Final Report

U.S. - ASIA CONFERENCE

on

ENGINEERING FOR MITIGATING NATURAL HAZARDS DAMAGE

14 - 18 December 1987
Bangkok, Thailand

Arthur N.L. Chiu • Pisidhi Karasudhi • Prinya Nutalaya

September 1988

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organized by

University of Hawaii at Manoa

Asian Institute of Technology

Arthur N. L. Chiu

Pisidhi Karasudhi

Prinya Nutalaya

September 1988

PARTICIPANTS AT THE U.S.-ASIA CONFERENCE ON ENGINEERING FOR MITIGATING NATURAL HAZARDS DAMAGE, 14-18 DECEMBER 1987, BANGKOK, THAILAND

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PREFACE

The U.S.-Asia Conference on Engineering for Mitigating Natural Hazards Damage (EMNHD) was held in Bangkok, Thailand, to: (1) provide a forum for mutual exchange of information on research and practice in regard to natural hazards mitigation; and (2) identify and propose cooperative projects that will be of mutual benefit. Four natural hazards were selected for discussion: extreme-wind hazard; flood hazard; ground-failure hazard; and earthquake hazard.

The conference was a success with 95 participants attending. In addition to the keynote address, eight theme papers and 48 shorter papers were presented. A workshop was scheduled for discussing projects that would be of current concern and needs regarding these four natural hazards. Based on their deliberations, the four Working Groups recommended various cooperative projects that could be pursued either bilaterally or regionally.

This volume contains an overview of the conference, the speeches at the opening session, the list of recommended projects, the reports from the four Working Groups, the resolutions, the abstracts of the papers, the conference program, and the list of participants. The papers that were received in time for publication can be found in the *Proceedings of the U.S.-Asia Conference on Engineering for Mitigating Natural Hazards, December 14-18, 1987, Bangkok, Thailand.*

Acknowledgment is made of the interest and support from the U.S. National Science Foundation (Grant ECE-8616600) and the Office of Foreign Disaster Assistance, U.S. Agency for International Development (Grant PDC-0000-G-SS-8016-00). Any opinions, findings and recommendations in this publication do not necessarily reflect the views of the sponsoring organizations.

The enthusiastic support provided by the faculty, staff and students from the Geotechnical and Transportation Engineering Division as well as the Structural Engineering and Construction Division of the Asian Institute of Technology is appreciated very much. Acknowledgment is also made of the enthusiastic cooperation of all speakers in the preparation of their papers and of the active participation in the conference program by all registrants. These combined efforts were responsible for the success of the Conference and the Workshop. The assistance provided by the Co-Chairmen and the Rapporteurs of the four Working Groups, as well as by G.L.F. Chiu and V.K. Chan, in the preparation of this report is acknowledged.

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September 1988


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OVERVIEW

Natural hazards cause significant loss of life, property and economic resources every year. These losses are well documented as reports of cyclones (typhoons and hurricanes), ground failures, floods and earthquakes can be found regularly in the news and technical publications. Some prominent examples are the 1977 tropical cyclone that devastated the east coast of southern India, resulting in the loss of 10,600 lives, and the 1976 earthquake that virtually destroyed Tangshan, China, killing over 240,000 people. Because natural hazards occur worldwide, the mitigation of resultant damage is of concern to scientists and engineers of many countries. Many projects have been carried out in attempts to model natural hazard events and the response of man-made structures to them. The understanding of natural hazards phenomena and resultant structural response continues to improve due to research efforts.

The U.S.-Asia Conference on Engineering for Mitigating Natural Hazards Damage was held in Bangkok, Thailand, 14-18 December 1987 to encourage the exchange of information and ideas, as well as to identify and propose possible cooperative international projects. Cooperative projects would benefit both regions of the world by reducing duplication of efforts and creating a synergistic research environment.

A total of 95 participants registered for the conference. They came from the U.S.A., Japan, Korea, China, Hong Kong, Thailand, Malaysia, Singapore, Indonesia, Australia, Bangladesh, Nepal, India and Pakistan. The list of participants, the names of the committee members, and a detailed program are included in this report.

Opening Session

The opening session was chaired by Prof. Pisidhi Karasudhi of the Asian Institute of Technology (AIT). Welcoming remarks were offered by President Alastair M. North of the Asian Institute of Technology and a message from President Albert J. Simone of the University of Hawaii was read by Prof. Arthur N. L. Chiu.

His Excellency Mr. Banyat Bantadtan, Minister of Science, Technology and Energy, Royal Thai Government, gave the opening address for the conference.

The welcoming message and the opening address are reprinted in subsequent sections of this report.

Program

Four types of natural hazards were selected for discussion at the conference, viz., extreme-wind hazard, flood hazard, ground-failure hazard, and earthquake hazard. The conference program consisted of: a keynote address, 56 technical papers and two days of workshops covering the four conference themes. One afternoon was devoted to a field trip around Bangkok to observe problems of land subsidence. Dinners, receptions and an evening of traditional Thai entertainment complemented the technical program.

The keynote address and the abstracts of the technical papers are also presented in subsequent sections of this volume. A separate volume of Extended Abstracts was sent to each speaker in advance of the conference with the anticipation that it would encourage discussion among the participants. The *Proceedings of the U.S.-Asia Conference on Engineering for Mitigating Natural Hazards Damage, 14 - 18 December 1987, Bangkok, Thailand* contain the full papers that were received in time for publication prior to the conference. Copies of the *Proceedings* can be ordered from the EMNHD Conference Secretariat, Geotechnical and Transportation Engineering Division, Asian Institute of Technology, GPO Box 2754, Bangkok 10501, Thailand. A limited number of single copies are available from Prof. Arthur N. L. Chiu, Department of Civil Engineering, University of Hawaii at Manoa, Honolulu, Hawaii 96822, U.S.A.

Workshops

Following the technical sessions, the delegates were separated into four Working Groups to identify areas of research that are of mutual concern and should be addressed soon. The four groups followed the themes of the conference, viz.,

- o Extreme-wind hazard
- o Flood hazard
- o Ground-failure hazard
- o Earthquake hazard

Recommended Projects

The workshops' efforts have resulted in four reports that summarize areas of concern and delineate research projects or concepts that should be investigated as soon as possible. A total of 29 projects were recommended and were classified as Category A or Category B. These were defined, respectively, as priority projects and important projects but of lesser priority. The numbers of projects recommended from the working groups are as follows:

- o Extreme-wind hazard - 15 projects (4A, 11B)
- o Flood hazard - 5 projects (5A)
- o Ground-failure hazard - 6 projects (4A, 2B)
- o Earthquake hazard - 7 projects (4A, 3B)

The details are presented in subsequent chapters containing the separate reports from the Working Groups.

Closing Session

The Conference Chairman started the final plenary session by acknowledging again the support from the U.S. National Science Foundation (Grant ECE-8616600) and the Office of Foreign Disaster Assistance, U.S.A.I.D. (Grant PDC-0000-G-SS-8016-00). He thanked the Coordinating Committee, the Organizing Committee, all speakers, and all participants for their efforts in making the U.S.-Asia Conference on Engineering for Mitigating Natural Hazards Damage a success. Special acknowledgment was made for the excellent facilities, food and services provided by the Imperial Hotel, venue of the Conference. The student volunteers from the Asian Institute of Technology were also thanked for their careful and flawless handling of the audio-visual equipment; each student volunteer was presented with a copy of the *Proceedings* as a token of appreciation. The secretarial staff received special thanks for providing efficient and meticulous handling of the logistics in connection with the Conference; Mrs. Kwanjai Sodsee was especially acknowledged for her outstanding service.

Final Reports from Working Groups

The final draft reports were then presented by the co-chairmen of each Working Group, and these draft reports were accepted by the participants for publication in the Final Report of the conference.

Resolutions

Various resolutions were proposed by the participants for discussion and adoption. The resolutions adopted by the assembly are given below.

- The Organizing Committee expresses their sincere appreciation for the contributions of the participants from the following countries in providing valuable information and dedicating their time and efforts to make this Conference a success:

Australia	Bangladesh	China
Hong Kong	India	Indonesia
Japan	Korea	Malaysia
Nepal	Pakistan	Singapore
Thailand	U.S.A.	

- The Conference participants wish to thank the U.S. National Science Foundation and the Office of Foreign Disaster Assistance, U.S. Agency for International Development for their interest, encouragement and support of the Conference; they wish to acknowledge especially the personal participation of Dr. J.E. Sabadell who provided many helpful suggestions during the course of the conference/workshop sessions.

- This Plenary Session requests that the Final Report of the U.S.-Asia Conference on Engineering for Mitigating Natural Hazards Damage, when published, be disseminated as widely as possible, especially to those agencies responsible for planning, designing and implementing natural-disasters prevention strategies, with the recommendation that the appropriate agencies consider the projects, presented in the Final Report by the four Working Groups, for inclusion in their future natural hazards damage mitigation programs.

- The participants note with satisfaction that the U.S.-Asia Conference on Engineering for Mitigating Natural Hazards Damage (EMNHD) :

  (a) has provided a superb forum for participating countries and individuals to exchange their ideas, state of knowledge and future direction;

  (b) has outlined distinctly the scope for future cooperative research in extreme-wind hazard, flood hazard, ground-failure hazard and earthquake hazard;

  (c) has brought out the concept of multiple-hazard mitigation; and,

  (d) has adopted the reports prepared by the four Working Groups.

  Therefore, this Plenary Session recommends that the activities initiated under this program be continued to achieve the ultimate goal of this conference by proposing the following resolutions for adoption:

1. **An Advisory Committee should be constituted to plan the future course of action;**

2. **EMNHD Conferences should be organized henceforth every two years by rotation in different countries within the region; and**

3. **An organizational structure in the form of a Center at a convenient location should be set up. This Center should arrange regular manpower training, information exchange, and data storage and dissemination to the scientific community; preparatory work for the next conference and interaction with various funding agencies in different countries and U.N. agencies should be undertaken by this Center.**

Adjournment

The Conference was officially adjourned at 4:10 pm, 18 December 1987.

WELCOMING REMARKS

by

Albert J. Simone
President, University of Hawaii

It is my very great pleasure to send greetings on the occasion of the U.S.-Asia Conference on Engineering for Mitigating Natural Hazards Damage. I deeply regret that I am unable to attend personally, but I know that Professor Arthur Chiu, who bears this message for me, will be able to share with you the University of Hawaii's great pride at contributing to such an important conference.

We in Hawaii are no stranger to the four natural hazards that will be addressed by this conference. From time to time, we experience hurricanes, tsunamis, fresh-water flooding, landslides, and earth tremors. In addition, our volcanoes persist in creating new land for us, sometimes at the expense of existing structures and cultivation. Yet, in terms of experience elsewhere in the world, Hawaii is very fortunate.

Although we do not suffer from cataclysmic disasters, Hawaii and its university believe strongly in assisting other peoples whenever and as much as we can. In speaking for the University of Hawaii, I can assure you that we take great pride in our role in making this conference possible.

The purpose of this conference is, of course, to share our experiences and explore ways that we can work together. This cooperation is vital, for in the face of natural disasters we are one people, one world.

Natural hazards are a fact of life and will continue despite our best efforts. But, by our cooperation, we must hope that in the future we may be able to minimize the extensive damage these hazards cause to us.

In the light of the recent typhoons that have so badly damaged some of our Pacific neighbors, I feel that this conference is very timely, and I applaud the sincere efforts that will be made here over the next few days.

In closing, I should like to commend Professor Arthur Chiu, of the University of Hawaii at Manoa, and Professors Prinya Nutalaya and Pisidhi Karasudhi, of the Asian Institute of Technology, for their fine efforts in organizing this conference. And also the U.S. National Science Foundation and the U.S.A.I.D. Office of Foreign Disaster Assistance for making this conference possible.

On behalf of the University of Hawaii, I wish you all a most valuable experience and hope that the deliberations here will have a profound impact on worldwide preparation against natural disasters.

OPENING SPEECH

by

H.E. Mr. Banyat Bantadtan
Minister of Science Technology and Energy
Royal Thai Government

Excellencies, Mr. President of the Asian Institute of Technology, Professor Arthur Chiu of the University of Hawaii at Manoa, delegates, distinguished guests, ladies and gentlemen.

It is my pleasure to deliver these opening remarks on the occasion of the US-Asia Conference on Engineering for Mitigating Natural Hazards Damage.

Many of you have probably experienced at least one type of natural hazard, and most of you have traveled long distances to come here to share your knowledge and understanding of the effects of natural hazards as well as methods for minimizing their potential damage. I appreciate your participation in this conference.

I have been informed that the end product will be a Final Report containing the recommendations for possible cooperative projects in mitigating natural hazards damage. I will look forward to receiving a copy of that report and hope that we at the Ministry of Science, Technology and Energy could be a part of the overall plan for your noble endeavors.

Tremendous forces are unleashed by mother nature during occurrences of natural hazards, such as tropical cyclones, floods, earthquakes, ground failures, cataclysmic volcanic eruptions, tsunamis, and storm surges. These phenomena are constant worldwide threats that recognize no geopolitical, cultural or economic boundaries.

Accompanying the loss of life has been devastating economic loss and the hardships a strong natural hazard entails for survivors. A single hazardous event can destroy crops, buildings, highways, ports, and dams. It can severely disrupt community lifelines -- the systems that provide food distribution, water supply, waste disposal, and communication locally and with the rest of the world.

Losses from these events rise each year, despite progress in understanding natural hazards and how to mitigate their effects. Though economic losses are highest in monetary value in industrialized nations, the greatest burden from natural catastrophes falls on developing nations where high death tolls and greater relative economic loss deal a double blow.

Natural hazards are facts of life and will continue to inflict harm and damage to mankind and his environment. Although science and technology have made great strides in reducing the possible destruction from these events, there is still much more to be learned and we must continue doggedly to seek improvements to our knowledge and technology in mitigating natural hazards damage. The increasing population, the growth of the urban and industrial environments, the increasing tendency of the shift of the population toward cities, the use sometimes of inappropriate design of construction methodologies, etc., are factors that tend to create a scenario vulnerable to catastrophic destruction by natural hazards. The challenge then is upon the design professionals to band together in the continuing quest of finding better ways to mitigate natural hazards damage.

I know you will be very busy with the conference during the week. However, do take some time, or stay over after the conference, to visit our city and enjoy our cultural programs. You are here at a most opportune time: we are celebrating our King's 60th birthday and this is also the "Visit Thailand Year".

I hope that you will return soon for the next U.S.-Asia Conference on Engineering for Mitigating Natural Hazards Damage to review the implementation of your recommendations and your plans for future endeavors in seeking ways to mitigate natural hazards damage.

It will be appropriate to mention that although this conference is technically oriented towards the engineering aspects of hazard mitigation, we should also keep in mind both the socio-economic impacts caused by natural hazards as well as the disaster preparedness for occurrences of natural hazards. Perhaps these two topics could be included in the next U.S.-Asia Conference.

On this occasion, we should gratefully acknowledge the University of Hawaii at Manoa and the Asian Institute of Technology for organizing this conference, and the U.S. National Science Foundation and the U.S.A.I.D. Office of Foreign Disaster Assistance for the generous support.

Ladies and Gentlemen, I now declare open the U.S.-Asia Conference on Engineering for Mitigating Natural Hazards Damage.

TEN YEARS OF NATURAL HAZARDS RESEARCH IN THE U.S.A.

Keynote Address
by
J. Eleonora Sabadell
Division of Critical Engineering Systems
National Science Foundation
Washington, D.C., U.S.A

Natural Hazards Policy in the U.S.A

The role of governments in dealing with the impact of natural disasters on their population and on their national patrimony is to find ways and means to minimize life and economic losses and to provide relief at a minimum cost. To these ends, policies are generated, legislative and executive actions are taken, institutional arrangements are put in place, responsibilities and funds are allocated, information systems are developed, research needs are identified and research is funded.

In the U.S., policies and actions for coping with natural disasters have centered mainly on the management of emergencies with limited attention given to preventive measures.

In general, the management of a natural or any other disaster can be divided into four phases:

1. Pre-Disaster Mitigation/Prevention. Steps taken to alleviate the impact of or to prevent a hazardous event. Examples range from building codes to public education.

2. Pre-Disaster Preparedness. Plans, warning systems and other means adopted in advance of a disaster to minimize its impact.

3. Disaster Response. Activities occurring during and immediately after a disaster. Examples range from search and rescue to providing food, shelter, clothing.

4. Post-Disaster Recovery. Long-term reconstruction. Example: governmental financial assistance. (Cleary, 1985)

Major pieces of U.S. legislation and executive orders have addressed some or all of these four activities but the emphasis generally has been placed on phases three and four. Some of the important laws and governmental actions taken in the last 20 years are:

- National Flood Insurance Act of 1968
- River and Harbor, and Flood Control Acts of 1970
- Flood Disaster Protection Act of 1973
- National Disaster Relief Act of 1974
- Earthquake Hazard Reduction Act of 1977
- Flood Plain Management Executive Order 11988 of May 1977
- Community Emergency Drought Relief Act of 1977

- o Federal Emergency Management Reorganization Plan of 1978
- o Federal Emergency Management Agency Creation by Executive Order, April 1979
- o Coastal Zone Management Improvement Act of 1980
- o Multihazard Research, Planning and Mitigation Title of PL 96-472, of 1983

By these successive actions the U.S. Government has recognized the importance of the impact of natural hazards on the life of the Nation, and the need for special programs and organizations to deal with natural disasters.

It should be pointed out that in general governments respond to hazards in two ways: one, during "normal" times when these activities have a low priority and are placed on a slow track; and the other after a disaster, when the response is swift and the priority is very high (May and Williams, 1986). These fluctuations can be observed in the allocation of federal funds and by the laws passed by Congress before and after some major disaster with the largest support going to relief and recovery efforts.

Another observation related to natural hazards policy and decision-making has to do with the nature of each disaster. Some hazards, like droughts, are quite frequent but slow to be detected, with a prolonged inset period, affecting at times very large regions, and with damages quite difficult to assess because of their creeping nature, overlooked indirect impacts, and long-lasting consequences. Drought relief measures usually taken are short-term and when rains return the political interest rapidly declines.

