	6	REVIEW OF WEEK'S DISCUSSIONS. 4 Hours Question and answer session. Develop communication capability between participants and lecturers.
2	7	EARTHQUAKE-RESISTANT DESIGN AND CONSTRUCTION OF BUILDINGS. 4 Hours a. Importance of construction aspects: quality control of materials, workmanship, and inspection. Illustrations. b. Importance of maintenance aspects. Illustrations.
	8	ASPECTS OF EARTHQUAKE-RESISTANT DESIGN OF BUILDINGS. 8 Hours a. Selection of design earthquakes: uncertainties. Need for microzonation. b. Selection of building configuration, structural layout, structural material, and nonstructural elements. Importance of conceptual design: Main guidelines for efficient earthquake-resistant design. c. Illustration of importance of following main guidelines for efficient earthquake-resistant design. d. Modeling of the structure and nonstructural elements and stress analysis: Uncertainties. e. Preliminary design. f. Review of preliminary design: final detailing. g. Analysis of the reliability of the final design.
	9	FOUNDATION ENGINEERING. 4 Hours a. Typical foundations: Isolated footings, continuous footings; raft foundations; compensated foundations; friction piles; bearing piles; pier foundation; etc. b. Earthquake performance of building foundations. c. Guidelines for earthquake-resistant design of building foundations.
	10	USE OF COMPUTERS. 8 Hours Use of software and hardware packages. Use of computer programs in the analysis and design of structures.
	11	EARTHQUAKE-RESISTANT DESIGN OF TYPICAL BUILDINGS: (A) DESIGN OF A WOOD FRAME (2-STORY) BUILDING. 8 Hours a. Review of mechanical behavior of wood. b. Develop design scheme; ALL calculations, explain; show how to develop wood details; bolts, nails, plywood diaphragms, etc. Handouts required.

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WEEK	SESSION	MATERIAL TO BE COVERED
	12	HOMEWORK. 8 Hours Give a 2-story wood structure to be designed. Participants must develop scheme and tell why. Make all calculations (for seismic loads), use codes. Make necessary sketches (emphasis on proper detailing of critical connections and regions).
3	13	REVIEW OF ONE ANOTHER'S WORK. 8 Hours Critique work to acquaint participants with checking procedures.
	14	DESIGN OF MASONRY STRUCTURE. 8 Hours a. Review of mechanical behavior of masonry materials. b. Design using wood diaphragm. c. Design using concrete diaphragm. d. Design using steel diaphragm.
	15	HOMEWORK. 8 Hours Give a 2-story masonry structure to be designed. Participants must develop scheme and tell why. Make all necessary calculations, sketches, etc.
	16	REVIEW AND CRITIQUE ONE ANOTHER'S WORK. 8 Hours Critique work to acquaint participants with checking procedures.
	17	GENERAL DISCUSSION OF DESIGN AND CONSTRUCTION OF THE WOOD AND MASONRY STRUCTURES. 8 Hours Each participant now gives about a 15- to 20-minute discussion of the problems HIS country would face with the above examples.
4	18	DESIGN OF STRUCTURAL STEEL FRAME BUILDING. 8 Hours a. Review of mechanical behavior of structural steel. b. Design using conventional frame. c. Design using braced frame with diaphragms (concentric and eccentric braces).
	19	HOMEWORK. 8 Hours Give a 2-story steel frame structure to be designed. Participants make all necessary calculations and sketches (as above).
	20	REVIEW ONE ANOTHER'S WORK AS PREVIOUSLY DONE. 4 Hours

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WEEK	SESSION	MATERIAL TO BE COVERED
	21	DESIGN OF REINFORCED CONCRETE STRUCTURES. 8 Hours a. Review of mechanical behavior of reinforced concrete materials: Need for using confined concrete at critical regions. b. Design using shear walls, diaphragms, relative rigidities, etc.
	22	HOMEWORK. 8 Hours Participants design 2-story concrete structure, etc.
	23	REVIEW ONE ANOTHER'S WORK. 4 Hours
5	24	DESIGN OF DUCTILE CONCRETE FRAMES (DMRSF). 8 Hours Discuss problems of infill walls. (Soft stories and effect on torsional forces.)
	25	HOMEWORK. 8 Hours Design 2-story concrete frame structure. Each participant must discuss how exterior walls are to be constructed.
	26	REVIEW AND CRITIQUE ONE ANOTHER'S WORK. 4 Hours
	27	DESIGN AND CONSTRUCTION OF WALL-DMRSF CONCRETE STRUCTURES. 8 Hours Discuss infill walls and torsional effects. Each participant gives 15- to 20-minute discussion of problems HIS country will face with above concepts.
	28	DISCUSSION BY GROUP OF ALL COST FACTORS. 4 Hours Participants should try to relate relative cost figures for all of the above schemes. Each country should try to make a relative cost comparison of schemes used.
	29	DISCUSSION OF CONSTRUCTION REVIEW. 8 Hours Testing procedures. Inspection procedures. How to develop design values for masonry when none are available. Discuss testing of masonry, plywood, etc.
6	30	FIELD TRIPS. 8 Hours a. One-half of the group goes to wood frame and masonry structures under construction. b. One-half of the group goes to masonry and wood frame structures under construction.

