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U.S./JAPAN JOINT SEMINAR: URBAN DESIGN & SEISMIC SAFETY

A PROJECT FUNDED UNDER A GRANT FROM THE NATIONAL SCIENCE FOUNDATION

DEPARTMENT OF ARCHITECTURE
UNIVERSITY OF HAWAII at MANOA

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INTRODUCTION

INTRODUCTION

The form and patterns of today's cities are not arbitrary. In some cases their layout may be unintentional, but not accidental. Existing metropolitan areas are the product of decisions made for single, separate purposes, whose relationships and effects have not nor ever have been fully undersood or even considered on a large scale. Certainly, in terms of seismic safety, the overall, general form and design of today's contemporary cities have never been examined from a hazards mitigation emphasis.

There are several historic examples of a city's form being influenced by the principles of hazards mitigation which resulted in the design of urban areas as a shelter from outside threats to life safety. Michaelangelo's and Leonardo da Vinci's designs of some Italian cities reflected this during the Renaissance. The walled cities of western and eastern cultures during the Medieval Period also represent another example of an urban design response to hazards and public safety. In our contemporary period of city planning and urban design, little attention has been paid to the relationships of city form to hazards mitigation or threat. In dealing with seismic safety and urban design, the premise is that a direct relationship exists between the two which needs investigation and assessment. Study of earthquake hazards mitigation which can be achieved at the urban design scale constitutes a significant expansion of the range of approaches to limiting earthquake losses.

Despite many technological advances in earthquake engineering and earthquake prediction at an international level, major metropolitan centers still remain extremely vulnerable to major seismic events. Because of rapid urbanization and continuted development in existing, well-established urban concentrations, recurrence of a major earthquake impacting a city center would result in much greater damage and life loss than ever before. Clearly the risk to populations exposed to earthquake is most critical for those living in highly congested urban centers in contrast to those residing in the less crowded suburbs.

To address these issues, a grant was received from the Division of International Programs (INT) and the Division of Applied Science and Research Applications, Problem Focused Research Applications, (ASRA/PFRA), of the National Science Foundation (NSF) as a vehicle to conduct an initial basic research effort on the subject of urban design and seismic safety. As part of the grant, an international level, joint US/Japan Seminar was convened in Tokyo in May 1979 under the US/Japan Cooperative Scientific Exchange Program sponsored by the National Science Foundation (NSF) and the Japan Society of the Promotion of Science. (JSPS). Co-organizers of the Seminar were the Department of Architecture of the University of Hawaii at Manoa and the Department of Urban Engineering of the University of Tokyo through the laboratory of Urban Safety Planning.

The initial and primary focus of the Seminar at an international level was as follows:

1) Development of an initial comprehensive document in a new research area related to urban design and seismic safety.

2) Identification of urban design/seismic research needs of joint cooperative benefit.

3) Development of future specific cooperative projects in urban design and seismic safety.

Because relatively little work has been done to date on the research subject identified by the Seminar, three fundamental objectives were pursued as follows:

1) Identification of seismic safety topics of major urban design concern to both countries and cooperative development and verification for appropriate study.

2) Exchange and assessment of topics of mutual benefit and presentation of professional papers on issues of fundamental concern to both countries.

3) Assurance that research findings and recommendations resulting from the Seminar be published for dissemination to the participating delegates and other interested design professionals in both nations after the Seminar.

Both the United States and Japan are highly developed countries with major urban concentrations located in severe seismic areas.

Large scale urbanization has been intensified within both countries during the past three decades. Assessment of the physical growth of cities during the US/Japan Joint Seminar indicated that many fundamental urban design principles in hazards mitigation may not have been considered. Critical consequences of many design decisions were not foreseen due to the fact that the urban environment is a complex fabric composed of many interdependent activities, services, and functions.

The vulnerability of many metropolitan areas in both countries is further complicated by the fact that most are unprepared to absorb a major seismic event. Professor Karl Steinbrugge, former Chairman of the Seismic Safety Commission of the State of California, and others, have indicated that some major cities are "catastrophes waiting to occur" in the event of a severe earthquake due to a high concentration of population in high density areas. Tables 1 and 2 indicate the population at risk of selected major urban centers in Japan and the United States. As can be seen in these two tables, both countries have several metropolitan areas of high risk related to high density population concentration.

In the United States and Japan, the evolution of urban design as an emerging field within Architecture is a recent phenomenon and has been identified with the rapid urbanization which has occurred throughout the world. Little research to date has been done on an integrated urban design approach to seismic safety concerns at an international level. It is apparent that a holistic, urban design analysis should be used to address the relationships found in major metropolitan areas when considering earthquake hazards reduction programs.