On the other hand, hazards like earthquakes which are quite infrequent, come with little or no-warning, can have catastrophic consequences in a short period of time and in a relatively small area with losses easily quantifiable. Even though, to date, annual earthquake losses in the U.S. have been a fraction of what every year is lost in floods or hurricanes, this hazard enjoys a very high and constant public perception and reactions have produced natural hazards policies and activities not always consistent with the nature of the risk. Research has not been an exception to this reality, and each natural hazard has received disparate and uneven U.S. governmental support during the past decade.

Federal Natural Hazards Research

The acquisition of new and better knowledge, by investigating the causes and effects of geophysical extreme events, is needed for improving the management and mitigation of, and the recovery from, natural disasters.

The U.S. Government has given some federal agencies the responsibility to fund or carry out research on natural hazards. The main organizations with research programs and facilities are:

Federal Emergency Management Agency (FEMA)

National Oceanic and Atmospheric Administration (NOAA)

U.S. Geological Survey (USGS)

Department of Transportation (DOT)

Department of Agriculture (DOA)

Department of Housing and Urban Development (HUD)

U.S. Army Corps of Engineers (Corps)

Bureau of Reclamation, DOI (BuRec)

National Science Foundation (NSF)

National Bureau of Standards (NBS)

Nuclear Regulatory Commission (NRC)

National Aeronautic and Space Administration (NASA)

Tennessee Valley Authority (TVA)

All of these agencies, with the exception of NSF, are operational and the research they support is directly related to their specific missions, e.g., NRC is interested in the survivability of nuclear power plants; NBS in setting building and material standards; Corps and BuRec in building structures that will withstand ground failures, winds and floods.

Within any of these agencies different kinds of research programs exist that fit the agency's diverse activities. For example: methods for hazard identification, monitoring and measurement; design and development of warning systems; improved design of structures and buildings; methods for retrofitting and rebuilding damaged structures; procedures for response, rescue and removal; public education techniques; methods for land use planning; mapping techniques; damage assessment methods and others. Support for these programs has changed through time.

Results of Research to Date

Research done over the last 10 to 15 years has produced improvements in many areas related to the response to and the management of natural disasters as for example, on data gathering and analysis, on warning systems, design and construction of structures, and damage assessment. Some of the physical processes underlying the occurrence of natural hazards are now better understood than before, but not yet sufficiently.

For the pre-disaster activities data collection, archival methods and computational capabilities, as well as the instrumentation used, have improved. Communication systems are better and high technology, such as remote sensing and imaging techniques for mapping areas of high risk, is now in common usage.

Gradual progress has been made in understanding how to construct buildings and structures to resist damage due to natural hazards such as earthquakes, high winds and floods. This advancement is due mainly to improved physical and mathematical simulation techniques, and to better field measurements. Codes have been developed and adopted, though not always officially incorporated in all the states and regions at risk.

Post-disaster activities also have advanced. Damage assessment methods are improving; response to disasters is better coordinated, though still with serious problems; land use planning sometimes takes into account the possibility of natural disasters; in reconstruction the variation of extreme loads and other stresses on structures is being recognized, though not always acted upon.

Federal funding for natural hazards research in general has remained flat (in actual dollars) during the last eight years, but in constant dollars the support has decreased. The U.S. Geological Survey and FEMA have been very active in mapping high risk areas in the U.S., but now are winding down these activities. Only earthquake engineering research, which is mandated by Congress, has kept up with inflation and reductions. On the other hand, the National Science Foundation created in 1985 a program on Natural and Man-made Hazards Mitigation in the Critical Engineering Systems Division.

The International Decade for Natural Disasters Reduction (IDNDR), a concept developed in the U.S., established by the 1987 UN General Assembly and that will run from 1990 to 2000, may serve as a vehicle for eliciting a more generous support for natural hazards research from the U.S. and other Governments. Activities during the IDNDR will facilitate also the transfer of available knowledge where and when needed and it is hoped that a network of institutions and data bases can be established by the end of the century.

Future Natural Hazards Research

Novel and traditional areas of research will open new opportunities for substantially improving our capabilities to cope with natural disasters. Research on natural hazards now engage a significant number of disciplines ranging from meteorology to hydrology, soil mechanics, fluid dynamics, structural engineering, applied and theoretical mechanics, seismology, social sciences, geology, computer science, and economics to name only a few. It is hoped that other disciplines will join future research efforts.

Some examples of potential topics for natural hazards research are:

Improve the use of advanced sensing techniques (e.g., radar, microwaves); building smart structures; develop advanced instrumentation using high-tech concepts and materials; normalize kinds and numbers of geophysical parameters to be measured, monitoring techniques and quality control methods used.

Develop economic/friendly software and hardware for data and information storage/retrieval (e.g., optical storage, interactive compact disk, data compression); incorporate the use of advanced communication systems for data banks and warning systems; improve networking methods.

Generate advanced physical and mathematical simulation techniques; develop improved methods for risk assessment, management and communication; refine dynamic analysis methods.

Expand the concept of interactive structural materials, e.g., ceramic composites; develop advanced and non-destructive diagnostic methods for existing construction.

Future research will continue to involve many scientific and engineering disciplines, but better integration of specialties will be necessary to solve the compounded problems presented by the impact of natural hazards on an increasingly complex society.

It is also felt that the present level of research activities in the U.S. and other countries is not sufficient for reducing the magnitude of the present life loss, and economic and physical damage being experienced by so many, nor will it be enough for coping with the growing consequences of natural disasters on the economy and well-being of developed and developing nations alike.

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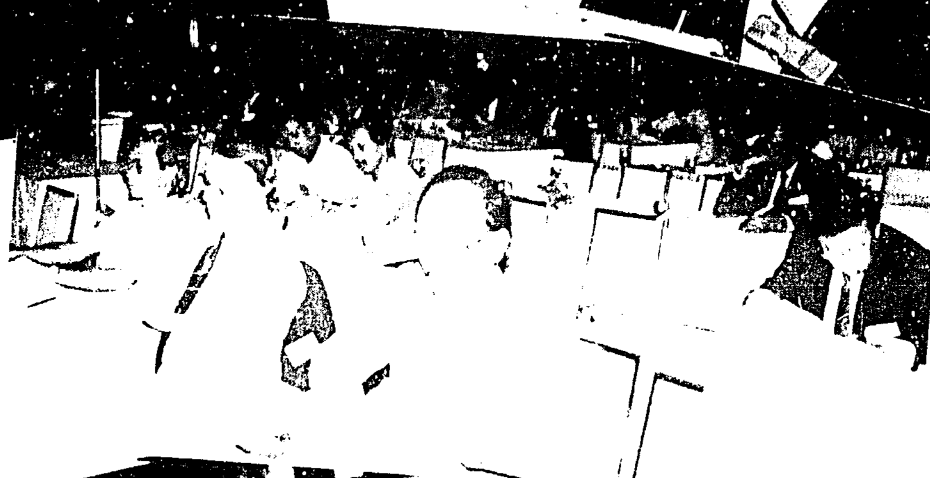


SUMMARY OF WORKSHOPS

Introduction

The participants were involved in discussion groups during the final two days of the conference. Four groups were formed, one for each of the conference theme topics. The objective of each of these Working Groups was to develop a report which would identify cooperative research projects of high priority and great interest to participating countries. The projects recommended by the four groups are listed in this chapter; the full reports are presented in the following chapters.

The projects identified by the groups have the following common attributes:

- o The projects enhance the flow of information and experiences across national and geographic boundaries;
- o The projects provide demonstrable results, within the period of performance, that clearly advance engineering understanding and are implementable into practice;
- o The projects have a critical mass of investigative capabilities and commitments; and
- o The projects provide an efficient use of local and regional expertise and information bases.

The groups prepared long and comprehensive lists of projects of interest. The projects considered to be of most significance are identified as follows:

- o **Category A projects**(priority projects); and
- o **Category B projects** (projects of importance and interest but of lesser priority).

The titles of these projects are listed in the following sections for each of the four groups:

Extreme-Wind Hazard	-	15 projects (4A, 11B)
Flood Hazard	-	5 projects (5A)
Ground-Failure Hazard	-	6 projects (4A, 2B)
Earthquake Hazard	-	7 projects (4A, 3B)

EXTREME-WIND HAZARD

Category A Projects

1. Characterization of extreme winds in tropical cyclones and typhoons -

   a. Development of instrumentation for severe-wind measurements,

   b. Specification of uniform data recording, tabulation and dissemination procedures, and

   c. Development of extreme-wind response and warning systems based on an expert-system approach.

2. Simulation of extreme winds and their influence on buildings and structures -

   a. Characterization of cladding loads on small, medium and tall structures, and

   b. Concurrent instrumentation of full-scale structures for physical and numerical model validation.

3. Development of design and code information related to extreme-wind hazards -

   a. Design and specification of construction techniques for wind-resistant mass housing,

   b. Application of risk and cost/benefit analyses to the use of such construction, and

   c. Specification of regional uniform building codes.

4. Preparation of wind-engineering training and workshop materials.

Category B Projects

(See the Wind Hazard Workshop Report for classification by topics)

1. Severe thunderstorm meteorology.
2. Regional analysis of tropical cyclones.
3. Cross-facility validation of physical modeling facilities.
4. Physical model studies of sand movement to prevent desertification.
5. Low-cost housing vulnerability.
6. Shelter design for people and property.
7. Vegetative and man-made shelter belts.
8. Response and protection of transmission lines.
9. Urbanization effects on wind hazards.

10. Cost/benefit analysis of mitigation techniques.

11. Community education programs.

FLOOD HAZARD

Category A Projects

1. Development of a methodology for identifying appropriate models for flood forecasting.

2. Determination of spatial inundation depths on wide flood plains.

3. Estimation of flood probabilities for risk-based decision making.

4. Flood prediction from failure of dams and flow-retaining structures.

5. Estimation of economic damage resulting from flood inundation.

GROUND-FAILURE HAZARD

Category A Projects

1. Methodology for ground-failure hazard mapping.

2. Simple and reliable instrumentation for real-time monitoring and warning systems.

3. Studies of relationships among precipitation, pore pressures, and slope failure.

4. Multiple-hazard research.

Category B Projects

1. Socio-economic aspects of landslide hazards.

2. Subsidence-hazard identification and mitigation.

EARTHQUAKE HAZARD

Category A Projects

1. Seismic-hazard mapping and seismic zonation for engineering and planning purposes.

2. Strengthening and retrofitting of existing structures.

3. Improvements in construction practices of low-strength masonry buildings.

4. Formulation and revision of earthquake-resistant design criteria and codes.

Category B Projects

1. Preparedness and response to earthquake emergencies.
2. Assessment and evaluation of regional and local economic losses due to earthquakes.
3. Quality control and assurance as related to earthquake engineering.

EXTREME-WIND HAZARD WORKSHOP REPORT

Co-Chairmen: R.N. Meroney
B. Venkateswarlu
Rapporteurs: E.D.H. Cheng
B.E. Lee

Introduction

Wind storms are estimated to cause worldwide an average of 30,000 deaths and over $2.3 billion in damage each year. Disasters associated with a single severe storm can cover hundreds of square kilometers, lead to hundreds of thousands of casualties and cause billions of dollars in economic loss. Complete structural collapse or severe damage is experienced by 93% of the buildings damaged by tornadoes and by 51% of those damaged by hurricanes. Loss of life correlates directly with such extreme damage. The worldwide losses and deaths observed are expected to increase substantially in the coming years due likely to increases in population, concentration of people and properties in cities, settlement in exposed coastal areas, higher construction and repair, costs and more hazardous technologies.

Wind storms can be classified into four categories based on severity and physical origin. Storm types include tornadoes (winds to 500 km/hr), hurricanes (cyclones or typhoons, winds from 115 to 250 km/hr) and severe winds (thunderstorms, downbursts, downslope winds, etc., winds from 80 to 300 km/hr). Due to the variety of such wind-storm drivers, virtually no community in the world is immune from a wind-related natural disaster.

Over the past several decades, various international programs have been carried out to help cooperating countries understand and mitigate the effects of wind related natural hazards. In the Asian area, for example, an Indo-U.S. Workshop on Wind Disaster Mitigation was held in Madras, India, in December 1985. In June 1987, a Seminar/Workshop on WIND ENGINEERING: The Past to the Future was held at Colorado State University, U.S.A., to identify and prioritize research needs in wind engineering for the North American continent.

To foster international cooperation, this report proposes cooperative research projects on wind hazards among U.S. and Asian countries for their mutual benefit. As noted in the flow chart (Fig. 1), wind-storm drivers result in various destructive wind fields to which different characterization attributes can be assigned. These combine with the principles of mechanics to result in different types of structural response. Engineers and scientists use various physical and numerical models to predict such response and subsequently design structures to protect people and property. The engineering knowledge is implemented into various design procedures and codes which must be disseminated to the engineering design, regulatory and administrative communities.

The public has an increasing desire for mitigation as opposed to post-disaster relief and reconstruction. In general, mitigation which results in reduced loss of human lives and property might be applied to all three driving factors in wind hazards: the hazard, the exposure and the vulnerability. These concepts were considered during the deliberations of the Extreme-Wind Hazard Workshop on possible cooperative research projects. During the deliberations, it was found that all projects discussed fell into the following subject categories:

* Wind characteristics;
* Numerical and physical modeling;
* Codes and design information;
* Pre- and post-disaster risk analysis; and
* Education and workshops.

The recommended **Category A projects** are:

1. Characterization of extreme winds in tropical cyclones;

2. Simulation of extreme winds and their influence on buildings and structures;

3. Development of design and code information related to extreme-wind hazards; and

4. Preparation of wind-engineering training and workshop materials.

These projects are detailed in the following sections. Additionally, the titles of 11 **Category B projects** are listed toward the end of this chapter for consideration in future conferences.

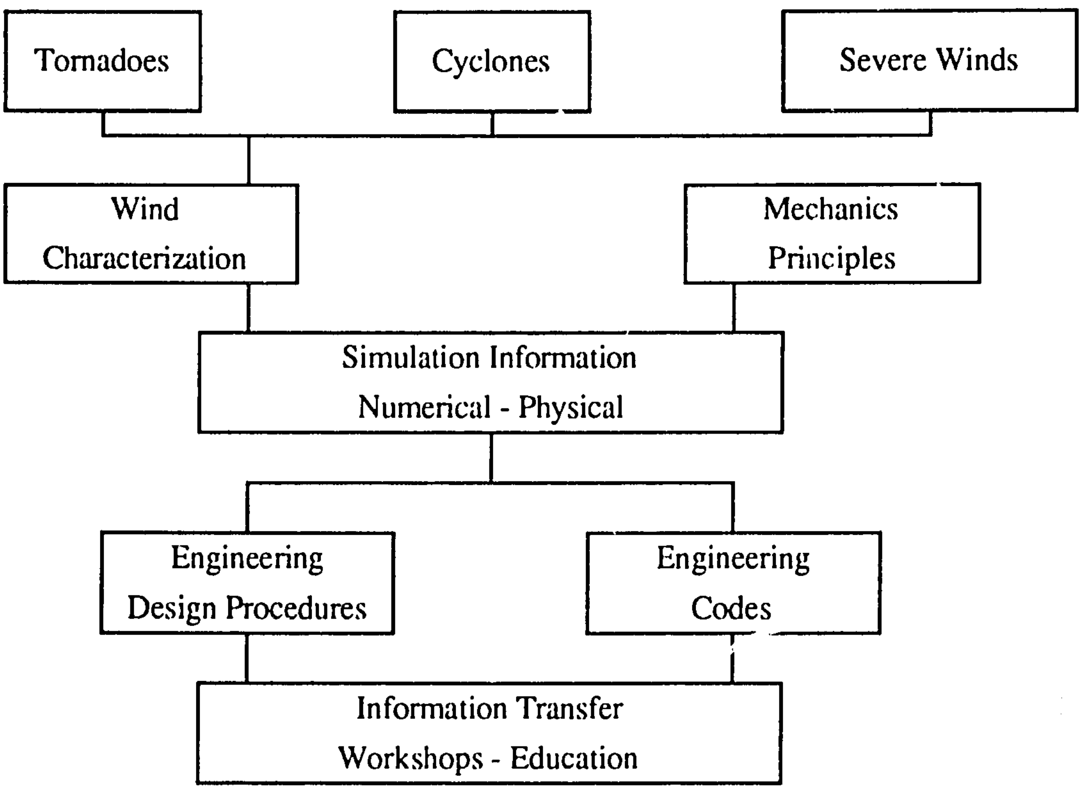

Fig. 1 Extreme-Wind Hazards

Project 1 (Category A)

Characterization of Extreme Winds in Tropical Cyclones

Project Goals

The overall project goal is to maximize the cooperative use of the meteorological resources in the Asian area. The goals of the subprograms are to develop a consensus in a regional area on the most effective instrumentation, data recording and dissemination procedures to be used with extreme-wind response and warning systems that can result in wind hazard mitigation. It is hoped that the associated improvement in data quality and quantity will lead to better understanding of wind phenomena and to improved predictive models.

The subprograms and their goals are:

(a) Development of instrumentation for severe wind measurements

The standardization of instruments for cyclone wind measurements and their calibration are required. This will provide correlatable data taken at stations in as many parts of the Asian region as possible. The standards should be reviewed every five years so that new developments in instrumentation can be incorporated. Additional instruments may be installed as necessary to enhance the quality and scope of cyclone meteorological information.

(b) Specification of uniform data recording, tabulation and dissemination procedures

The goal of this subtask is to establish standards for measurement, storage and retrieval of wind data. An extension of this subtask would define standard methods to convert between the different wind intensity definitions currently used.

(c) Development of extreme-wind response and warning systems based on an expert-system approach

The goals are to create a regional extreme-wind data base for decision making in specified applications, to offer knowledge-based advice for specified applications and to establish warning systems pertaining to various levels of risks anticipated.