WEEK	SESSION	MATERIAL TO BE COVERED
	31	FIELD TRIPS. 8 Hours a. One-half of the group goes to structural steel and concrete structures under construction. b. One-half of the group goes to concrete structures and structural steel buildings under construction.
	32	DISCUSS FIELD TRIPS. 8 Hours Lessons learned.
	33	FINAL DISCUSSIONS. 8 Hours Question and answer period. Certificates awarded.

APPENDIX D

Summary of Program Activities

SUMMARY OF PROGRAM ACTIVITIES

The Program scope includes nine distinct activities in three major elements as follows: two research activities, five technology transfer activities, and two implementation activities. The following is a tabular summary of these various activities.

Activity	Scope and Objective
Cooperative Research Element:	
R1 Research Workshops and Conferences	Two- to four-day workshops and conferences on specific topics held in the U.S. and foreign countries to identify research needs and to exchange research knowledge.
R2 Research Performance	One- to three-year research projects conducted for the purposes of generating new information needed for earthquake hazard mitigation and developing research capabilities of personnel in participating countries.
Technology Transfer Element:	
T1 Orientation Seminars	Three- to five-day seminars held in the U.S. for highly placed government officials and leading technical personnel. These seminars are conducted for the purpose of providing U.S. and foreign country decision makers with an overview of the nature and scope of earthquake hazards and of measures for mitigating the potentially disastrous effects of earthquakes.
T2 Technical Courses Held Abroad	Two- to five-day seminars held in foreign countries, conducted by U.S. earthquake specialists (or organized by foreign country specialists with assistance by U.S. specialists). These courses are held for the purpose of stimulating interest in earthquake hazard mitigation in a broad audience of practicing professional architects, engineers, geoscientists, and urban planners in foreign countries.
T3 In-Depth Technical Seminars	Six-week seminars held in the U.S. for practicing design professionals and other technical leaders from various countries who are responsible for the implementation of earthquake hazard mitigation measures. The objective of these seminars is to provide the participants with conversational knowledge of all aspects of the

Activity	Scope and Objective
T3 (Continued)	earthquake problem and a working knowledge of a specific topical area (e.g., earthquake-resistant structural design, geotechnical engineering, etc.)
T4 Long-Term Education and Training Programs	Two distinct activities fall in this category: (1) participation by foreign nationals in degree-granting programs in the U.S. (two- to five-year scholarships at Universities) and (2) participation by foreign nationals in a proposed 11-month Earthquake Engineering Education and Training Center program in the U.S. The objective of these activities is to provide a small number of individuals having high academic and leadership potential with the opportunity to become highly skilled in a specific earthquake discipline or, generally, in earthquake engineering.
T5 Visits of Foreign Experts	Invite foreign country earthquake experts to the U.S. to: (1) lecture at universities and at meetings of professional societies, (2) participate in special courses or workshops, and (3) discuss with appropriate groups means for enhancing the effectiveness of various earthquake hazard mitigation activities. The length of stay for these visits may range from a week to several months.
Implementation Element:	
I1 Seismic Hazard and Risk Assessments	Seismic hazard and risk assessment reports prepared for each country participating in the Program for the purpose of identifying the most fruitful activities that should be undertaken to mitigate earthquake hazards and risk in the country.
I2 Ad-Hoc Implementation Assistance Abroad	Provide foreign country technical and political leaders with assistance, as requested and as is programmatically feasible, in connection with implementing earthquake hazard mitigation procedures. The objective is to maximize the implementation of earthquake hazard mitigation procedures abroad.

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