Through urban design, as with the comprehensive design of a building for seismic resistance, the appropriate physical design of an urban center can assist in the achievement of significant goals in public safety by mitigating earthquake hazards. Most city planning provisions and building ordinances throughout the world usually do not take into account the possibility of surface faulting due to earthquake. In recent times, responsible design professionals and practitioners in the U.S. have been known to sometimes persuade clients to consider alternative urban sites only to have the faulty site developed by others who may have been uninformed of the hazard. Currently, in the U.S., only the State of California has a fault-zone hazards ordinance in effect which mandates cities to take fault-line hazards into account before site development begins.

In the United States and Japan many professional urban designers remain unaware of the specific seismic hazards being confronted by metropolitan areas throughout the country. Professional urban designers do not have the training or experience to understand and apply earthquake hazards information, nor have they been

TABLE 1

POPULATION OF SELECTED MAJOR URBAN CENTERS IN THE UNITED STATES

Urban Area:	Seismic Zone 1976 - UBC	Population at Risk
Los Angeles, California	4	8,960,000
San Francisco, California	4	4,450,000
Boston, Massachusetts	3	3,795,000
Seattle-Tacoma, Washington	3	1,788,000
San Diego, California	3	1,355,000
Atlanta, Georgia	2	1,780,000
Cincinnati, Ohio	2	1,162,000
St. Louis, Missouri	2	1,747,000

SOURCE: (a) 1977 Commercial Atlas & Marketing Guide
Rand McNally & Company

(b) UBC, 1976 Edition

TABLE 2

POPULATION OF SELECTED MAJOR URBAN CENTERS IN JAPAN

Urban Area:	Seismic Zone Factor* AIJ Standards	Population at Risk
Kawasaki	1.0	1,025,000
Kobe	1.0	1,365,000
Kyoto	1.0	1,461,000
Nagoya	1.0	2,080,000
Osaka	1.0	2,750,000
Sapporo	0.9	1,277,000
Tokyo	1.0	8,600,000
Yokohama	1.0	2,659,000

*NOTE: Seismic Zone Factor is a reduction factor of the seismic coefficient to be multiplied to base shear.

SOURCE: (a) 1977 Commercial Atlas & Marketing Guide
Rand McNally & Company

(b) Design Essentials in Earthquake Resistant Buildings
Architectural Institute of Japan (AIJ)

specifically recruited to address the problem. Although many professional urban designers and city planners have had some experience with natural hazards, such experience is generally related to flooding, extreme winds, or soil problems. At the moment, no guidelines, criteria, or design models exist for the application of earthquake hazards reduction plans to the design of cities. If urban design is to play a significant role in reducing the vulnerability of cities to earthquake hazards in mitigating damage and life loss it is essential that information continue to be exchanged at an international level. Basic principles must be identified and documented to enable urban design professions to address the issue mandated by public safety goals.

The US/Japan Joint Seminar which took place in Tokyo represents an effort to initiate research and dialogue on urban design and seismic safety issues of common concern between two highly urbanized and industrialized nations. It is essential that this exchange of information continue between the design professions of each country.

A fundamental goal of the Seminar was to achieve an understanding of earthquake hazards mitigation by approaching the problem from an international perspective. Attempts were made to correlate seismic safety concerns to urban design concerns so that the two could be combined in a common attack on a new way of addressing earthquake hazards mitigation measures.

In addition to uncovering a new research dimension to a problem, the Seminar on the subject of urban design and seismic safety was of mutual benefit to both countries in exchanging and developing new information on the subject. The subject is most timely because of the large scale urbanization that has taken place, and continues to take place, in the two highly developed nations. As a new subject, it is clear that it is appropriate for further study by members of the research community and design professions of both countries who are responsible for the planning and design of cities and the redevelopment of existing city cores.

As part of the Post-seminar activities, this report of the Seminar's proceedings, invited papers, and recommendations represents a distillation of the concerns resulting from the four day meeting which included discussion and exchange of information. In addition, the report identifies and indicates:

1) Future Urban Design/Seismic Safety research needs joint benefit.

2) Recommendations for specific cooperative projects in Urban Design and Seismic Safety.