Background and Strategy

(a) Instrumentation for severe-wind measurements

Today, even within a single country, different agencies such as national meteorological departments and research institutes are working without strong coordination. In addition, among research institutes there is very little exchange of instrumentation experience. A survey of instrumentation practice and pitfalls is expected to increase the coordination and cooperation between various agencies. Increased communication and coordination of meteorological researchers can also contribute to standard instrument specifications and calibration procedures. Such pooling of information will help the other tasks arrive at some commonality between national codes, and the improvement in data reliability should lead to designing safer and more economical structures.

(b) Uniform recording, tabulation and dissemination procedures

Different countries within the Asian region use different definitions and statistics for extreme winds. This causes difficulties and inconvenience when data from different areas of the region are used to evaluate the character and impact of a given tropical storm.

Such differences in nomenclature are common and tend to limit and confuse engineers when they work on projects outside of their own geographical areas. Teams of researchers will meet to normalize the methods of measurement and presentation of wind data.

(c) Expert-system approaches for extreme winds and warning systems

Rarely does a meteorologist or engineer have available the resource of expert opinion when interpreting cyclonic winds or other wind storms. Yet lives and property often depend upon making the "best" decisions related to warning, protection or evacuation. A knowledge-based expert system for extreme-wind warning systems constructed from an internationally based collection of area experts could put "expert advice" at the fingertips of meteorologists and engineers. A cooperative program would draw upon regional wide experience to produce an application-oriented program which could be disseminated among region nations.

Potential Benefits

There was a consensus among the Extreme-Wind Hazard Workshop participants that the three subprograms discussed above are of interest to the participant nations. It was felt that substantial accomplishments could be made on the projects listed above in a three-year program. Each representative identified potential collaborating institutions in his country which has been compiled into a list and is available upon request.

The standardization of instrumentation, recording and dissemination procedures will lead to:

- Pooling of data across national boundaries;
- The linking of data sets across large regional areas for a better understanding of tropical storms which encompass or intercept more than one country; and
- The potential standardization of engineering practice and codes.

Expert system based wind response and warning systems will permit effective use of personnel and knowledge otherwise separated by national boundaries and language barriers.

Project 2 (Category A)

Simulation of Extreme Winds and Their Influence on Buildings and Structures

Project Goals

The goals of this project are: (1) To obtain improved specifications of wind loads acting on components of a building envelope for tall buildings as well as shorter buildings such as warehouses, apartment complexes and private domiciles; and (2) to provide a source of full-scale data which can be used by wind tunnel operators and numerical modelers to evaluate the reliability and accuracy of their modeling techniques and to monitor the various comparison exercises.

Background and Strategy

Engineers work with analytic, physical or numerical models to design engineered structures such as buildings, towers, bridges, and industrial facilities. These models are only as reliable as the phenomenological understanding of wind, upon which they are based. In order to improve engineering practice and national design codes, there is an urgent need for improved validated models. This need suggests a two-part research program consisting of a laboratory- and full-scale measurement program, viz.,

(a) Characterization of cladding loads on small, medium and tall structures; and

(b) Concurrent instrumentation of full-scale structures for physical and numerical model validation

Lack of design information about the behavior of cladding and external building components to wind often results in under-design and failure under extreme wind conditions. Information of this type can be used in code preparation, post-disaster failure analysis and wind zoning of land for commercial or private use. There does not seem to exist any conceptual limitation to research programs of the types suggested below; however, a commitment of resources is necessary. Research periods of three to five years are anticipated to provide substantial information.

(a) Characteristics of cladding loads

Research into building-component failure can be subdivided into studies related to the:

- Evaluation of cladding response to static versus dynamic effects, load duration, material properties and internal pressures;
- Evaluation of the effects of loads and failure associated with wind-borne missiles and debris; and
- Response of roofing systems and roof materials to strong winds.

Research tasks would include post-failure analysis of damaged structures, wind-tunnel measurements and full-scale testing of components or modules of buildings.

(b) Instrumentation and measurements on full-scale buildings

The derivation of a full-scale data set, e.g., the Aylesbury house, is very expensive and time consuming. The Arts Tower monitoring program at Sheffield, U.K., took place over an eight-year period from 1975 to 1983. Thus, few new full-scale data sets are likely to become available in the next decade. For this reason, international support of full-scale measurement programs is essential, as is international comparison of laboratory and numerical modeling observations.

An international research team needs to identify a limited set of buildings with various heights, which represent particularly popular but wind-vulnerable structures. These buildings should be instrumented and data gathered over a period of at least three years. Subsequently, the data should be analyzed in a uniform manner and comparable laboratory and numerical experiments must be performed to evaluate simulation techniques.

Potential Benefits

Characterization of cladding and structural loads is a subject of high interest in coastal areas around the eastern-Pacific and Indian basins where increased population density has resulted in rapid urbanization. Failure of buildings and other structures can often result in massive loss of employment, death, homelessness and economic losses equal to a sizeable fraction of a nation's gross national product. Design codes are recognizing increasingly the need to specify the use of wind-tunnel and other modeling techniques to provide design data for cases not covered by the codes. Such specifications are already included in the United States, Japanese and Hong Kong codes, and are likely to appear more widely as other national codes are revised. Thus, as the design profession moves away from uniform, if conservative, code-derived data to individual specifications based on ad hoc modeling tests, the degree of variability within a design system is likely to increase. In order to control an inevitable increase in the degree of uncertainty associated with any particular test, the modeling techniques must be calibrated against a number of reliable and accu[illegible] data sets derived from full-scale observations.

Project 3 (Category A)

Development of Design and Code Information Related to Extreme-wind Hazards

Project Goals

Improving the understanding of the action of wind on actual structures is desirable with an emphasis on a more precise definition of the wind forces for structural design. Yet, to be cost effective this understanding must be integrated with actual economic and risk assessments to produce a rational engineering design approach specified by consistent and clear codes.

The overall goal of this project is to develop better guidelines for design and construction against wind effects. Three tasks are proposed in this total project with their respective goals as follows:

(a) To develop design and construction methods for mass housing in extreme-wind zones;

(b) To apply risk and cost/benefit analysis to the use of extreme-wind construction techniques; and

(c) To develop specifications for a regional uniform building code.

Background and Strategy

(a) Mass housing in extreme-wind zones

There is an acute shortage of housing in most of the countries in Asia. Every year in the coastal belts of cyclone-prone countries a large number of houses are damaged due to the high winds of cyclones. Large sums of money are spent every year to repair and renovate damaged structures. Some of the non-engineered structures are non-repairable, further aggravating the shortage of housing. Thus a large effort should be devoted to developing construction techniques for wind-resistant mass housing in cyclone-prone regions.

Much work needs to be done to understand the flow patterns of cyclonic winds, particularly in the vicinity of clusters of residential buildings. The effect of interference between groups of buildings and complicated residential building shapes on wind loads has not been frequently investigated. Since wind-resistant design and construction are often not utilized in Asian countries, the available studies of building arrangements are not necessarily appropriate for Asian housing. The study will begin with a state-of-the-art review of regional building practices. Current building practices will be critiqued, and a program of analytical, physical and numerical studies proposed to evaluate alternate design methodologies.

(b) Wind-related risk and cost/benefit analysis

Types of structures, different construction methods and geographic, meteorological and cultural characteristics must be examined. If cost were not a factor, all structures could be built to resist a large wind hazard. However, economic realities cause builders, engineers, and administrators to make design and construction choices based on probable wind-related risks, costs and benefits of sturdier designs. Research engineers must join with economists, meteorologists and statisticians to develop a design approach which will permit the "optimum" selection of design criteria from available alternatives. This task will examine:

- o Probabilistic assessment of wind data taking meteorological and topographical parameters into consideration;
- o Aerostatic and aerodynamic characteristics of non-engineered and engineered structures, the associated failure mechanisms of structures and the costs of revised construction; and
- o A probabilistic evaluation of the benefits of design changes on structural safety against wind loads.

(c) Specifications for a regional uniform building code

This task will gather national practices and code information for Asian countries, identify commonalities and differences, and propose a uniform code structure for wind effects suitable for analysis and design throughout Asia.

It is expected that the above three tasks will require a minimum of three years for communication among interested research groups, review of data, examination of new research results and incorporation of results into code recommendations.

Potential Benefits

Since wind-related damage has frequently burdened the economies of regional nations, it is in their own interests to mitigate wind hazards and thus conserve human and property resources.

An acute shortage of housing in most of the countries of Asia has made mass housing a common social and economic problem. It is desirable that minimal resources be used to repair and renovate mass housing structures that could be damaged by frequent severe winds. Yet, large losses are incurred because of the failure of poorly designed or constructed housing under extreme winds.

Cooperative studies of the types of materials and methods of construction that will provide better resistance to wind damage are mutually beneficial to all countries. Knowledge about the wind risks and benefits of improved construction techniques will help planners distribute community resources. This same knowledge will benefit insurance carriers and should reduce premium costs.

It is obviously inefficient to limit the exchange of engineering consultation and advice due to the presence of conflicting and confusing national codification practices. In some cases there are contradictory provisions. Coordination will lead to improvement in code preparation, lower construction costs and greater reliability.

Project 4 (Category A)

Preparation of Wind Engineering Training and Workshop Materials

Project Goal

The goal is to prepare guidelines, lists of topics and teaching aids for disseminating knowledge on wind engineering practices among meteorologists and design professionals. These resources will be used to present wind-engineering workshops and symposia to train new staff and upgrade existing employees.

Background and Strategy

Although the topic of wind hazards and wind-engineering design is of great importance to all Asian countries, there are only a few national institutions which offer structured training in these areas. The interest in this topic was universal, and workshop members indicated that their countries would be interested in participating in this project.

Experts in wind engineering will be requested to prepare written and visual-aid course materials suitable for presentation to short courses, workshops and symposia. These materials will be coordinated into a complete program which can be distributed to participating countries. Since very few of the Asian countries possess experts in all aspects of wind-related hazards, the pooling of knowledge should provide an opportunity for a region-wide improvement in wind-related engineering practices.

It is also expected that as research results emanate from the cooperative research projects listed earlier, the new information should be disseminated through updated workshop materials prepared for this task.

Potential Benefits

New engineering information is only useful if it reaches the administrators and engineers making construction decisions. This task is an integral part of the entire research program described in the flow chart described at the beginning of this workshop section. Education, practice, criticism, code revision, and re-education are necessary for a dynamic engineering profession.

Category B Projects

In addition to the Category A projects, the Wind Hazard Working Group agreed that the following list of 11 Category B project titles, grouped according to subjects, should be presented in this report for consideration by future EMNHD conference participants.

Wind Characteristics

1. Severe thunderstorm meteorology

2. Regional analysis of tropical cyclones

Model Studies

3. Cross-facility validation of physical-modeling facilities

4. Physical-model studies of sand movement to prevent desertification

Codes and Design

5. Low-cost housing vulnerability

6. Shelter design for people and property

7. Vegetative and man-made shelter belts

8. Response and protection of transmission lines

Pre- and Post-Disaster Risk Analysis

9. Urbanization effects on wind hazards

10. Cost-benefit analysis of mitigation techniques

Education and Workshops

11. Community education programs

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FLOOD HAZARD WORKSHOP REPORT

Co-Chairmen: S.J. Burges
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Floods have and will continue to create hazardous situations which cause loss of life and damage to human-engineered environments. Much activity occurs on lands that have been made relatively level over geological time by movement of floodwaters. With increasing populations living on floodplains and in coastal zones subject to hurricanes, cyclones, or typhoons, the risks to societies worldwide will continue to increase unless flood-damage mitigation measures are improved and additional measures implemented.

As river systems continue in their evolution, and as civilizations locate close to life-maintaining and life-taking rivers and shoreline zones, there will be lives forfeited and economic damage experienced. For example, in the 100-year period to 1980, it is estimated that as many as six million lives have been claimed by China's Hwang Ho (Yellow River). In the United States between 1965 and 1985, there were 392 flood-related Federally-declared disasters with associated damages of US$4.7 billion (1982 dollars). Hurricane damage is reported separately; Hurricane Agnes alone was estimated to have caused damage of almost US$5 billion (1980 dollars). Enormous losses of lives have occurred during typhoons in some parts of the world. The 1970 Bangladesh typhoon claimed between 300,000 and 500,000 lives. More recently, in late July 1987, more than 300 people were killed by floods and associated hazards during violent storms in South Korea. In mid August 1987, heavy monsoon rains in Bangladesh left almost one million homeless, destroyed almost 1000 square miles of rice fields, and caused flooding leading to the deaths of at least 238 people. Much needs to be done to mitigate these devastating losses. Successful completion of the research tasks identified here will provide more complete tools for the ongoing fight of minimizing losses from one of nature's oldest hazards.

Five **Category A projects** were identified by the Flood Hazard Working Group:

1. Development of methodology for identifying appropriate models for flood forecasting;

2. Determination of spatial inundation depths on wide flood plains;

3. Estimation of flood probabilities for risk-based decision making;

4. Flood prediction from failure of dams and flow-retaining structures; and

5. Estimation of economic damage resulting from flood inundation.

Project 1 (Category A)

Development of Methodology for Identifying Appropriate Models for Flood Forecasting

Project Goal

The goals of this project are:

(a) To develop procedures and criteria to determine what kinds of models are appropriate for a particular catchment. Appropriate models would be identified in terms of climate, meteorology, catchment characteristics, and major flood-producing mechanisms.

(b) To identify what meteorological, hydraulic, hydrological and environmental (storm surge, etc) data are needed in models identified in objective (a). Meteorological data include measured and forecasted precipitation and wind fields.

Problem Importance

Numerous models (including deterministic and state-space predictor-corrector) have been developed for estimating or forecasting catchment response to flood-producing fluxes. However, at present no systematic methodology is available for identifying an appropriate model. Developments in new instrumentation for environmental sensing (including radars and satellites) provide opportunities for modifying or improving existing forecasting schemes to take advantage of spatial and temporal measurements that were not possible when existing systems were implemented.

Potential Participants

The research approach requires examination of climate, meteorological and catchment configurations from the U.S. and several Asian countries ranging in latitudes from Indonesia to Northern Japan.

Project 2 (Category A)

Determination of Spatial Inundation Depths on Wide Flood Plains

Project Goal

The goals of this project are:

(a) To develop methods for predicting the flood-plain inundation levels from typhoon-generated tidal surge.

(b) To develop and evaluate methods for predicting spatial inundation depth resulting from overbank flow of estimated (or measured) riverine flood hydrographs.

Problem Importance

Present schemes for estimating flood-plain inundation are based on steady-state flow conditions. This is appropriate for uncommon floods on narrow flood plains but does not reflect the three-dimensional unsteady flow of major floods over wide flood plains. This is particularly important in relatively densely human- and animal-occupied areas where accurate depth estimates are needed for flood emergency measures (human and animal evacuation and property-damage mitigation).

Potential Participants

Wide flood plains exist in a number of Asian countries as well as in the U.S. Experience of flood inundations in these various geographic locations, particularly as the density of human and animal occupation increases, emphasizes the need for improved accuracy of inundation-depth estimation. This problem has received recent research attention in Japan and the U.S.

Project 3 (Category A)

Estimation of Flood Probabilities for Risk-Based Decision Making

Project Goals

The general goal of this cooperative project is to improve and develop new procedures for predicting floods of large return periods (small exceedance probabilities).

The specific objective is to develop and test the use of non-conventional approaches and models for flood prediction. These will include specifying alternative cumulative probability functions, realistic spatial structure in the underlying distribution functions, appropriate regional parameterization, and appropriate model parameter estimation techniques.

Importance

Flood prediction is necessary for risk-based design of flood structures and for flood-plain delineation. Despite advances made in the past 15 years, basic and applied research in this area is needed as indicated in scientific reports published recently in various countries including the U.S. This is especially true in case of estimating floods of large return periods due to the limitation of the data bases available. Cooperation in this area will provide the basis for exchange in methods, software, and data.

Potential Participants

This problem is important to all Asian countries and the U.S. Fundamental research on the subject is being carried out in the U.S. as well as in China and Japan. Consequently it is anticipated that these three countries will have immediate interest in this research.

Project 4 (Category A)

Flood Prediction from Failure of Dams and Flow-Retaining Structures

Project Goal

The general goal of this cooperative project is to improve existing procedures and to develop new procedures for estimating the flood and sediment hydrographs resulting from the failure of earth dams and levees.

The specific objectives are:

(a) To identify and test an appropriate model to determine the progression of the dam or levee breach resulting from different triggering mechanisms, including overtopping and sudden collapse of part of the structure. Various boundary conditions will be considered as well as different designs of the structures.

(b) To develop and test mathematical models for estimating the flood hydrographs from dam/levee breaches.

Importance

A number of natural and man-made dams and dikes have failed in Asian countries and the U.S. causing considerable economic and human losses. In recent years considerable attention has been given to this problem. Most of the work done stems from dam safety investigations carried out to determine the safety of the dam. Likewise, some research has been done to examine modes of dam failures, to model the breach process mathematically and to estimate the resulting flood hydrographs. A number of factors need to be investigated to predict flow and sediment hydrographs more accurately. These factors include the: geometry of the embankments, structural materials, initial breach configuration, boundary conditions, effects of sediment and flow conditions and geometry of the channel. The proposed research will be based on both mathematical and physical models.

Potential Participants

This research will be of interest to the U.S. and most Asian countries. While various participating countries can provide data from some dam failures, Japan and the U.S., and possibly China, may have the greatest immediate interest in this research.

Project 5 (Category A)

Estimation of Economic Damage Resulting from Flood Inundation

Project Goal

The goal of this project is to assess methods used in various Asian countries and the U.S. for estimating economic damage from flood inundation.

Importance

Data have been collected to permit estimation of flood-inundation damage. Typically, one common measure is to relate inundation depth to appraised economic damage. In addition to flood-inundation depth, flood duration, sediment deposition, debris movement, and flow velocity contribute to socio-economic losses. These losses include disruption to society, actual property costs, and loss of cultural treasures. It will be beneficial to assess what data have been collected in Asian countries and the U.S. that would permit quantification of such losses.

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GROUND-FAILURE HAZARD WORKSHOP REPORT

Co-Chairmen: Z.C. Moh
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Definitions

For the purpose of this report, ground failure is the term given to three broad categories of failures: slope failures, seismically induced liquefaction, and subsidence. Slope failures are caused by downward and outward movement of slope materials--rock, soil, and artificial fill. Slope failures range from slumps and slides in these materials, through falls, avalanches, and flows. The general category of slope failure will be referred to by its common term, "landslide."

Another destructive ground-failure process is seismically induced liquefaction of saturated granular soils. Liquefied soils lose their capacity for support of overlying structures, and, in cases where these soils are on slopes, they may flow laterally and form landslides.

A less dramatic but potentially equally damaging form of ground failure is subsidence, which is defined as the downward movement of a relatively horizontal ground surface with no lateral component of movement. Subsidence of particular concern in this report is caused by removal of fluids from near-surface soil horizons. Ground subsidence due to withdrawal of fluids is particularly a problem in large urban areas constructed on consolidation-prone river deltas along coast lines.

Socio-economic Effects of Ground Failure

Annual economic losses in Japan, India, Italy, the United States, and a few other countries due to landsliding have been estimated to exceed US$1 billion per year in each nation. For example, N. Ohhira, former Director General of the Japanese National Research Center for Disaster Prevention, has noted that annual losses in Japan from landslides total about US$1.5 billion (personal communication, 1982), and the U.S. National Academy of Sciences has estimated that U.S. landslide losses are US$1-2 billion annually (Committee on Ground Failure Hazards, 1985). Landslide losses in most Asian countries are not as well documented as in Japan and India, and are not as large as those given above. However, losses in China, the Philippines, Indonesia, the Himalayan nations, Taiwan and the Asian part of the U.S.S.R. are large, with some of them exceeding US$100 million per year. In addition, the urban areas of Hong Kong have experienced extremely costly landslides.

Deaths due to catastrophic landslides have occurred throughout the world since people began to congregate in areas subject to slope failure. The burgeoning populations of the world in this century have worsened the problem. During the period 1971-74, an average of nearly 600 people per year were killed by slope failures worldwide (Varnes, 1981). Interestingly, about 90 percent of these deaths occurred within the Circum-Pacific region (i.e., in those countries in or on the margin of the Pacific Basin); a significant proportion of these deaths took place in Asian nations.

The greatest recorded loss of life in any single group of landslides occurred in Gansu Province, China, in 1920, when approximately 100,000 people were killed by earthquake-triggered landslides in loess (Close and McCormick, 1922). Another disastrous Asian landslide occurred in 1949, when an earthquake in the Tien Shan Mountains of Soviet Tadzhikistan triggered a series of landslides that buried 33 population centers, killing an estimated 12,000 to 20,000 people (Wesson and Wesson, 1975; Jaroff, 1977). In 1921, a large debris flow in Alma-Ata, the capital of the Soviet Kazakh Republic, killed 500 people and inflicted considerable damage to the city. Earthquake-induced landslides in the Min Range of northern Sichuan, China, killed approximately 8,000 in 1934 (Chang, 1933).

Among industrialized nations, Japan has suffered the greatest continuing loss of life and property from landslides. Casualties have been particularly large in heavily populated urban areas at the bases of steep mountain slopes. In July 1938, Kobe, one of Japan's largest cities, was swept by debris flows generated by torrential rainfall, resulting in 450 to 600 deaths and the destruction of more than 100,000 houses (Nakano et al., 1974; Japan Ministry of Construction, 1983). In the city of Kure in 1945, 1,154 people were killed by debris flows generated by heavy rains accompanying a typhoon (Nakano et al., 1974). Data accumulated by the Japan Ministry of Construction (1983) indicate that landslides killed an average of 150 people per year in Japan from 1967 to 1982.

The costs of soil liquefaction are not as well documented, particularly for Asia. However, losses due to liquefaction were significant in the 1964 Niigata, Japan, earthquake. Buildings in Niigata rotated as much as 60 degrees and sank into liquefied sand. During the 1964 Alaska earthquake, ground failure caused an estimated 60 percent of the US$300 million in damages; much of this ground failure was caused by loss of soil strength due to liquefaction (Youd, 1978).

Precise loss figures for subsidence are not available. However, several of the world's major cities have undergone significant losses due to subsidence caused by pumping of groundwater from underlying sediments. It is estimated that annual losses in the United States due to all types of subsidence are about US$100 million (Holzer, 1984). Mexico City was subjected to major financial losses due to as much as 8 m of subsidence in the center of the city in the 1950's and 1960's due to pumping of groundwater. Bangkok also has suffered significant economic losses due to subsidence.

Interrelationships of Ground-Failure Hazards with other Natural Hazards

As noted in the previous sections, landslides often are triggered by earthquakes. They also are associated with other natural hazards. They may be triggered by earthquakes, volcanoes, typhoons, floods, or tsunamis, and their occurrence sometimes results in major flooding. This report attempts to treat the interrelationships among natural hazards by proposing a research project dealing with multiple hazards.

Organization of Report

The Ground-Failure Hazard Working Group has selected six research projects that are the most significant currently. These areas of research have the best potential for high return and significant impact on ground-failure hazard mitigation. The main goal of all the proposed activities is to increase the effectiveness of efforts at ground-failure mitigation both in Asia and in the United States, with particular emphasis on the developing nations of Asia.

The Category A projects are:

1. Methodology for Ground-Failure Hazard Mapping;

2. Simple and Reliable Instrumentation for Real-Time Monitoring and Warning Systems;

3. Studies of Relationships between Precipitation, Pore Pressures, and Slope Failure; and

4. Multiple-Hazard Research.

The **Category B projects** are:

1. Socio-Economic Aspects of Landslide Hazards and

2. Subsidence-Hazard Identification and Mitigation.

The Working Group also recognized the need for training and for technology transfer, without which, the research efforts cannot serve the community at large. Thus, the development of strong cooperative efforts in the following areas are proposed as **Category B** projects:

3. Education and Training in Ground-Failure Hazard Mapping;

4. Ground-Failure Information Dissemination; and

5. Development of Codes of Practice for Ground-Failure Hazard Mitigation.

While the identified research topics should be considered for funding by agencies responsible for sponsoring fundamental research, such as the U.S. National Science Foundation, funding of efforts in training and technology transfer will have to come from other governmental and non-governmental organizations (both U.S. and non-U.S.) that sponsor international aid and development, such as the U.S. Agency for International Development (AID) and the World Bank. For developing a data base of appropriate contacts, a list of national contact agencies and organizations on ground-failure hazards will be provided upon request.

Project 1 (Category A)

Methodology for Ground-Failure Hazard Mapping

Project Goal

The main goal of this project is to develop appropriate methodologies for ground-failure hazard mapping; this mapping will serve as a data base for evaluation of current land-use practices and future development.

Background

Identification and delineation of ground-failure hazards including landsliding, liquefaction, and subsidence are essential steps in the planning, design, and construction of engineered structures and in land-use planning. Early identification of hazards allows the development of appropriate avoidance and/or mitigating strategies.

While in the past decade there has been a substantial effort to develop mapping methods and map-presentation techniques, interpretive landslide-hazard maps cover only limited areas of Asia and the United States and, at present, generally applicable and accepted techniques for the preparation and evaluation of such maps do not exist.

Strategy

The emphasis for this research on ground-failure hazard mapping should be on the development and testing of mapping methodologies for future use in large-scale mapping efforts; specific attention should be given to:

- o Standardized, international mapping methodologies and map-presentation techniques suitable for use by both technical and non-technical personnel
- o Development of procedures for mapping seismically induced landslide hazards
- o Hazard-mapping criteria for lifelines
- o Development of procedures for mapping liquefaction hazards
- o Subsidence-hazard mapping procedures for identification of impact of future or altered land use
- o Inexpensive computer techniques for ground-failure susceptibility mapping and for ground-failure data retrieval

Project 2 (Category A)

Simple and Reliable Instrumentation for Real-Time Monitoring and Warning Systems

Project Goal

The main goal of this project is the development of simple, reliable, and inexpensive instrumentation for in-situ and on-site monitoring and for warnings.

Background

Simple and reliable instrumentation is essential for studies of the processes involved in landslide generation, and for use as sensors in hazard-warning systems. Recent studies in the United States (Johnson and Sitar, 1987; Keefer et al., 1987) and Hong Kong (Cowland and Richards, 1985) have shown that continuous measurement of field parameters can lead to substantial improvements in the understanding of the processes involved, and that measurements can serve as a basis for issuing appropriate warnings when failures appear imminent.

The major difficulty with the effort to date has been a lack of simple and reliable monitoring instrumentation. In particular, the resistance of instrumentation to adverse environments has been a serious problem; failure rates have exceeded 50 percent in many installations.

Strategy

The monitoring and warning systems consist of two components: (1) field instrumentation; and (2) data-acquisition and data-transmission equipment. In the area of instrumentation, there is a need for the following:

- o Dual, integrating, and event-triggered rain gauges
- o High-resolution, miniature pressure transducers for in-situ pore-pressure measurement
- o Inclinometers and tiltmeters suitable for rapid installation with light equipment.

In the area of data acquisition and data transmission, the needs are:

- o low-cost, environmentally stable, programmable data-acquisition systems
- o low-cost sending and receiving units for instrument monitoring and hazard warning.

Project 3 (Category A)

Studies of Relationships between Precipitation, Pore Pressure, and Slope Failure

Project Goal

The main goal of this project is the development of a fundamental understanding of the quantitative relationships between precipitation, pore-pressure generation, and landslide/debris flow initiation.

Background

The fact that landslides are initiated by high pore-water pressures due to rainfall or melting of snow is well recognized. In the past, there has been a significant effort to develop empirical correlations between the magnitude, duration, and intensity of rainfall in generating slope failures, and particularly debris flows. These relationships generally have relied on the measurement of precipitation and on past records of landslide events and, therefore, have tended to be qualitative and specific to particular sites or regions. Recently, it has been shown that real-time measurement of pore pressures can provide a quantitative measure of groundwater response and possibly can improve the accuracy of the predictions. However, because at this time such measurements have been obtained at only a few sites, much research is needed before pore-pressure monitoring can be used for public landslide warning and prediction.

Strategy

In order to develop the necessary relationships, comprehensive studies involving the following efforts are needed:

- o Collection of precipitation and pore-pressure measurements from sites in different climatic and geologic environments
- o Measurement of strength and moisture-retention characteristics of soils at instrumented sites
- o Quantitative evaluation of the influence of measured pore-pressure response on slope stability and of the influence of antecedent rainfall on pore-pressure generation and landslide initiation.

Project 4 (Category A)

Multiple-Hazard Research

Project Goal

Reduction of the hazards involved is the main goal of multiple-hazard research.

Background

Ground-failure processes affecting widespread terrains often occur in combination with other natural hazards. Combinations of volcanic eruptions-earthquakes-landslides, earthquakes-landslides-floods, hurricanes-floods-landslides, bursting of natural dams-floods-siltation, and earthquakes-landslides-tsunamis are some of the examples that result in disasters and cause great loss of life and extensive damage. Such multiple-hazard ground failures have great damage potential and adversely impact environments in mountainous terrains and coastal regions. There is little understanding of either the interrelated mechanisms of such failures or the overall significance of these occurrences. Systematic investigations are required to develop data bases for criteria and methods for location and mitigation of such multiple hazards.

Strategy

Research on multiple-hazard ground failures should concentrate on the following interrelated hazards:

- o Landsliding, erosion, and subsidence in coastal regions;
- o Landslides, floods, debris flows, and siltation in high-altitude catchment basins;
- o Landslides, debris flows, and damming of rivers due to volcanic eruptions in mountainous terrains; and
- o Outburst hazards from natural landslide and glacial-moraine dams.

This research should specifically deal with: (1) interrelationships of hazard mechanics; (2) mitigation of multiple hazards; and (3) response to disasters caused by multiple hazards.

Project 1 (Category B)

Socio-economic Aspects of Ground-Failure Hazards

Project Goals

The main goals of this research project are to develop the criteria for:

(a) Selection and implementation of mitigative measures to prevent ground failure (primarily landslides), commensurate with the socio-economic constraints inherent in different Asian societies; and

(b) Reduction of fear and panic in the populace resulting from ground-failure (primarily landslide) predictions and warnings.

Background

Regions affected by catastrophic ground failures suffer significant social and economic impacts. Worldwide population growth and its increasing concentration in urban centers in vulnerable areas pose continued threats of ground-failure disasters and necessitate states of awareness of ground-failure hazards by national and local governments and by the people under their jurisdictions.

Strategy

The project envisages undertaking research on the following topics:

(a) Investigations of socio-economic factors and evolution of criteria for implementation of mitigative measures for ground-failure hazards; and

(b) Assessment and reduction of negative impact of ground-failure predictions and warnings on the people affected.

The right of being kept informed, so that individuals and communities are able to participate in the decision-making process, helps and encourages the populace to take part in ground-failure mitigation measures and preparedness programs. Interaction with sociologists and economists by earth scientists, engineers, land-use planners, and other professionals is required to establish relationships between socio-economic constraints and landslide disaster-reduction requirements, and to develop criteria for implementation of mitigation measures. Responses of countries (with various levels of development), states and provinces (with different physiographic terrains and resource potentials), and various socio-economic groups and communities to different types of ground failures must be evaluated. In addition, sociological studies of the assessment of impact on the populace of warnings and predictions of landslides are needed.

Project 2 (Category B)

Subsidence-Hazard Identification and Mitigation

Project Goals

The goals of the project are:

(a) To identify cities and areas at risk from subsidence; and

(b) To develop land-use plans and mitigation measures for these cities and areas.

Background

Development of metropolitan cities and large urban conglomerations over soft argillaceous sediments deposited in large inland lakes, on river flood plains, and in deltaic regions and coastal areas has created serious subsidence problems in many parts of the world. Combined with extreme hydro-meteorological conditions, such subsidence leads to disasters resulting from floods, differential settlement of foundations, and collapse of structures. In addition to providing low bearing capacity for foundations, the soft surface deposits give rise to amplification of ground motion during earthquakes and poor surface-water infiltration leading to floods during monsoons in South and Southeast Asia. Systematic studies are required to identify the governing factors and to develop mitigative measures for safety of structures and lifelines against ground-subsidence hazards.

Strategy

The project envisages research on the following topics:

(a) Identification of areas currently undergoing active subsidence and areas at risk from subsidence due to consolidation of weak soils due to pumping of groundwater; and

(b) Development of appropriate mitigation measures.

The Bangkok area, which has been facing active subsidence hazards (currently being studied), could provide an excellent prototype for the initial research effort. Results of studies of subsidence in Bangkok would then provide guidelines for similar studies in other areas threatened with ground subsidence in South and Southeast Asian countries.

Project 3 (Category B)

Education and Training in Ground-Failure Hazard Mapping

Project Goal

The goal of this project is the development of curricula for short courses in ground-failure-hazard mapping techniques and map presentation.

Background

The task of developing ground-failure hazard maps covering entire countries requires coordinated efforts involving large numbers of scientists and engineers. The ultimate success of these endeavors will hinge on the ability of these people to compile and report field observations in a consistent and mutually compatible manner. This can only be achieved through common training in mapping techniques and data presentation. The most effective means of providing such training is by means of short courses carried out on site.

Strategy

The courses will have to be designed to allow rapid assimilation of course information by the students and will also have to account for the varied educational backgrounds of the students, who may have previous training in science (typically geology), or engineering (typically civil engineering). While the actual development of the technical contents of the courses will not require research beyond compiling the necessary information, the preparation of course format and organization will have to consider the varied backgrounds of the students and, therefore, should be carefully evaluated. A cooperative research program involving experts in the field of science education and engineering education aimed at developing the most effective teaching approaches appears highly desirable and is recommended.

Project 4 (Category B)

Ground-Failure Information Dissemination

One of the major problems for engineers and scientists engaged in hazard mitigation work is access to comprehensive, reliable disaster- or hazard-related data bases.

This is particularly true of the developing countries of Asia. Thus, it is important that centers be promoted in Asian countries to provide this access. As an outstanding example of a successful effort in providing information dissemination on ground-failure hazards, the Asian Disaster Preparedness Center (ADPC, at the Asian Institute of Technology in Bangkok), which was established in 1986, has placed "Information Dissemination" as one of its primary activities. The ADPC sees itself as the focus of an Asian/Pacific disaster-information network, both within the region and as a node in the worldwide network of disaster-interested agencies. The ADPC acquires not only published materials, but also is developing a project under which historical disaster literature will be collected and collated on a country-by-country basis. In addition to acquisition, the ADPC publishes newsletters and bibliographies, and provides other information dissemination services. In addition to the ADPC, the AIT has four other information centers. The Asian Information Center for Geotechnical Engineering is particularly relevant to hazard/disaster information.

Funding for ground-failure information activities of the ADPC should be encouraged, as should the development of other ground-failure information services in Asian countries.

Project 5 (Category B)

Codes of Practice

Design, building, and grading codes are the regulatory vehicles by means of which governmental entities ensure proper design and construction practices in areas subject to ground-failure hazards. Due to differences in geologic/geographic natures, degree of ground-failure risk, and the cultural and social backgrounds of various countries, it is not possible to establish a uniform code of practice for design of slopes or for development of hillside areas to mitigate landslides. For Asia, there is not a single country that has a uniform construction code or standards as related to hillside areas. The same is true within the United States, where many agencies at all levels of government apply design criteria for slope stability that are tailored to their own specific needs. Although there are some outstanding design criteria and documents that have been developed in the United States by government agencies and professional and private organizations (for example the Office of Naval Research and the American Association of State Highway and Transportation Officials), most hillside developments and land-surface modifications throughout the country, both public and private, proceed without reference to a major design code. Nevertheless, some very effective landslide regulations have been implemented by local and state governments.