Since the Seminar represents the first time that preliminary research on a cooperative, international basis was held on the subject of urban design and seismic safety, this publication represents the first document in a newly identified research area of significance to highly industrialized countries located in earthquake zones. A further objective of this publication is an educational one to be used as a tool to demonstrate and test the validity of the results of the Seminar which illustrate the following issues of mutual concern:

1) The applicability of urban design to seismic safety and the necessity to define its role to a wider, general public audience and to the design professions.

2) The interrelationships and correlations between urban design and public policy in addressing public safety.

3) The intricate nature of urban design as a part of comprehensive planning programs and general plans in hazards mitigation.

4) The diversity of urban design approaches and alternatives relative to community needs in cities and regions which have their own distinctive characteristics.

5) The review and examination of "the state of the art" in urban design and its relationships to seismic safety as an evolving professional field.

BACKGROUND PAPERS

HAZARDS REDUCTION

URBAN DESIGN AND NATIONAL NEEDS IN EARTHQUAKE HAZARDS REDUCTION

KARL V. STEINBRUGGE

INTRODUCTION

The Federal government of the United States has adopted a multidisciplinary program on earthquake hazards reduction which involves national, state, and local governments in a shared responsibility as well as relating to academia, professional/scientific organizations, and others. While much emphasis is given to myriads of specific facets, the best overview (and indeed its direction) is seen as being principally an urban problem. Obviously, urban design is an important component in any overall program such as this one. The complexity of the problems allow for no simple solutions.

The principal thrust towards solutions of hazard mitigation problems in the United States has come from the engineering/scientific sectors of government and academia and not from persons having interests in urban design. However, it seems that the urban public would be better served if seismic hazards were more strongly recognized by the urban planner, developer and designer.

Current governmental interest in seismic safety was substantially strengthened with the enactment of the "Earthquake Hazards Reduction Act of 1977" (so-called Cranston Bill). This public law represents the culmination of actions in both the Executive and Legislative Branches of the Federal government that go back a number of years. Specifically, the legislation states, "It is the purpose of the congress in the Act to reduce the risks of life and property from future earthquakes in the United States through the establishment and maintenance of an effective earthquake hazards reduction program." At the first step, the legislation further states: "The President shall develop...an implementation plan which shall set year-by-year targets through at least 1980, and shall specify the roles for Federal agencies, and recommend appropriate roles for State and local units of government, individuals and private organizations, in carrying out the implementation plan."

Two major governmental reports stating national policy were released in 1978 and, with their bibliographies and references, comprise a reasonably complete history and background of the subject.

This paper will identify and review several important aspects of the United States' national plan for earthquake hazard reduction from an urban standpoint.

"ISSUES" FOR AN EARTHQUAKE HAZARD REDUCTION PROGRAM

The first of these two governmental reports, "Earthquake Hazards Reduction: Issues for an Implementation Plan" (henceforth "Issues Report") was written and reviewed by individuals and organizations drawn from a broad spectrum of disciplines ranging from the physical and engineering sciences through the social sciences and city planning. The report identified and described 37 major issues (or problem areas). See appendix "A". Each issue contained a statement of the problem, followed by background information, alternative solutions, and in some cases recommendations and conclusions. Wherein reasonable, each problem focused on and identified agencies and/or professional disciplines which could have a lead role in addressing specific issues.

Life safety must be the primary objective of any earthquake hazards reduction program. It is the buildings and other structures which man constructs that are the major sources of life hazard. The "Issues Report" summarizes on this subject as follows:

1) "....If lives are saved, then the cost of reconstruction after an earthquake, great as it is, can be borne more easily. The secondary objective is to reduce economic losses. The total value of construction at the risk in the United States will be an estimated $2.3 trillion by 1980. In addition, the contents and processes at risk may far exceed the value of the building in which they are housed and conducted.

2) New, more restrictive design standards will generally result in a nominal increase in the cost of construction. However, in many instances, a better architectural design concept of the building lay-out or configuration may be achieved at no additional cost and sometimes may actually save money.

3) For years to come the major threat to life will come from existing buildings, structures, and facilities. A very high percentage of all structures, even those constructed only a few years ago under then-current seismic building codes, are technically deficient in the light of subsequent knowledge. The cost of correcting all such structures is almost incalculable. Widespread public support for channeling a high proportion of our national resources into such a narrow area is difficult to expect. Yet, it is essential to achieve a wider use of earthquake-resistant design and construction practices and to pursue a gradual balanced program of improving the resistance of existing structures.

4) The Federal government's involvement in construction includes direct construction of facilities for Federal use and the regulatory impact of insuring mortgages or granting funds for construction or plans for construction. Thirty-five agencies are directly or indirectly concerned with construction. There are approximately 450,000 Federal buildings--approximately 400,000 are owned by the government and 50,000 are leased..."