In Southeast Asia, Hong Kong is the only national entity that has a highly developed code of practice. The government publication, *Geotechnical Manual for Slopes*, not only is the official code of practice in Hong Kong, but also serves as a guideline for slope design in many other countries. A similar effort is currently under way in Taiwan where the federal government is in the process of developing a nationwide code of practice for design and construction on hillside slopes

In spite of the wealth of experience with landsliding and landslide mitigation, insufficient use is made worldwide of what has been learned in these areas. It is necessary to develop international guidelines for codes dealing with construction on slopes. The detailed codes should be organized at national or local levels in response to specific regional and local physical and cultural conditions. Research should be undertaken to improve the technical base for the development of design and construction codes applicable to areas susceptible to landsliding. Encouragement and assistance should be given to professional societies in various countries for the development of such codes. Leadership should be established on an international level. A logical group to undertake such an effort is the Technical Committee on Landslides of the International Society for Soil Mechanics and Foundation Engineering; this committee should cooperate with other organizations, such as The Japan Society of Landslides and the Commission on Landslides and other Mass Movements of the International Association for Engineering Geology.

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EARTHQUAKE HAZARD WORKSHOP REPORT

Co-Chairmen: T. Katayama
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"Every year about 50,000 earthquakes large enough to be recorded on strong motion instruments occur worldwide. Some of these earthquakes cause widespread injuries, deaths and economic disruption. According to data compiled by the United Nations, more than 50% of all deaths between the years 1900 and 1976 due to natural hazards were caused by earthquakes. In addition to the personal tragedies created by such natural disasters, the affected regions suffer innumerable long-range social, political and economic impacts. It is difficult to estimate the impact of the 1973 Managua, Nicaragua, or the 1976 Tangshan earthquakes on the socio-economic and political aspects of the countries involved. It is clear, however, that the impact was long range and profound."*

The Earthquake Hazard Working Group delineated seven projects that should be considered.

The **Category A projects** are:

1. Seismic hazard mapping and seismic zonation for engineering and planning purposes;

2. Strengthening and retrofitting of existing structures;

3. Improvement in construction practices of low-strength masonry buildings; and

4. Formulation and revision of earthquake-resistant design criteria and codes.

The **Category B projects** are:

1. Preparedness and response to earthquake emergency;

2. Assessment and evaluation of regional and local economic losses due to earthquakes; and

3. Quality control and assurance as related to earthquake engineering.

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* Earthquake Engineering Research Institute, Subcommittee on International Decade of Hazard Reduction, 1987.

The relative efforts needed in research, implementation and training for each of the seven projects are tabulated below.

Project	Research	Implementation	Training
1	0.5	0.3	0.2
2	0.7	0.2	0.1
3	0.5	0.3	0.2
4	0.4	0.5	0.1
5	0.2	0.4	0.4
6	0.6	0.3	0.1
7	0.3	0.3	0.4

For the recommended projects to come to fruition, it is essential that local and regional data and information centers be established. Such centers should have past earthquake occurrence catalogs and (when available) damage statistics. Post-earthquake reconnaissance reports, socio-economic and census data, engineering manuals for design, etc. should be available at such centers. All participants indicated that establishment of such information centers is desirable in developing cooperative research projects. Such centers can disseminate regional and other available information to participating researchers when needed.

In the following sections, some considerations and issues related to each of the above seven projects are presented.

Project 1 (Category A)

Seismic Hazard Mapping and Seismic Zonation for Engineering and Planning Purposes

Project Goal

The goal of this project is to devise standard procedures that can be used to produce seismic zonation maps. Such maps can be used for building codes, design and construction practices, land-use planning and for repair and strengthening of existing buildings. Development of such maps is the first step in formulating earthquake-resistant design and retrofitting practices.

Background and Strategy

There are many regions of the world where earthquake codes need revision or they are under development for the first time. It is essential that a standard philosophy and procedure be developed to obtain seismic zone maps for these regions. This first step is crucial for a region or a nation to develop its earthquake disaster mitigation policy. In developing such zonation maps, the following points should be stressed:

- o Existing regional co-operative efforts toward this end should be strengthened and new co-operative efforts should be encouraged.

- o If a strong-motion instrumentation network for a region is not available, it should be acquired. It is not possible to develop such zonation maps unless relevant attenuation and frequency-content information is made available. Maps that are developed without any local data will have large uncertainties.

- o Such maps should delineate the hazard of far-field and near-field earthquakes.

- o Such maps should be developed through probabilistic modeling and should reflect the underlying degree of uncertainty.

Besides the hazard maps for ground shaking, other earthquake-induced hazards need to be mapped. In heavily populated and rapidly growing areas, microzonation for liquefaction potential, land-slide potential and other relevant hazards should be mapped. Such maps can be developed with close collaboration among geologists, geophysicists and geotechnical engineers.

Project 2 (Category A)

Strengthening and Retrofitting of Existing Structures

Project Goal

The goal is to develop the technical methods and related implementation procedures for the seismic strengthening of buildings with "brittle" structural systems. The term "brittle" applies to ordinary reinforced concrete frames, unreinforced masonry walls, and the combinations of these two materials. They are extremely vulnerable to the effects of seismic ground motion, and their failure has been the principal cause of death and injury in past earthquakes.

Background and Strategy

In dealing with existing buildings, only the buildings with "brittle" structural systems need to be considered. It is most unfortunate that such buildings behave very poorly even in moderate earthquakes. Many of the deaths due to earthquakes are caused by the collapse of unreinforced masonry and adobe structures.

The required tasks should include the following:

- o Technical methods for strengthening structures, with emphasis on unreinforced masonry buildings and adobe dwellings for improved lateral resistance.

- o Development of a technical basis for formulating engineering guidelines for decisions on the type and level of retrofitting existing structures.

Project 3 (Category A)

Improvement in Construction Practices of Low-Strength Masonry Buildings

Project Goal

The goal of this project is to develop improved construction practices for achieving earthquake resistance of low-strength masonry buildings.

Background and Strategy

Low-strength masonry buildings (walls in brickwork, stone masonry and adobe construction) are still under construction in most developing countries, even in seismically affected regions. The collapse of such buildings during earthquakes is the main cause of loss of lives and property, creating tremendous emergency and reconstruction problems.

Initial research so far carried out for improving the earthquake resistance of such buildings has shown good promise. More detailed and intensive research efforts are now needed to arrive at appropriate and economical measures for achieving seismic safety of such buildings. Bilateral and multinational cooperation in this research effort will be not only useful, but necessary, to achieve quick results. The implementation of the results of this research project has the promise of saving large numbers of lives, as well as property, in future earthquakes in the developing countries.

Project 4 (Category A)

Formulation and Revision of Earthquake Resistant Design Criteria and Codes

Project Goal

The goal of this project is first to examine the rationale of existing building codes and then to formulate proper earthquake resistant design criteria.

Background and Strategy

The guidelines under which the revisions or new formulations are made must contain all of the essential elements necessary to determine the seismic loading, methods of analysis, types of structural systems, and design of structural elements. They must be adaptable to the particular seismicity, materials and methods of construction for any designated region or country.

The proposed guidelines should also incorporate the following:

- o Considerations of acceptable risk through reliability formulation.
- o Calibration of proposed revision relative to existing codes.
- o Representation of far-field effects through spectral content representation.

There are many regions of the world where no seismic design requirements currently exist. This has been due to the fact that no major events within the boundary of that country has occurred during recent times. However, as brought home very clearly from the Mexico City event of 1985, even far-away earthquakes can cause considerable death and destruction. The adverse effects of lateral forces, with special emphasis on seismic loading should be examined in the so-called moderate or low seismic regions of the world.

Project 1 (Category B)

Preparedness and Response to Earthquake Emergency

Project Goal

The goal is to provide access to reliable and timely planning advice, checklists, and model plans. These plans can serve as resources for countries to use in the development and evaluation of their earthquake preparedness and response plans.

Background and Strategy

Earthquakes provide a critical test of the ability of any emergency plan to function well. Major earthquakes provide a most comprehensive test of a nation's and a community's ability to respond to a rapid onset of emergency.

The collective learning of many countries can help to identify approaches to preparedness and response planning that work and those that are doubtful. As the urbanization of seismic regions increase, it is important to recognize the value of such plans and to take actions to implement such plans. By focusing on the similarities and differences between the situations from past earthquakes, considerable experience can be gained to improve such plans and performance.

The greatest benefit to be gained is in reduction of loss of life and property. In addition, fewer domestic and international resources will be required if the community is well prepared. Finally, there will be increased social, economic and political stability in the region where the population perceives that the emergency situation was handled effectively.

Project 2 (Category B)

Assessment and Evaluation of Regional and Local Economic losses Due to Earthquakes

Project Goal

The goal of this project is to develop models to evaluate regional, local and building-specific vulnerability. Such vulnerability analysis could provide information for short-term and long-term economic losses for the region or for the community.

Background and Strategy

A major earthquake in any metropolitan region of the world can disrupt economic activity not only for the local region but, for some cases, for the entire nation. The political, social and developmental consequences of such events can be devastating. In the past, engineers and researchers have mainly concentrated their efforts (and justifiably so) on mitigating loss of life. In some cases, the economic impacts can also be quite severe. To assess impacts of such rare events, models and procedures need to be developed. Such research can help not only planners and politicians, but could also be invaluable to real-estate investment bankers, the insurance industry and to urban developers.

Project 3 (Category B)

Quality Control and Assurance as Related to Earthquake Engineering

Project Goal

The goal is to develop scientific methodologies, construction procedures, and management and inspection codes for appropriate quality control and assurance of earthquake-resistant structures. Through this, it is expected that the entire construction process is properly controlled, resulting in the constructed structures being highly reliable in their seismic performance.

Major aspects of the project include studies on the effects of human factors on structural construction and the implication of those factors in structural design, construction management and inspection.

Background and Strategy

It is often observed that supposedly well-engineered structures undergo severe damage in strong earthquakes. This takes place in all seismically active countries including, for example, Japan where aseismic design codes are well-developed. This undesirable fact is largely attributed to the fact that there are no proper common standards of practice for construction management and inspection that should ensure the quality of construction. The importance of common standards of practice should be particularly emphasized in the case of reinforced concrete structures, since potential defects caused by poor construction are difficult to detect after its completion. Those defects only become visible after an earthquake many years later with disastrous consequences.

To avoid this type of disaster, appropriate standards of practice for management and inspection during construction must be developed for the purpose of quality control and assurance.

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ABSTRACTS

Abstracts of the papers are presented in this chapter. They are arranged in alphabetical order by authors' surnames in the following groups:

A. Extreme-wind hazard
B. Flood hazard
C. Ground-failure hazard
D. Earthquake hazard
E. General

The papers that were received in time for publication are contained in the *Proceedings of the U.S.-Asia Conference on Engineering for Mitigating Natural Hazards Damage 14-18 December 1987, Bangkok, Thailand.* Copies of the *Proceedings* can be ordered from the EMNHD Conference Secretariat, Geotechnical and Transportation Engineering Division, Asian Institute of Technology, GPO Box 2754, Bangkok 10501, Thailand. A limited number of single copies are available from Prof. Arthur N. L. Chiu, Department of Civil Engineering, University of Hawaii at Manoa, Honolulu, Hawaii 96822, U.S.A.

A. EXTREME-WIND HAZARD

STOCHASTIC SIMULATION OF EXTREME WINDS IN A TROPICAL CYCLONE-PRONE REGION

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In order to utilize limited historical wind records for estimating extreme wind speeds in a tropical cyclone-prone region for natural hazards damage mitigation, a stochastic simulation model for generating long-term annual extreme winds, on the basis of short-term records, is investigated. Basically, this simulation model consists of three components. The first component is the wind simulator which is capable of generating non-storm wind data. The second component is the storm simulator which is for simulating tropical cyclones or other extratropical winds. The last component is a cyclone occurrence simulation program called storm occurrence simulator. An application of this proposed model is demonstrated.

EXTREME VALUE ANALYSIS OF WIND GUSTS IN SINGAPORE

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It has been recognized that winds exhibit seasonal trends and are random in occurrence and intensity. However, on the assumption that long term climatic conditions remain statistically stationary over the years, it is possible to consider extremal values for a given calendar month over different years to come from the same population.

This paper considers all the monthly maxima of 3-sec gusts at two stations in Singapore & four different approaches in extreme value analysis are studied and their results are compared. These are: (1) Case A where distributions of monthly maxima are assumed independent and identically distributed and the distribution of the maximum for any year is derived from Order Statistics, (2) Case B where distributions of monthly maxima are independent but not identically distributed and the distribution of the maximum for any year is derived, (3) Case C where the Fisher-Tippett Type 1 distribution is used and (4) Case D where a chronological sequence of exceedences above a prescribed base level is used based on stochastic model by Zelenhasic [1970].

TYPHOON RISKS AND TYPHOON-RESISTANT DESIGN OF NUCLEAR POWER PLANTS IN KOREA

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This study investigates models and methods of probabilistic description and statistical analysis of typhoon wind speeds at a site, and proposes an operational method of typhoon risk assessment in Korea. Two probability models for extreme typhoon winds are used to fit distributions either to the direct statistical data or indirect simulation data. First, the applicability of the direct statistical method for the extreme wind model is investigated for those sites where historical typhoon wind data are available. Next, the applicability of two indirect simulation and fitting methods is discussed, and they are compared for those sites where historical wind speed data are not available. A common indirect method, based on Russell's procedure, is used which generates about 1000 simulation data for typhoon winds. An alternative procedure proposed in this paper simulates extreme typhoon wind data of about 150-200 years directly to fit the Weibull distribution to the generated data.

As an example of the application, this paper briefly describes the typhoon-resistant design for reinforced concrete structures and steel transmission towers at nuclear power plants in Korea. Finally, design wind speeds and load factors for typhoon-resistant design are proposed for these structures.

ENGINEERING DESIGN FOR EXTREME WIND OCCURRENCE IN HONG KONG

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Hong Kong is periodically subject to typhoons which may occur during the period May to September each year. These events can result in high windspeeds and thus allowance for wind effects is an important feature of a number of engineering design problems.

This paper commences with a brief review of typhoon data and indicates the important features of the structure of typhoons, giving information on extreme speeds for design purposes. The major provisions of the wind loading Code of Practice for Hong Kong are described. The need for additional design guidance for wind-sensitive buildings is indicated, particularly with regard to the dynamic response estimates of tall buildings with low values of structural damping and stiffness. The problems of cladding design for glass curtain wall buildings are also discussed. Finally, mention is made of a further range of wind sensitive engineering design problems including anchorage points for shipping and wind generated wave action.

ESTIMATION OF ANNUAL MAXIMUM WIND SPEED DISTRIBUTION BY A PROBABILISTIC PROCEDURE FOR TYPHOON-PRONE REGIONS

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A probabilistic procedure based on statistical properties of typhoons is applied to the evaluation of extreme value distributions of annual maximum wind speed in a typhoon-prone region. The estimated distributions are compared with observed data at five weather stations in and near the Ryukyu Islands of Japan. In general, the calculated distributions cor- respond well to the observed ones. It is observed that the former distributions are more stable than the latter since the statistical data of typhoons are stable. Several parameters are then investigated for their influence on the calculated distributions.

MITIGATION OF WIND RELATED DAMAGE DUE TO SEVERE WIND STORMS AND HURRICANES*

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Wind storms, cyclones and tornadoes are estimated to cause average total annual building losses in the United States exceeding earthquakes, expansive soils, landslides or floods. Since 72% of wind losses result from severe damage or collapse situations, whereas, on the average, tsunamis, earthquakes and storm surges cause only 6% of the losses in the severe or collapse category, the severity of losses from extreme winds is greater than the severity of losses from all other natural disaster situations combined. Nonetheless, by effective use of land zoning, planning procedures, building to codes and incorporation of modern design information into new structures, some estimates suggest projected damage could be reduced by 35%.

* Theme Paper

RECENT ACTIVITIES OF DESIGN CONSIDERATIONS FOR WIND EFFECTS ON LONG-SPAN BRIDGES

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This paper presents recent activities in Japan concerning design and code considerations for wind effects on long-span bridges. Illustrations are given of practical situations and consideration is given to the variety of uncertainties in the determination of reference wind speeds to be covered nationwide, the understanding of limit states subjected to strong winds, and the influence of simplifications introduced into design procedures and codes.

SOME ASPECTS OF COMMUNITY PREPAREDNESS PLAN AGAINST CYCLONES

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Cyclonic Storm which is associated with strong devastating winds and high storm surge is a serious natural hazard for the Indian Sub-continent and littoral states of Bangladesh, Burma and occasionally Ceylon that incurs a heavy toll of lives and property. Even with technological advances we cannot prevent or dissipate the fury of these cyclones. But with careful landuse planning, taking recourse to modern techniques of monitoring cyclones, issuing advanced warnings to the coastal population and designing wind resistant houses, industrial complexes, high rise buildings, chimneys, communication towers, etc. we can minimize the loss to lives and property substantially. The various aspects of community preparedness against cyclones, such as the work of risk microzonation of wind and thus delineation of cyclone prone areas, flood risk zoning, proper designing of cyclone shelters, raising of the shelter belt, and devising and enforcing proper building code, etc. are discussed in this paper.

PEAK GUST AND PEAK MEAN HOURLY WINDS IN INDIA - PROBLEMS IN A MIXED POPULATION

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On the basis of an earlier observation that an FT1 plot (Fischer - Tippett Type I) of observed peak gust (PG) at many stations in India showed a distinct convex curvature, the question as to whether the Mean Hourly Winds (MHW) at the corresponding times also show a curvature has been examined on a monthly basis to approximate their ratios for use in existing probabilistic wind loading theories. It is found that the MHW, defined by the India Meteorological Department as the average of the winds during the last 10 minutes of an hour, do follow FT1. The different behaviors of PG and MHW seem to suggest that different mechanisms cause them. It is suggested that PG be obtained by considering only the points near the top end of the sample in an FT1 plot and a pseudo-MHW of one full hour average be obtained by using the recommended ratios for pressure systems until wind loading models appropriate to the winds causing peak loads such as those due to cyclones have matured for practical use. This procedure, as an interim measure, is necessary to prevent gross under- estimation of wind loads that will occur if the actual MHW is used in cyclonic regions.

CONFIDENCE INTERVALS AND DESIGN WIND SPEEDS

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It is necessary that computed extreme wind speeds be corrected for sampling errors by assigning suitable confidence intervals. This aspect is particularly relevant to the coastal areas of India which are prone to frequent wind hazards. The extreme peak wind speeds are computed from the meteorological records of yearly extremes by Type I (Gumbel's) distribution.

In the present investigation three widely used methods for estimating the confidence intervals are examined and critically compared. The basic design wind speeds are compared with those specified by the Indian Standards Code (Revised Draft) and recommendations are given for future use. Ten typical meteorological stations of India have been chosen for the present study.

A SURVEY OF METEOROLOGICAL DISASTERS OVER TAIWAN AREA

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The meteorological disasters resulting mainly from typhoons, excessive rainfall, drought and cold-air outbreaks in the Taiwan area during the last 25 years (1961-1985) were studied. The subjects in this study include the life losses and property damage in agriculture, fishery, transportation, water conservancy, electric power, telecommunication facilities and buildings. Among the above-mentioned disasters, the most serious was typhoons followed by excessive rainfall. The water conservancy facility destruction was the most serious one; it included 360 km of levees and revetments, 1,430 spur-dikes and diversion dams, for a loss of US$107 million per year. The agricultural damage came next and was estimated at about US$70 million annually. It was also found that the damage caused by the meteorological disasters during the recent 5 years (1981-1985) was estimated at US$1.2 billion, which approximately corresponds to 0.48% GNP per year.

EXTREME WIND HAZARDS IN ASIA*

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Severe cyclones, also called typhoons in the Pacific, and hurricanes in the Atlantic regions, originate between 5° and 30° latitudes on either side of the equator. In addition to cyclones, tornadoes associated with thunderstorms also occur in these regions. Every year the typhoons across the Asia Pacific coast and the cyclonic storms across the Indian Ocean coasts, particularly in the Coromandel coast across the Bay of Bengal, cause havoc destroying millions of houses and other structures, damaging crops, and most important of all, killing people and livestock. The characteristics of the abnormal winds of these cyclones are different from those of the normal winds of a well-behaved wind climate.

At present, the effects of these abnormal winds are not considered in the design of structures. Hence many of the structures built in the cyclone-prone areas fail due to buffeting, aerodynamic instability, excessive deformation, high differential pressures and fatigue caused by the cyclonic winds. With a view to emphasizing the need for research on cyclone-resistant structures, typical illustrations of the failures of roofing sheets, wall cladding and foundations of residential and industrial buildings in India, Bangladesh, Philippines, Vietnam and other Asian countries, are presented in this paper. Failures of tall chimneys, towers, bridges and other structures in the cyclone-prone regions are also highlighted.

* Theme Paper

THE CHARACTERISTICS OF WIND FORCE OF TYPHOONS AND THEIR PREDICTION METHODS IN THE TAIWAN AREA

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Two empirical wind force prediction methods of typhoons affecting the Taiwan area are developed, in which the hourly wind force and the peak gust predictions at a given location are assumed to be a function of typhoon position, intensity, direction and terrain effects. A total of 90 typhoons that invaded the Taiwan area since 1949 are used and applied to the meteorological stations of Taipei, Hsinkong and Taichung. In the real time operation, once a typhoon track and its intensity are predicted, the hourly wind force and the peak gust at a given station can be obtained readily from a set of statistical diagrams. In addition, the characteristics of wind force of typhoons affecting Taiwan are also discussed. The problem of a wind field of typhoons affecting the Taiwan area may be considered as a viscous rotating fluid past an immersed body (the Central Taiwan Mountain Range). The associated phenomena including the boundary layer, flow separation, vortex and wake zone are all found in Taiwan. The dynamic effects of the large-scale flow passing over a barrier can also be applied to these situations. Generally, most of the wind force characteristics while under the influence of typhoons over Taiwan and its vicinity can be explained by the aforementioned theories. Certain useful results are obtained and their applications to forecasting are discussed.

AN OUTLINE OF STUDY ON WIND HAZARD PREVENTION OF STRUCTURES IN CHINA

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China is located along the northwest Pacific Ocean and suffers from more typhoons than any other country in the world. China has experienced many successes and also some failures in the protection against wind hazards since the network organization of wind and flood hazard prevention covering the whole country was set up in the 1950's. This paper describes an outline of the studies on wind hazard prevention of structures in China. Emphasis is placed on the state-of-the-art wind loading provisions in the China Code of Bridge Design and the wind-resistant design of cable-stayed bridges in China.

STRONG WIND IN NORTHERN CHINA; GENERAL DESCRIPTION, HAZARD AND MITIGATION

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Northern China usually refers to the Yellow River Valley and other regions further north. The strong winds in Northern China may be classified as follows: cold wave strong winds, typhoons, strong winds due to terrain effects, tornadoes, and squalls. Strong winds cause severe damage including damage to buildings and structures, to trees and agriculture products, the overturning of ships and off-shore structures, the overturning of railway trains in the "Hundred-Li Wind Region" and the desertification of cultivated lands and pastures. Improvements of weather forecasting and better cooperation between meteorological stations and relevant organizations have mitigated wind hazard losses. In particular, the construction of the "Three-North" Protection Forest System since 1978 has made great progress in protecting the land from desertification by increasing grain yield and in weakening sand storms.

B. FLOOD HAZARD

FORECASTING HAZARDOUS FLOODS*

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Developments in real-time flood forecasting activities are reviewed and model, data needs, and computational requirements for improving flood forecasting to reduce flood hazard consequences are explored. Hurricane, hurricane surge, frontal rain, convective rain, and snowmelt generated floods are discussed and the different modeling and data networks needed for predicting the magnitudes and consequences of these phenomena are described. Formal schemes for incorporating meteorological and catchment antecedent uncertainties into forecasted flood responses are reviewed. All schemes are evaluated considering catchment size, forecast quality and forecast lead time to show what methods are most useful. Needed research and implementation of known technologies relevant to flood hazard mitigation through flood forecasting are addressed.

* Theme Paper

FLOOD PROBLEMS OF BANGLADESH

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The main causes of floods in Bangladesh are spillage from rivers, drainage congestion of local runoff, storm surges and human interference. The main structural methods of flood protection in Bangladesh are embankments for preventing spillage from rivers, submersible embankments for delaying the flooding, channel improvements and local drainage improvements. The monetary loss in terms of damage to crops, roads, embankments and property is estimated to average about US$200 million a year. Scarcity of drinking water and outbreaks of water-borne diseases become serious during and after floods. Another mitigation concept associated with floods is that a river basin-wide flood control plan must be developed jointly by the Governments of the co-basin countries in order to combat the floods in the Ganges, the Brahmaputra and the Meghna rivers. A flood plain land use regulation along with a program regarding the formation of a flood brigade is needed. Techniques should be developed so that accurate forecasts of flood levels as well as areas that could be flooded can be made well in advance with at least three days lead time.

FLOOD HAZARDS AND ITS PREVENTION ON THE LOWER REACHES OF THE YELLOW RIVER*

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Broad features of the flood hydrology of the Yellow River, the second largest river in China, are described together with comments on historical flood episodes. In the 2000 years preceding 1949, almost 1600 flood episodes inundated up to 250,000 sq km of the flood plain as levees and the channel system evolved. Flood damage mitigation methods since 1949 in the lower reaches of the river are described with the history of construction of reservoirs, dykes and groins given. The spatial genesis of floods throughout the river basin dictates largely the effectiveness of mainstream flood damage mitigation reservoirs either extant or planned. Flood damage is caused by both water and massive sediment deposition. Mitigation schemes have been enhanced by explicit recognition of sediment contributions from the loess plateau in the upper and middle basins. Maintaining the stability of the lower channel system is of primary importance for damage mitigation.

* Theme Paper

COMPARATIVE STUDY OF FLOOD-RUNOFF ANALYSIS IN VIEW OF DISASTER RESEARCH

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The present study consists of three parts, of which the first is concerned with the classical one-dimensional flood flow in channels, the second with the two-dimensional flood encroachment in flood plains and the third with the three-dimensional expansion of floods in estuarine areas.

All parts of the study are made by simulation techniques with a super-computer. The results are also useful for a flood control project in a watershed.

PREDICTION OF WATER AND SEDIMENT OUTFLOW HYDROGRAPH CAUSED BY DAM AND RIVER-LEVEL FAILURES

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Floods produced by dam and/or river-levee failures cause severe damage to property and loss of human life. This paper describes the breaching and hydraulic characteristics of dam and river-levee failures on the basis of field and laboratory experiments that predict the water and sediment outflow hydrographs. The most common cause of failure by heavy rainfalls in smaller earth dams for irrigation was overtopping, and their breaching usually formed a "V" shape with a mean side slope angle of 36°. An empirical formula to estimate the peak outflow discharge from a breach was obtained by experiment and it agreed with the field data. The outflow hydrographs in cases of partial dam-breaks and reservoir with sedimentation were examined by experiments and mathematical models. Regardless of the causes of river-levee failures, the topographies of breaches and scour holes were similar in shape. The changes in the levee breaches and the outflow discharge with time are described by two kinds of experiments. A simple model for the prediction of breach enlargement and outflow rate were developed and verified by experimental results. Measures for mitigation of breach enlargement and effective closure methods are explained.

ON PREDICTION OF FLOOD HAZARDS

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The main purpose of this paper is to review and describe the current knowledge on prediction of flood events. Developments on flood prediction models including mixture and multivariate models are reviewed in relation to their properties and their applicability for at site single and regional flood frequency studies. Likewise, methods for estimation of parameters and flood quantiles are presented including approaches for transfer of information. In addition, criteria for model selection and procedures for treating special flood prediction problems are outlined. Suggestions for needed research in some areas are given.

URBAN FLOOD MITIGATION WORKS IN SINGAPORE BUKIT TIMAH CATCHMENT

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Heavy rainfall events over rapidly and extensively developing low lying areas, having water courses which are influenced by tides, pose the problem of flooding in some parts of Singapore. Strategies developed to prevent and control floods in one such area,the Bukit Timah Catchment, are presented. Use of urban drainage models KWRM, MITCAT and FLOW2D in assessing the current flooding situation and in evaluating the available options for flood mitigation works are illustrated. The models were calibrated and verified using six major historic storm events and then used to evaluate the performance of the proposed diversion scheme for different storms and land-use conditions.

MEASURES AND PROBLEMS OF FLOOD MITIGATION

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Malaysia, situated very near the Equator, comes under the influences of the South-west (May to August) and North-east (November to February) monsoons, which are the major contributors to the 2500 mm overall annual rainfall. The topography is characterised by a steeply sloping core made up of a series of roughly parallel ranges from which the runoff is comparatively rapid and interspersed by less elevated undulating country. The river courses are relatively short with steep gradients in their upper courses and comparatively flat meandering stretches in the lower reaches, so that flood flows are transient in the upper reaches but increase in duration towards the coastal plains. The bulk of Malaysia's population is concentrated in towns and villages situated in the valley tracts and coastal plains. Any flooding in these areas, therefore, affects large numbers of people and their livelihood. Multi-pronged and systematic approaches are engaged to combat the flood problems, namely both structural and non-structural measures as well as long-term hydrological data collection. Structural measures include the Kuala Lumpur Flood Mitigation Project, the Western Johore and the Kemasin-Semerak Integrated Agricultural Development Projects whilst Disaster Relief and Preparedness Plan, Flood Forecasting and Warning System, Flood Risk Analysis and Mapping are some examples of non-structural measures. Establishing a Hydrology Branch in 1972, the Drainage and Irrigation Department aims to solve, to a certain extent, the problem of a lack of hydrological data.

FLOOD AND DISASTER MANAGEMENT IN INDONESIA

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The Indonesian archipelago consists of more than 13,000 islands. It has 128 active volcanoes and more than 3,924 main rivers. With a Mean Annual Rainfall of about 2,810 mm. and the specific characteristics of the country, floods occur very frequently. Local inundation, river overtopping, flash floods and lahar floods are some types of floods.

Some natural phenomena, especially rain and human interference in the environment, are generally the main cause of floods. Rainfall intensity, duration and its distribution can be manipulated to some extent, for the benefit of mankind. Though flood occurrence cannot be avoided, mitigation technology has been developed in many countries to avoid and decrease losses. The development of a living environment has also been introduced.

However, floods and associated disasters can still happen due to limits and constraints of countermeasures. A case study of floods in the area of Mt. Galunggung Volcanic Debris Control Project is expected to identify such limits and constraints and conclude with some recommendations.

NEW STRUCTURAL AND NON-STRUCTURAL MEASURES AGAINST FLOOD DAMAGE IN THE METROPOLITAN AREAS OF TOKYO, JAPAN

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In recent years, the city of Tokyo and its surrounding districts have been subjected to a new type of flood damage caused by rapid urbanization. This damage is not easy to avoid effectively by ordinary flood control systems or structural measures such as river improvement works because it is almost impossible to widen rivers or raise the height of levels in heavily urbanized areas. Comprehensive measures for flood control by means of various structural and non-structural measures were adopted and promoted. They take the form of new river improvement works, underground diversion channels and the control of rainfall runoff flowing into rivers.

In this paper, the author aims to describe the above structural and non-structural measures against flood damage, using the Kanda river in Tokyo as an example. In addition, the comprehensive water-control countermeasures in other densely populated cities such as Osaka and Nagoya are also described.

A NEW APPROACH ON INTEGRATED FLOOD CONTROL OF BANGKOK

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Flooding in Bangkok and its suburban areas are caused by the combination of the high discharge of the Chao Phraya river from the north, high tides at the river mouth, heavy rainfall in the city and land subsidence. Due to frequent floodings, the Bangkok Metropolitan Administration has requested the Asian Institute of Technology to make a joint study with the Thai-Austrian Consortium to recommend the most feasible flood control scheme. The study was accomplished in a one year period in 1986 and recommended an integrated flood control scheme which combines flood protection, urban development, domestic water supply, salinity control, navigation and socio-economic development in the most effective way. The scheme which can lower the river level 2.7 m below the present flood level consists of an upstream diversion dam at Pak Kret (Km 70), a 60 Km long diversion channel of 135 m basewidth, a seabarrier structure near the river mouth (Km 2) and surrounding embankments on the east and west banks. The results show that the scheme is economically feasible with the benefit-cost ratio of 5 and rate of return of 30%. The period of implementation is expected to be 10 years.

THE IMPACT ON FLOOD FROM THE SLOPELAND DEVELOPMENT

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From experimental watersheds of 7.17 hectares and 15.75 hectares at Da-ken, Taichung, Taiwan, we have quantitatively determined that the slopeland development will increase the gross runoff coefficient, peak runoff coefficient and sediment yield. The sediment yield has the highest rate of increase. All of them decrease significantly after one year due to natural vegetation. For reducing the floods in a small watershed, the flood detention dam with a compound spillway, introduced in this paper, can automatically reduce the peak flow, elongate the duration, and control the outflow from the dam within the allowable flow capacity of the downstream channel. Model experiments are used to find the outflow from the width and effective water depth at the opening. The dimensionless unit hydrograph and triangular unit hydrograph are used to derive the hydrograph for hydrological routing analysis. The detention effects for Watershed A of 7.17 hectares are 32.27% for a return period of 10 years and 25.29% for return a period of 25 years.

FLOOD FORECASTING SYSTEM IN TANSHUI RIVER BASIN

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Taiwan is invaded by typhoons several times a year accompanied by heavy rainfall, frequently resulting in severe flooding. Tanshui River, in the northern part of the island, runs through the Taipei Metropolitan Area where floodings have often occurred in the past. In order to reduce the risk of flooding, several important measures for flood mitigation have been taken in the last decade, including the implementation of a flood forecasting system, construction of a floodway and upgrading of levees. The information gathered at gaging stations in the forecasting system are transmitted on-line to the Forecasting Center for processing and/or computation, using flood routing models. The forecasted flood stages at various locations are then released to proper authorities for appropriate actions. Initially a simplified routing model was adopted. However, a reservoir and a floodway have since been added to the Basin. To take the effects of these changes into account, a dynamic wave model has been developed to replace the simplified routing model. Furthermore, a typhoon rainfall forecasting model has also been developed. It is expected that the system will be greatly improved in the near future.

C. GROUND-FAILURE HAZARD

SLOPE FAILURES IN HONG KONG AND THEIR MITIGATION

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Hong Kong has a long history of slope failures, many of which have had a direct consequence on the population. Experience has shown that these failures occur on a regular basis, are related to heavy rainfall and range in size and character from minor earth or boulder falls to major, disastrous landslides. The effects of these frequent events, be they large or small, on the population in the densely urbanised Hong Kong situation receive an immediate response by the authorities.

Following a brief description of the main causes, types and number of failures, the varied and numerous pre-emptive planning, and engineering and statutory procedures currently used in Hong Kong to prevent, counter, remedy and generally mitigate the impact of these events are discussed in detail.

A STUDY ON THE EROSION CHARACTERISTICS OF NANHUA MUDSTONE

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Nanhua Mudstone is exposed in the hilly land east of Tainan, Taiwan and covers an area of 280 square Km. This mudstone has a very serious erosion problem. An understanding of the erosion characteristics of this geological formation should help the mitigation work for erosion control. The author did some measurement and analysis work on this subject. This paper presents the results of the study. The results of a topography study show that the great majority of the naked slopes dip southward and the thick and pure mudstone lithology has given this geological formation the worst erosion problem. The analysis of the field erosion rate data indicates that the slopes, which are longer, flatter and dip closer to the south, will have a higher erosion rate. The measurements also show that the slopes generally have a higher erosion rate in the first half of the rainy season and that the erosion rates tend to be decreasing yearly. From the results of depth moisture measurements on the naked slopes, it is known that only less than 40cm thickness of the top layer of these slopes will change their moisture content during the rainy and dry seasons. Based on the discoveries of this research, an erosion control method is suggested for an engineering project in the Nanhua Mudstone area.

LANDSLIDES IN INDONESIA, ITS OCCURRENCES AND THE EFFORT MADE TO OVERCOME THE PROBLEMS

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Indonesia consists of more than 13,200 islands, spreading from 95°-142° longitude East and 6° North - 10° South latitude. It is a tropical country characterized by high precipitation and tropical rainforests. Five big islands, Sumatra, Java, Kalimantan, Sulawesi and Irian Jaya, are relatively densely populated.