If one holds that urban design is principally oriented towards a broad regional planning and physical design viewpoint with lessor emphasis on specific details at each specific site, then one valid approach to earthquake hazard reduction can come via land-use planning, large scale three-dimensional design, and its implementation. From this standpoint, the "Issues Report" gives the following commentary and direction:

1) "Land-use decisions, based on sound information as to earthquake hazards and implemented over an extended period of time, can be among the most effective measures for saving lives and minimizing disruptions in the event of an earthquake. In the United States, land-use plans are largely prepared by local governments and implemented through zoning and other similar controls. Increasingly, however, the States have recognized that many land-use problems transcend local boundaries and are re-examining the State and local roles. Nevertheless, the Federal government, directly and indirectly, exerts a strong influence over land-use decisions at all governmental levels and in the private sector.

2) Federal programs in land-use planning involve: (1) identifying the appropriate use, development, and management of Federal lands; (2) encouraging and assisting State, regional, and local governmental and special-use jurisdictions in planning for the use, development, and management of their lands; and (3) planning for such developments as housing, transportation, recreation, and water and sewer systems which have significant impacts on land use or related resources and are accomplished with Federal assistance.

3) The political realities in earthquake-hazard reduction at the local level generally dictate that all hazards, including landslides, floods, hurricanes, fires, and others be addressed through various mechanisms available at the local level. Despite their availability to local government, land-use regulations have seldom been used to encourage the adoption and enforcement of measures to reduce earthquake hazards."

But urban design, to be effective in any implementation plan, requires communication and education with the affected population. The Working Group summarized their views as follows:

1) "Before a population can respond effectively to the threat of an earthquake, it needs certain kinds of information. The population must know the nature of the threat and what can be done to minimize it. Information, then, is a key to reducing the impact of earthquakes and other hazards on society.

2) Multiple ways of imparting information should be encouraged. A single exposure to new information, especially if it is complex or differs considerably from a user's previous knowledge, is often insufficient. Repeated exposures in different formats and through several channels may be required. This technique is particularly successful when new information is provided by persons who are customarily looked to for guidance, such as members of the same professional groups.

3) A population does not constitute a homogeneous group; people differ widely in their requirements for information and their capacity to absorb information.

Engineers, architects, and planners have requirements that differ from those of State and local government officials and private citizens. Thus, detailed technical reports that are suitable for practicing engineers would be unsuitable for most state and local officials and certainly for the vast majority of private citizens.

4) Dissemination of information and educational programs concerning natural hazards should be designed for persons responsible for making decisions and setting policies that will influence the well-being of large numbers of individuals and groups. The persons needing the information include Federal, State and local officials and legislators; such professionals as architects, engineers, and planners, and public interest groups. Also, the programs should be focused on areas of the country that are earthquake prone."

SOLVING THE "ISSUES": AN IMPLEMENTATION PLAN

It is one thing to identify and describe the "Issues", or problems, concerning an earthquake hazards reduction plan; it is quite another effort to implement the program solving the "Issues". Implementation policy is described in "The National Earthquake Hazards Reduction Program" (henceforth "Implementation Plan"). Guidelines for implementation of the entire earthquake hazards reduction plan include the following directives (among others):

1) The priorities of hazards reduction are to be based on relative risk; that is, the probability of significant loss of life and property, considering the population exposed, the nature and magnitude of the hazards posed by manmade structures to the population, and the likelihood and character of significant earthquakes. Regional differences in the nature and magnitude of the risk and of the perception of the risk require a flexible approach.

2) While the Federal government can take a strong, exemplary position with regard to its own facilities and develop guidelines and standards for Federally-assisted or licensed critical facilities, the effort to improve local land use and building codes--as a basis for all private construction, including federally assisted, non-critical construction--must be

accomplished by persuasion and encouragement, particularly through working with professional organizations and State and local officials.

3) Earthquake hazards reduction must not only take into account the direct natural hazards from faulting and vibration, but also the indirect natural hazards from tsunamis, seiches, landslides, floods, soil consolidation, soil failure, and slumping. Damage to works of man by these natural hazards leads to both primary hazards such as structural failure, and secondary hazards such as fires, flood, and the escape of contained toxic or hazardous fuels and materials.

4) Prediction cannot, in the near future, be relied upon as an effective tool to reduce earthquake casualties (for example, to avoid the problem posed by existing hazardous buildings). However, since scientific breakthroughs could come at any time, we must prepare to cope with different levels of predictive capability.

--"Implementation Plan", see Appendix.

CURRENT STATUS AND THE FUTURE

Clearly, the half-dozen major reports over the past 15 years have led to major increases in hazard reduction programs, and the current studies will also do so. Over this period of time, the viewpoint of these reports has broadened from a comparatively narrow engineering/science stance to become broadly interdisciplinary. The urban designer is now a recognized part of the process, but the designer must become truly knowledgeable before his results become effective.

It is too early to evaluate the ultimate effect of the policies and programs being implemented. But past experience based on similar efforts shows that reevaluation should, perhaps, be made at five to ten year intervals. After each reevaluation, new thrusts and renewed efforts should be given to earthquake hazard reduction.

At this writing, a new disaster-oriented Federal agency is about to be formed (Federal Emergency Management Agency--FEMA). Its role, among others, is to implement earthquake disaster mitigation programs which should also reduce the wasteful financial processes of post-earthquake recovery.

One may conclude that substantial progress in earthquake hazard reduction will occur over the next decade.

Publications Cited

Steinbrugge, K. V., Chairman. "Earthquake Hazards Reduction: Issues for an Implementation Plan," Working Group on Earthquake Hazards Reduction, Office of Science and Technology Policy, Executive Office of the President, Washington, D.C. 1978.

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Appendix A

Issues for an Earthquake Hazards Reduction Implementation Plan

Issue 1. Lack of Contingency Response Planning

Issue 2. Lack of Planning to Lessen Socioeconomic Impacts of an Earthquake Prediction

Issue 3. Lack of Hazards Reduction Policy for Immediate Use After an Earthquake

Issue 4. Lack of Hazards Reduction Planning for Reconstruction After an Earthquake

Issue 5. Possible Inequities After an Earthquake Prediction and/ or Earthquake

Issue 6. Evaluation of Predictions

Issue 7. Administrative Response to Prediction

Issue 8. Guidelines for Issuing Predictions

Issue 9. Upgrading the Tsunami Warning System and Improving Mitigation Practices

Issue 10. Existing Hazardous Buildings

Issue 11. Vital Community Facilities

Issue 12. Siting of Dams and Other Hydraulic Structures

Issue 13. Fire Following Earthquake

Issue 14. Lifelines

Issue 15. Development of Earthquake-Resistant Design Criteria

Issue 16. Risk-Based Analysis for Buildings

Issue 17. Risk Map Development

Issue 18. Decision Delays for Critical Facilities

Issue 19. Seismic Design and Architectural Education

Issue 20. Critical Facilities - Their Siting and Post-earthquake Operation

Issue 21. Impact of Financial Incentives

Issue 22. Federally Financed Rehabilitation

Issue 23. Lack of Earthquake Hazards Reduction Criteria in Federal Grant Programs

Issue 24. Earthquake Insurance

Issue 25. Lack of Adequate Information for Land Use

Issue 26. Lack of Understanding of Earthquake Hazards and Failure to Apply in Land-Use Planning

Issue 27. Lack of Program Coordination in Land-Use Planning

Issue 28. Lack of Training or Experience by Planners in Use of Hazards Information.

Issue 29. Federal Development of Technical and Public Information

Issue 30. Improving Public Information

Issue 31. Formal Educational Systems and Information Programs

Issue 32. State and Local Government Input to Federal Government Policies

Issue 33. Evaluation Program On Dissemination of Technical Information

Issue 34. Are Model Programs and Pilot Projects to Increase Seismic Safety Warranted?

Issue 35. Training Emergency Medical Personnel

Issue 36. Emergency Health Support

Issue 37. International Coorperation

SEISMIC GEOLOGY & LEGISLATION MITIGATING EARTHQUAKE HAZARDS

LLOYD S. CLUFF

ABSTRACT

Mitigating the effects of earthquakes through urban design requires a combination of scientific and engineering knowledge, as well as social, economic, and political action at the local, state, and federal levels. The extent to which mitigation actions are effective depends on the extent to which they are based on accurate information about the physical processes of the four basic earthquake hazards: surface fault rupture, strong shaking, ground failure, and tsunami. Provided we have accurate information about the hazards, it is possible to consider land-use restriction. Effective land-use constraints could provide a basis for avoiding a hazardous site or locating and character izing the hazards at and near the site so that the proposed facilities could be designed and built to accomodate the hazards.