Geologically, the territory of Indonesia is very unique and therefore many geoscientists desire to conduct investigations in the area. Indonesia is situated between three major plates: the Australian, the Asian and the Pacific. These plates have moved toward the archipelago to the present geologic time. This phenomenon has formed the volcanic chains along Sumatra, Java and Lesser Sunda Islands as well as Sulawesi island. Meanwhile a system of major fault zones inland or off the coast are also present due to the effect of collisions and dragging of the plates. The occasional movement of the faults results in earthquakes felt in nearby areas.

This paper describes landslide phenomena in Indonesia as one of the natural disasters resulting from the above mentioned geological processes combined with other natural phenomena.

There are five parameters to be considered related to landslide phenomena namely:

- Geological condition
  (Structural, morphology, lithology and stratigraphy)
- Rainfall
  (duration and intensity)
- Vegetation
  (forest condition, farming practice)
- Earthquakes
  (distribution and magnitude)
- Human exploitation.

Generally speaking landslides occur along the mountain ranges of Sumatra, Java, Lesser Sunda, North Sulawesi and Irian Jaya which are suited to the condition of the above-mentioned parameters to induce landslides. To overcome the problem, systematic landslide mapping on critical and potential landslide areas has been undertaken as part of a five year development programme. The maps produced are meant for guidance to authorities for the development plan of the country. An engineering geological investigation is conducted on an area struck by landslides to support engineering data on the reclamation of the areas.

LANDSLIDES IN MOUNTAIN SLOPES DURING THE ECUADOR EARTHQUAKE OF MARCH 5, 1987*

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The March 5, 1987 earthquake which battered the northeast province of Ecuador provoked a great number of landslides in the widespread ravine areas over the eastern slopes of the Andes mountains, and destroyed pipe- lines through a stretch of distance as long as 30 km. A visit was made to a landslide site to investigate the features of failure and subsurface soil conditions. Based on brief in-situ observations of soil conditions, a simple analysis of stability is made to offer an interpretation for clarifying the cause of the landslides.

* Not presented at Conference

A THEORETICAL PREDICTION OF LAND SUBSIDENCE DUE TO WATER LOSS FROM AQUIFERS

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This study presents the consolidation of saturated soils due to water loss from aquifers by pumping from deep wells. The soils are treated as porous isotropic elastic solids completely saturated with water. The Biot's consolidation theory is assumed to govern the behavior of the soils. The soil domains are infinitely extended radially. Hankel transforms with respect to the radial coordinate, and Laplace transforms with respect to the time variable are applied. Schapery's approximate formula is used for inverse Laplace transforms, and inverse Hankel transforms are obtained by direct numerical integration. Some particular cases have been evaluated and comparisons have been made with other existing studies. It is found that the solution presented can be applied to practical problems such as the estimation of the land subsidence due to well pumping in Bangkok.

RETAINING WALL FAILURE DUE TO HEAVY RAINFALL

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A 700-meter long retaining wall was constructed across the toes of several relatively steep slopes. Six months after the completion of the wall there was a period of unusual heavy rainfall which continued for 70 hours and deposited a total rainfall of 576 mm. This was about one-third of the normal average annual precipitation for that region. Immediately afterwards part of the wall was found to be completely collapsed and the remaining part was tilted and showed longitudinal cracks in the construction joints. Wide tension cracks were visible on the slope behind the wall. It was a gravity-type retaining wall, 3 to 4 meters in height, and the foundation was placed on the boundary between the residual soil and the weathered rock underneath. The soil itself was highly weathered and was classified as CL or ML in the Unified Classification System. The mechanism of the failure was examined based on the intensity of the rain. In the case of the prolonged heavy rainfall the wetting front advanced deeply into the soil and finally reached the existing water table. This gave the worst possible condition for the stability of the wall. However, it was known that the original wall design was not particularly critical for this condition. After a careful examination for the weathered soil profile it was found that joints and faults were well developed in the weathered rock. It was, therefore, concluded that the generation of an artesian water pressure through the joints and faults caused the wall to fail.

GROUND FAILURES IN SOUTHEAST ASIAN COUNTRIES*

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Ground failures occur in many different modes. Landslide is the most common type of ground failure which may occur due to natural processes or man-made activities or their combinations. With the exception of some large deltaic plains, a large proportion of the land area in Southeast Asia is hilly and mountainous. Warm, wet climatic conditions, sometimes augmented by seismic activities, are often responsible for landslide occurrence in the region. Due to the large variation in the properties of residual deposits and the complex geological conditions, many highways in mountainous terrain in Southeast Asian countries were constructed without applying geotechnically satisfactory design procedures but by judgement and precedents. Many slopes have failed and many others are unstable. These resulted in large maintenance commitment, inconvenience, traffic disruption and even safety. This paper describes a qualitative assessment approach for categorizing slopes for hazard mitigation adopted for two highways crossing mountainous terrains in Malaysia. The approach is extended and a quantitative rating system is established for the Central Cross-Island highway in Taiwan.

* Theme Paper

GEOLOGICAL ZONING FOR LANDSLIDES*

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Landslides or slope movements occur on specific zones; some types of landslides are found exclusively on special zones of geology. As an example, appropriate geological zonation will provide proper spatial prediction on landslides. The Japanese Islands can be divided into fifteen zones for slope movements. This zonation is based on geologic age, tectonic belts, character of slope material and landslides. Brief discussions are given for each zone on its engineering geologic character, predictability and mitigation of disaster caused by landslides.

* Not presented at Conference

LANDSLIDE-HAZARD REDUCTION IN THE UNITED STATES*

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Landslides cause $1-2 billion in economic losses and 25-50 deaths yearly in the United States. They occur in every state, and are a significant natural hazard in more than half the states. Reduction of landslide losses is achieved in one or more of three ways. First is the reduction of slope-failure occurrences and losses by avoidance, i.e., by restricting development in landslide-prone terrains, a function aided by mapping of landslide susceptibility. Second is the requirement that excavation, grading, landscaping, and construction on potentially unstable slopes be conducted in ways that do not activate landslides. These two approaches often are controlled by public legislation; such legislation is imposed and enforced by local and state governments. The third means of mitigation consists of physical control measures, such as drainage, modification of slope geometry, and structural methods of slope stabilization or landslide diversion.

* Theme Paper

STORM-INDUCED PORE PRESSURES AND DEBRIS FLOW INITIATION

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and K.A. Johnson
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A debris flow source area in the hills east of the San Francisco Bay was instrumented with continuously recording tensiometers as a part of an investigation of the mechanisms of debris flow initiation. The observations collected during two winter seasons show that the storm-induced pore pressures are highly transient and that the prediction of storms likely to produce debris flows might be feasible if field measurements of antecedent moisture conditions and pore pressures are available.

ENGINEERING FOR SAFETY AGAINST GROUND FAILURES

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Ground failures result in damage to structures and transportation routes during earthquakes and extreme hydrometeorological conditions. Ground improvement techniques and retaining and restraining methods are adopted to prevent ground movements at major engineering project sites. Inappropriate siting of buildings, roads and other structures result in catastrophic damage from ground failures during earthquakes. Ground failure investigations should be directed to consider the overall stability of hill slopes, keeping in view the mechanism of separation and movement of rock units culminating in landslides under the operative static (and dynamic) loads. Liquefaction of loose cohesionless material results in settlement, tilt, ejection of sand and lurching of ground. Collapse debris in river valleys build up water reservoirs and failure of such temporary dams cause floods and heavy siltation. Microzonation of ground failures portraying regions vulnerable to damage during normal conditions and also when subjected to earthquake and other natural hazards is an essential exercise.

D. EARTHQUAKE HAZARD

SEISMIC DAMAGE ANALYSIS AND DAMAGE-LIMITING DESIGN OF MASONRY BUILDING

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A damage index for masonry is defined as a function of the maximum deformation and the absorbed hysteretic energy. A simple method to estimate the damage index of a structure is proposed, in which damage is evaluated as the ratio of the seismic load to the structural resistance. The seismic load is described by the root-mean-square (rms) acceleration, the strong motion duration and the predominant period of the ground motion, whereas the structural resistance is described by the structure's strength and stiffness.

Calibration of the damage index to observed damage of unreinforced masonry buildings indicates that severe (irreparable) damage corresponds to a damage index greater than 0.25. A design method based on the equivalent lateral load procedure is developed in which the base shear coefficient is obtained as an explicit function of the limiting damage level. The design method is illustrated with an example; it is shown that buildings designed according to the proposed method have a probability of failure of less than 0.01 when subjected to the design earthquake.

EARTHQUAKE PROBABILITY IN BANGLADESH

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The history of earthquake occurrence in Bangladesh and the knowledge of its geology suggest that the country should be treated as a high risk zone for earthquake hazard. Nevertheless, the proper consideration of this type of loading in designing structures in Bangladesh is still not perfect. This is due to the lack of adequate earthquake records and insufficient study in this field of engineering. In the present work, the tectonic set up and the seismicity of the country are first discussed. A statistical study of the available earthquake records is then carried out, establishing the magnitude-frequency relationship for earthquake occurrence. The investigation defines peak ground motions for given return periods and is valuable in forming design loading assumptions in Bangladesh. The existing code provisions for earthquake resistant design in Bangladesh have also been reviewed in light of the present study.

ENGINEERING MASONRY BUILDINGS FOR DISASTER MITIGATION

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Masonry buildings, though very popular in most parts of the developing world, pose a serious threat to life and property in seismic areas. Such buildings are usually quite rigid and hence have short periods of vibration attracting large seismic accelerations during earthquakes. Further, because of poor tensile strength and brittle behavior, they crack due to earthquake loading, leading to their collapse. It is, therefore, necessary to ensure that such buildings be strengthened in order that the chance of total collapse is eliminated. The present paper highlights and brings out the dangers associated with masonry buildings and indicates the possibilities of improving their seismic-resistant behavior. It is concluded that this most popular form of construction can be adequately strengthened without any major modifications in the basic features of construction and at a very little extra cost.

ASEISMIC STRUCTURAL OPTIMIZATION WITH SAFETY CRITERIA AND CODE PROVISIONS

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This paper presents the optimization algorithm and optimum parameters of a nondeterministic seismic structure for both normal and lognormal distribution models. The optimization algorithm includes the UBC seismic loading and its coefficients of variation, the first order approximation of reliability analysis, objective function of construction and expected failure costs and various constraints of system displacement as well as member yielding and buckling. The optimum parameters consist of the influence of cost function and the sensitivity to variation of seismic loads on the optimum solutions. The optimum design results indicate that, for a given reliability criterion, the change of nonstructural member cost does not affect the structural sections; the influence of expected failure cost on the structural cross sections and on the total cost is significant at low reliability criteria but very small at high reliability criteria; the optimum solutions are very sensitive to the high variation of the UBC seismic load and high design reliability criteria; and a lognormal distribution demands a higher optimum solution than a normal distribution. Also included in the presentation are the comparisons of optimum solutions of deterministic and nondeterministic cases.

URBAN EARTHQUAKE HAZARDS REDUCTION PROBLEM AREAS AND NEEDS FOR MULTI-DISCIPLINARY RESEARCH

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An over-all framework of research needs, target and related areas for urban earthquake hazard reduction is developed as part of activities at the Urban Earthquake Hazard Research Center (UEHR), Kyoto University, which made its start in April 1986. Emphasis is placed on the needs for multi-disciplinary approach and research cooperation. First, a general view of the problem is presented with emphasis on the importance of integration of the various disciplines of earthquake disaster sciences. Then, a comprehensive list of items to be studied is presented in accordance with propagation of the earthquake effects on urban facilities and activities. Individual research fields that are needed for integration are identified and characterized from their roles. Some organizational efforts for this purpose are introduced.

BEHAVIOR OF BRICK WALL PARTITIONS UNDER OUT-OF-PLANE SEISMIC LOAD

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Ductile reinforced concrete frames filled in with brick wall partitions are very popular in Taiwan. Because the location of this island is at the Circum Pacific Seismic Zone, the possible damage due to the failure of these walls is of great concern. Three prototype specimens were built. Each of them had a ductile reinforced concrete frame filled in with a 1/2 B thick brick wall. The testing conditions of each specimen are different: No. 1 specimen was tested to determine the ultimate capacity of a virgin wall under uniformly distributed forces in the out-of-plane direction. The ultimate capacity is 6160 Pa. No. 2 Specimen was tested to understand the lateral stiffness degeneration corresponding to the increasing shear cracks in the wall. No. 3 Specimen was tested under the most severe conditions; a constant uniform load of order 0.4 times the weight of the wall was applied continuously on the wall in the out-of-plane direction while the reinforced concrete frame was cyclicly loaded and deformed in the in-plane direction. This wall collapsed with a cumulative ductility of 24.35.

NORTH-SOUTH PROBLEMS IN SEISMIC HAZARDS MITIGATION*

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University of Tokyo
M. Cassim and J. Izumi
United Nations Centre for Regional Development

The paper commences by noting differences between the developed countries (north) and developing countries (south). It observes that the interests of engineers and academics in the countries of the north, which determine the direction and dissemination of seismic hazards mitigation research, are distant from the needs of the countries of the south. Seeing that considerable loss of human life is at stake in the latter countries, the paper urges that such north-south differences be reduced. The fundamental problem stems from differences in economic strength and the sociocultural perceptions of disaster. Considering this, the paper contends that seismic hazard mitigation research and related technical assistance to developing countries must take a serious look at indigenous building practices and the knowledge implicit in these societies. It highlights the need to address a broad range of target groups, comprising not only of engineers and academics, but also the general public and policy makers. The paper concludes by recommending three areas for international cooperation, viz. the development of appropriate data bases, appropriate technologies and human resources, and outlines the operational steps for promoting such cooperation.

* Theme Paper

PROTECTIVE SYSTEMS FOR EARTHQUAKE HAZARDS MITIGATION*

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In recent years a number of methods and/or devices have been proposed for controlling the amount of energy that is transferred from ground motion into the superstructure during earthquake excitation. These range from passive systems such as the use of graded sands, the insertions of "soft materials", externally controlled friction devices, hydraulic dampers, etc., to active control systems which use external energy sources and "intelligent" devices. Combined systems also are possible.

Based upon analytical and other work recently carried out, a series of examples are introduced to illustrate the general concepts of seismic isolation and the potential to be realized by its adoption as a desirable design strategy. Further work is indicated, but the potential for significant improvements in design and construction practice in the years immediately ahead are clearly evident.

* Theme Paper

A STUDY OF EARTHQUAKE ACCELERATION RESPONSE SPECTRA AT FAR FIELD

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At distances greater than 200 km from earthquake sources, amplitudes of incoming seismic shear waves are generally small, unless amplified by an overlying soft soil layer. For structures which have fundamental periods close to that of the soil, the seismic risk needs to be reassessed. This was tragically demonstrated in the September 1985 Mexican earthquake. In this paper, a hybrid model that uses an accepted geophysical model incorporated with an amplification model is proposed to predict the response spectrum for such cases. This semi-analytical model is preferred since statistical models are accurate in areas where there is an abundance of seismic data or when the specific influence of local ground condition is not important. For areas like Singapore where there is little or no relevant seismic data, the hybrid model is especially useful as the parameters can be estimated a priori.

IRAS - AN EXPERT SYSTEM FOR EARTHQUAKE INSURANCE AND INVESTMENT RISK ASSESSMENT

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This paper summarizes the development of the Insurance and Investment Risk Analysis Systems (IRAS) that provides consultation for the earthquake insurance and investment banking industries. The features of this system will be briefly described in this paper, including: interactive input/ output facilities, graphic data retrieval, hierarchical knowledge-based management. an integrated system of independent program modules, combinations of backward-chaining and forward-chaining inference mechanisms, and approximate reasoning schemes based on fuzzy set theory to deal with linguistic and/or incomplete information.

A REVIEW OF HORIZONTAL FORCE FACTORS FOR MOMENT-RESISTING R.C. FRAMES

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Both the existing American Uniform Building Code and Taiwanese Building Code specify that the minimum base shear applied to a building be calculated by the formula V=ZIKCSW, where K is called horizontal force factor. K may vary from 0.67 to 1.33 depending on the capability of stress redistribution of the structure. As these two Codes say, any building with a ductile moment-resisting space frame, that is without shear walls or bracings, shall have K equal to 0.67 no matter how many bays or how many stories the building structure has. This is a rough estimation because the capability of stress redistribution of a rigid frame is strongly related to the level of redundancy. Therefore K must be a function of the number of bays and number of stories of the frame rather than just a constant 0.67.

This paper tried to investigate rational K values for ductile moment-resisting R.C. Frames in terms of redundancy by a static nonlinear method. Sixteen examples of R.C. frames, divided into 5 groups, were explored in the analysis. There were one-story frames, three-story frames, five-story frames, seven-story frames and ten-story frames. All frames were designed according to the existing Taiwanese Building Code, somewhat identical to UBC, by using K=0.67. Then the nonlinear load-deflection curve of each frame was investigated by incremental stiffness matrix method until total collapse of the structure. From each load-deflection curve, the upper bound and lower values of K were attempted by using an equivalent-energy process and an equal-ultimate-capacity process.

ON A PRACTICE TO PRODUCE SCENARIO OF FAILURE OF INDUSTRIAL FACILITIES UNDER SEISMIC CONDITION

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This paper deals with a way of forming scenarios of failure of indoor components in critical facilities such as nuclear power plants, petro-chemical industries, oil refineries, etc.

The methods of seismic-resistant design have been much improved. However, most ordinary facilities still have a possibility of failure under seismic conditions. It is significant for their design to estimate a failure scenario. Anti-earthquake design has been established mainly through the experience of failures in past earthquakes. Therefore, it is necessary to know the failure process due to a seismic event required by design specifications.

The author tries to introduce a new practical procedure to generate a scenario: how to fail by using transfer matrices which express the change of state on soil, foundation, building, supporting structure, and equipment and pipings. These matrices may have either crispy elements or fuzzy elements. In this paper, he develops the matrix on an indoor component.

This technique is applicable for seismic probabilistic risk assessment (PRA/PSA) of critical facilities as well as the anti-earthquake design practice of ordinary conventional facilities.

SEISMIC RELIABILITY OF BAKUN DAM IN SARAWAK, MALAYSIA

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The seismic reliability of the proposed Bakun dam, a zoned rockfill dam in Sarawak, Malaysia, is evaluated. The dam has a maximum height of 210 m, a crest length of 900 m , a volume of 26.5×10^6 m^3 and a reservoir capacity of 45.8×10^9 m^3. A reservoir-induced earthquake with a magnitude of $M = 6.4$ is assumed. Only the up-/down stream earthquake component is considered. The dam is modelled as a plane-strain system. Full reservoir condition is assumed. The pre-earthquake stresses are calculated simulating twelve construction layers and the dynamic response analysis is carried out by the equivalent linear method in order to simulate material nonlinearity. The probability of dam failure due to overtopping is investigated considering water level in the reservoir and dam crest settlements due to ground shaking as independent random variables. Monte Carlo simulation is employed to calculate the dynamic slope displacement according to Newmark's sliding block concept. The probability of overtopping is given for different values of the service life of the dam.

SOME ASPECTS OF EARTHQUAKE ENGINEERING IN CHINA

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Seismic zoning, microzonation and seismic risk analysis in China are briefly reviewed. The use of Bayesian techniques and the Maximum Entropy Principle in the evaluation of the probability distribution of the occurrence and magnitude distribution of earthquakes are also included. The design code for aseismic industrial and civil structures and the methods of appraising and strengthening brick and block masonry structures are also presented. The main features of the proposed revision of the current code are emphasized. The determination of the design strong ground motion for important structures are discussed with emphasis on the effect of local configuration and substrata and soil-structure interaction. Various methods for solving these problems are reviewed.

COMPARISON OF SEISMIC FORCES IN KOREA, USA AND JAPAN

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and C.S. Lee
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Seoul, Korea

From the seismicity study of the Korean peninsula, the necessity of aseismic design of general structures in Korea is justified. In order to establish concrete aseismic criteria and procedures, a comparative investigation is made using a proposed seismic zoning map of Korea, the American National Standard, and the Japanese Building Code. Equivalent lateral forces are calculated for two structural models assuming the structures are built in appropriate regions in Korea, Japan and the U.S. From the study, the application of the U.S. design criteria and design response spectrum to aseismic designs in Korea is proved to be reasonable.

E. GENERAL

SOME ASPECTS OF PAKISTAN WIND/EARTHQUAKE HAZARD MITIGATION --- A DISCUSSION

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In this paper the effects of natural hazards on structures in Pakistan is discussed.

The historical background of natural hazards (wind and earthquake) effects on structures and disasters due to them is explained in the first few paragraphs. The second part of the paper discusses in detail engineering aspects of natural hazards with respect to the type and form of structures.

At the end of paper a brief review of the research and development work going on in various institutions like NED University Karachi and other agencies in Pakistan is discussed. Certain recommendations for future research and practical considerations to be made for the safety of structures are outlined.

NATURAL DISASTERS AND THE CULTURAL HERITAGE

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Because it is widely recognized that natural disasters pose a threat to man and property, considerable efforts that have been made by public and private institutions to address these disaster planning and responses. Traditionally, these efforts have focused on life-threatening and life-sustaining matters. This talk will address the importance of conserving the cultural heritage -- museums, libraries, archives, historic sites, monuments, and monumental architecture -- and will stress the responsibility of society to proctect these world treasures.

The cultural sector has long understood the significant threat posed by disasters to artistic and historic works, but has had difficulty in developing adequate resources to address this concern. International organizations such as the International Council of Museums (ICOM), the International Centre for the study of the Preservation and the Restoration of Cultural Property (ICCROM), and the International Council on Monuments and Sites (ICOMOS) encourage the profession to develop disaster plans, and have participated in recovery operations to salvage significant collections after disasters (in the case of the 1966 Florence flood). Disaster planning, however, is only a fragment of the conservation picture and places increased demands on limited resources. In many developing countries, the cultural community is already overburdened to pursue its most basic objectives, leaving the task of disaster planning almost entirely to civil and technical agencies. A lack of experience and cooperation among architects, engineers, urban planners and cultural authorities has led to fragmented and inadequate attention to some of the most outstanding, and sometimes most fragile, accomplishments of mankind.

Disaster planning and response for the cultural heritage must be an interdisciplinary effort. Through its Disaster Planning Steering Committee, the Getty Conservation Institute hopes to provide orientation to individuals and agencies that can assist in the conservation of the cultural property worldwide.

GROUND FAILURE, EARTHQUAKES AND OTHER NATURAL HAZARDS IN NEPAL

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The Himalayas are a tectonically active mountain range with extreme contrasts in relief and climate that face Nepal with serious natural hazards.

Ground failure is due to both natural causes, including exceptional relief and steep slopes in soft friable bedrock with abundant fractures, heavy monsoon rains, bank undercutting by fast rivers, and calcareous solution subsidence, and to man-made causes including accelerating deforestation for fuel for a rapidly increasing population imposing agricultural pressure on steep marginal land, and rapid construction of roads, canals, dams and buildings.

Glacial lake outbursts have caused disaster to property in a number of places in Nepal during the last decade resulting in serious death tolls and destruction of agriculture and costly mountain infrastructure.

Floods cause serious annual hazard in the torrential monsoon rains in the absence of valley protection projects.

Earthquakes occur in the active seismic zone through the middle of the country between the Main Central Thrust and the Main Boundary Thrust, with epicenter concentration in western Nepal where a 1980 earthquake of 6.5 magnitude caused severe damage.

There is a pressing need for comprehensive programs in connection with improved understanding of the ecology, control of deforestation, reforestation, and regional geological studies of threatened areas. In the absence of indigenous technical and financial means for the mandatory steps that cry for immediate attention, international cooperation is urgently needed.

DISASTER PREVENTION RESEARCH IN TAIWAN

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and Y.T. Yeh
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In addition to being in the seismic zone of the western Pacific and on the course of typhoons originating in the Pacific, Taiwan has its special geomorphology and geology, with steep mountains, short streams and weak geological formations. As a consequence, disasters resulting from typhoons, floods and landslides take place several times each year. Occasionally, earthquakes also occur. The work of disaster mitigation and prevention has long been one of the major endeavors of governmental agencies and private organizations.

No major efforts, however, on disaster mitigation/prevention were made until 1982 when the National Science Council initiated an interdisciplinary Disaster Mitigation Research Program which includes five major areas: meteorology, flood mitigation, seismology, earthquake engineering and landslide prevention. The first 5-year plan of the program will be completed by mid-1987, and the second 5-year plan is now in the planning stage.

This paper will present the process of planning for the Program including the objectives and its goals in the first 5-year plan. The execution of research projects, evaluation of results and technology transfer are also to be discussed. It is hoped that the information presented will be of help to other countries where efforts of disaster mitigation/prevention research need to be coordinated and/or organized.

PROGRAM

U.S.-Asia Conference on Engineering for Mitigating Natural Hazards Damage

Monday, 14 December 1987

8:00 - 9:30	Registration
9:30 - 10:00	**Opening Session** Chairman - Pisidhi Karasudhi Welcoming Remarks - Alastair M. North, President, Asian Institute of Technology Albert J. Simone, President, University of Hawaii Opening Address - His Excellency Mr. Banyat Bantadtan Minister of Science Technology and Energy Royal Thai Government
10:00 - 10:30	Coffee
	Plenary Session I Chairman - Z.C. Moh
10:30 - 11.20	Ten Years of Natural Hazards Research in the USA - J. E. Sabadell
11:20 - 11:40	Natural Disasters and the Cultural Heritage - L. Monreal
11:40 - 12:00	Disaster Prevention Research in Taiwan - C.Y. Tsay, R.C. Hung, and Y.T. Yeh
12:00 - 13:00	Lunch
	Plenary Session II **Theme A : Wind Hazard** Chairman - D.K. Rakshit
13:00 - 13:45	Extreme Wind Hazards in Asia - B Venkateswarlu
13:45 - 14:30	Mitigation of Wind Related Damage due to Severe Wind Storms and Hurricanes - R. N. Meroney
14:30 - 15:00	Coffee
	Plenary Session III **Theme B : Flood Hazard** Chairman - S. Selvalingam
15:00 - 15:45	Forecasting Hazardous Floods - S.J. Burges
15:45 - 16:30	Flood Hazards and Its Prevention on the Lower Reaches of the Yellow River - S.Y. Gong and Z.Y. Wu
18:00 - 20:00	**Reception**

Tuesday, 15 December 1987

	Plenary Session IV
	Theme C : Ground Failure Hazard
	Chairman - A.S. Balasubramaniam
8:30 - 9:15	Landslide Hazard Reduction in the United States - R.L. Schuster
9:15 - 10:00	Ground Failures in Southeast Asian Countries - Z.C. Moh
10:00 - 10:30	Coffee
	Plenary Session V
	Theme D : Earthquake Hazard
	Chairman - S.L. Lee
10:30 - 11:15	North-South Problems in Seismic Hazards Mitigation - T. Katayama, A.M.M. Cassim and J. Izumi
11:15 - 12:00	Protective Systems for Earthquake Hazards Mitigation - R.L. Ketter
12:00 - 13:00	Lunch
	Simultaneous Sessions I
	Wind Hazard
	Co-Chairmen - M. Ito and H.N. Cho
13:00 - 13:15	Stong Wind in Northern China: General Description, Hazard and Mitigation - T.F. Sun, J. Xuan, Z.F. Gu and K.Q. Liu
13:15 - 13:30	An Outline of Study on Wind Hazard Prevention of Structures in China - H.F. Xiang and H.L. Xue
13:30 - 13:45	Some Aspects of Community Preparedness Plan against Cyclone - D.K. Rakshit
13:45 - 14:00	A Survey of Meteorological Disasters over Taiwan Area - S.L. Shieh and C.K. Chen
14:00 - 14:15	Recent Activities of Design Considerations for Wind Effects on Long-Span Bridges - T. Miyata and H. Yamada
14:15 - 14:30	Engineering Design for Extreme Wind Occurrence in Hong Kong - B.E. Lee
	Ground Failure Hazard
	Co-Chairmen - R.L. Schuster and Z.X. Xu
13:00 - 13:15	Storm-Induced Pore Pressures and Debris Flow Initiation - N. Sitar
13:15 - 13:30	Slope Failures in Hong Kong and Their Mitigation - A.D. Burnett
13:30 - 13:45	Landslides in Indonesia, Its Occurrences and the Effort Made to Overcome the Problems - J.D. Elifas
13:45 - 14:00	A Study on the Erosion Characteristics of Nanhua Mudstone - S.T. Chen
14:00 - 14:15	A Theoretical Prediction of Land Subsidence due to Water Loss from Aquifers - P. Karasudhi and S. Prechaverakul
14:30 - 15:00	Coffee

	Simultaneous Sessions II
	Flood Hazard
	Co-Chairmen - S.J. Burges and C.L. Yen
15:00 - 15:15	On Prediction of Flood Hazards - J.D. Salas
15:15 - 15:30	Flood Forecasting System in Tanshui River Basin - C.L. Yen
15:30 - 15:45	Measures and Problems of Flood Mitigation - K.C. Sieh and K.F. Law
15:45 - 16:00	Urban Flood Mitigation Works in Singapore Bukit Timah Catchment - S. Selvalingam, S.Y. Liong and K.G. Yap
16:00 - 16:15	Flood and Disaster Management in Indonesia - S. Sukardi
16:15 - 16:30	Prediction of Water and Sediment Outflow Hydrograph Caused by Dam and River-Levee Failures - Y. Muramoto and Y. Fujita
	Earthquake Hazard
	Co-Chairmen - R.L. Ketter and E.K. Kertapati
15:00 - 15:15	Some Aspects of Earthquake Engineering in China - Z.X. Xu
15:15 - 15:30	Seismic Damage Analysis and Damage-Limiting Design of Masonry Buildings - A.H-S. Ang and Y.H. Kwok
15:30 - 15:45	Engineering Masonry Buildings for Disaster Mitigation - A.S. Arya and B. Chandra
15:45 - 16:00	A Study of Earthquake Acceleration Response Spectra at Far Field - S.L. Lee, T. Balendra and T.S. Tan
16:00 - 16:15	IRAS-An Expert System for Earthquake Insurance and Investment Risk Analysis - H. Shah, F.S. Wang, W. Dong, M. Lamarre and G.H. Miyasato
16:15 - 16:30	Seismic Reliability of Bakun Dam in Sarawak, Malaysia - M. Wieland and K.S.L. Goh
19:00 - 21:00	**Thai Cultural Program and Dinner**

Wednesday, 16 December 1987

	Simultaneous Sessions III
	Wind Hazard
	Co-Chairmen - B.E. Lee and H. Ishizaki
8:30 - 8:45	Typhoon Risks and Typhoon-Resistant Design of Nuclear Power Plants in Korea - H.N. Cho
8:45 - 9:00	Stochastic Simulation of Extreme Winds in a Tropical Cyclone-Prone Region - E.D.H. Cheng and A.N.L. Chiu
9:00 - 9:15	Confidence Intervals and Design Wind Speeds K. Seetharamulu, B.L.P. Swami and K.K. Chaudhry
9:15 - 9:30	Peak Gust and Peak Mean Hourly Winds in India - Problems in a Mixed Population - G.N.V. Rao
9:30 - 9:45	Estimation of Annual Maximum Wind Speed Distribution by a Probabilistic Procedure for Typhoon-Prone Regions - M. Makino
9:45 - 10:00	The Characteristics of Wind Force of Typhoons and Their Prediction Methods in the Taiwan Area - S.T. Wang and T.Y. Wu
10:00 - 10:15	Extreme Value Analysis of Wind Gusts in Singapore - H.. Cheong, Y.T. Chew and P. Lo

	Ground Failure and Earthquake Hazards
	Co-Chairmen - A.D. Burnett and S.T. Chen
8:30 - 8:45	Engineering for Safety against Ground Failures - L.S. Srivastava
8:45 - 9:00	Retaining Wall Failure due to Heavy Rainfall - S.K. Kim
9:00 - 9:15	Behaviors of Brick Wall Partition under Out-of-Plane Seismic Load - C.C. Kao and I.C. Tsai
9:15 - 9:30	Earthquake Probability in Bangladesh - A.M.M.T. Anwar
9:30 - 9:45	On a Practice to Produce Scenarios of Failure of Industrial Facilities under Seismic Conditions - H. Shibata
9:45 - 10:00	Ground Failure, Earthquakes, and Other Natural Hazards in Nepal - V. Singh
10:00 - 10:30	Coffee
	Simultaneous Sessions IV
	Flood Hazard
	Co-Chairmen - J.D. Salas and Y. Muramoto
10:30 - 10:45	A New Approach on Integrated Flood Control of Bangkok - T. Tingsanchali
10:45 - 11:00	Flood Problems of Bangladesh - J.U. Chowdhury
11:00 - 11:15	New Structural and Non-Structural Measures Against Inundation - Damage in the Tokyo Metropolitan Areas - Y. Takahasi
11:15 - 11:30	Comparative Study of Flood-Runoff Analysis in View of Disaster Research - Y. Iwasa and K. Inoue
11:30 - 11:45	The Impact on Flood from the Slopeland Development - C.H. Tuan
	Earthquake Hazard
	Co-Chairmen - T. Katayama and A.S. Arya
10:30 - 10:45	Aseismic Structural Optimization with Safety Criteria and Code Provisions - F.Y. Cheng
10:45 - 11:00	Urban Earthquake Hazards Reduction, Problem Areas and Needs for Multi-Disciplinary Research - H. Kameda, S. Iwai, A. Kitahara and N. Nojima
11:00 - 11:15	Comparison of Seismic Forces in Korea, USA and Japan - C.S. Yu and C.S. Lee
11:15 - 11:30	A Review of Horizontal Force Factor for Moment-Resisting R.C. Frames - M.S. Sheu and P.C. Wang
11:30 - 11:45	Some Aspects of Pakistan Wind/Earthquake Hazard Mitigation -- A Discussion - S.M. Makhdumi
12:00 - 13:00	Lunch
13:00 - 18:00	**Field Trip**: Land Subsidence Observation and Flood Mitigation for Bangkok

Thursday, 17 December 1987

8:30 - 10:00	**Workshops: Group Discussions** **Theme A : Wind Hazard** Co-Chairmen - R.N. Meroney and B. Venkateswarlu Rapporteurs - B.E. Lee and E.D.H. Cheng **Theme B : Flood Hazard** Co-Chairmen - S.J. Burges and S.Y. Gong Rapporteurs - J.D. Salas and J.U. Chowdhury **Theme C : Ground Failure Hazard** Co-Chairmen - R.L. Schuster and Z.C. Moh Rapporteurs - L.S. Srivastava and N. Sitar **Theme D : Earthquake Hazard** Co-Chairmen - R.L. Ketter and T. Katayama Rapporteurs - H. Kameda and H.C. Shah
10:00 - 10:30	Coffee
10:30 - 12:00	**Workshops: Group Discussions (continue)**
12:00 - 13:00	Lunch
13:00 - 14:30	**Workshops: Group Discussions (continue)**
14:30 - 15:00	Coffee
15:00 - 16:30	**Workshops: Draft Preliminary Reports**

Friday, 18 December 1987

8:30 - 10:00	**Plenary Session V** Chairman - P. Karasudhi Preliminary Reports from Workshop Discussion Groups
10:00 - 10:30	Coffee
10:30 - 12:00	**Workshops: Finalization of Reports** **Theme A : Extreme-Wind Hazard** **Theme B : Flood Hazard** **Theme C : Ground-Failure Hazard** **Theme D : Earthquake Hazard**
12:00 - 14:00	Lunch
14:00 - 15:00	**Plenary Session VI** Presentation of Final Reports Chairman - A.N.L. Chiu
15:00 - 15:30	Closure

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