There is clearly a responsibility and an opportunity to influence earthquake safety by mitigating earthquake hazards through effective and intelligent urban design and appropriate legislation. This applies to new development or redevelopment of existing urban centers. There is an urgent need for accurate geologic and seismologic data so that urban designers and legislators can make realistic decisions and value judgments regarding the many trade-offs that exist when considering what risks are acceptable. Our most serious problem is ignorance. Through better communication between the many disciplines (geology, seismology, engineering, planning and architecture), our cities will be safer during future earthquakes.

Introduction

Mitigating the effects of earthquakes through urban design requires a combination of scientific and engineering knowledge, as well as social, economic and political action at the local, state, and federal levels. The extent to which mitigation actions are effective and the cost of the actions depend on the extent to which they are based on factual and accurate information about the physical processes of the four basic earthquake hazards: 1) surface fault rupture, 2) strong shaking, 3) ground failure, and 4) tsunami. Each of these hazards is affected by the local and regional geologic conditions, the type of soil and geologic properties at a given site, and the location of the site with respect to active faults and resulting earthquakes. Provided we have factual and accurate information about the hazards, it is possible to consider land-use restriction. Effective local, state, and federal land-use constraints could provide a basis for avoiding a hazardous site, or locating and characterizing the hazards at and near the site so that the proposed facilities could be appropriately designed and built to accommodate the hazards.

It is important that decision makers at local, state, and federal levels, as well as at family and corporate levels, have an understanding of the problem so that reasonable value judgments can be made about the level of risk that may be acceptable. The acceptance and effectiveness of earthquake hazard mitigation measures, which usually require a substantial economic commitment, will critically depend on society's perception of the necessity and utility of the measures, as well as on the reliability of the scientific and engineering information upon which they are based.

Within the United States, we are beginning to take advantage of our ability to recognize and delineate earthquake hazards. Over the past few years in the State of California, and now beginning in the State of Utah, information regarding earthquake hazards is being considered in the continuing development and expansion of our urban areas; land-use planning and regulation are being used as mitigating measures. In 1971, the California Legislature adopted an amendment to the State Planning Law that requires "a seismic safety element" as a mandatory part of the general plan of each city and county. Passage and implementation of the Alquist-Priolo Special Studies Zones Act in California in 1972 provide for public safety with regard to surface faulting. This act states that "no structure for human occupancy, public or private, shall be permitted to be placed across the trace of an active fault." The State of California also has a Safety of Construction of Hospitals Act, adopted in July of 1974. This regulation requires that construction of any new hospital or alteration to any existing hospital be preceded by a geologic and earthquake engineering evaluation. Development and implementation of similar acts and regulations are beginning to be considered by other states. Utah is likely to be the next state to officially adopt similar regulations.

The other earthquake hazards (strong shaking, ground failure, and tsunami) are being considered; however, the data base for these hazards is not developed to the extent that they can be adequately delineated. The assessment of these earthquake hazards at specific sites is limited to critical facilities, particularly those that pose high risks, such as nuclear reactors, dams, hospitals, and important high-rise buildings. In some cases, the assessments raise issues that are difficult to satisfactorily resolve because of the insufficient data base or an inadequate understanding of the threatening phenomena and how structures may be designated and constructed to accommodate them.

The availability of information about earthquake hazards does not of itself, ensure the effective use of that information in mitigating the hazards. It is becoming increasingly clear that no earthquake hazard mitigation measure can succeed in a society that does not have a reasonable understanding of the hazards by the general public. In the past, the dissemination of earthquake information to the U.S. public has been primarily by means of sensational press coverage of a disaster or threatened disaster. Little or no effort has been made to systematically educate the people about the causes and effects of earthquakes and what they can do to mitigate the effects.

Assessing Earthquake Hazards

Some techniques for locating, delineating,and evaluating earthquake hazards are relatively well developed. Within certain constraints, faults that have the potential for future surface rupture can be recognized and mapped. Techniques also exist for identifying and evaluating the potential for landsliding. The processes of liquefaction, lurching, and differential settlement are understood in general terms and in some cases, in detail. Techniques for estimating tectonic deformation, distortion, and level changes, critical for the prediction of post-earthquake operability of canals, pipelines, and other lifelines exist. The most widespread hazard, strong ground shaking, can be estimated within broad limits. The strength and character of ground shaking at a specific location is dependent upon the size of the earthquake, its location, the local and geologic and soil conditions. Methods for estimating earthquake losses are developing and will be of great value in making social and economic decisions about acceptable risk.

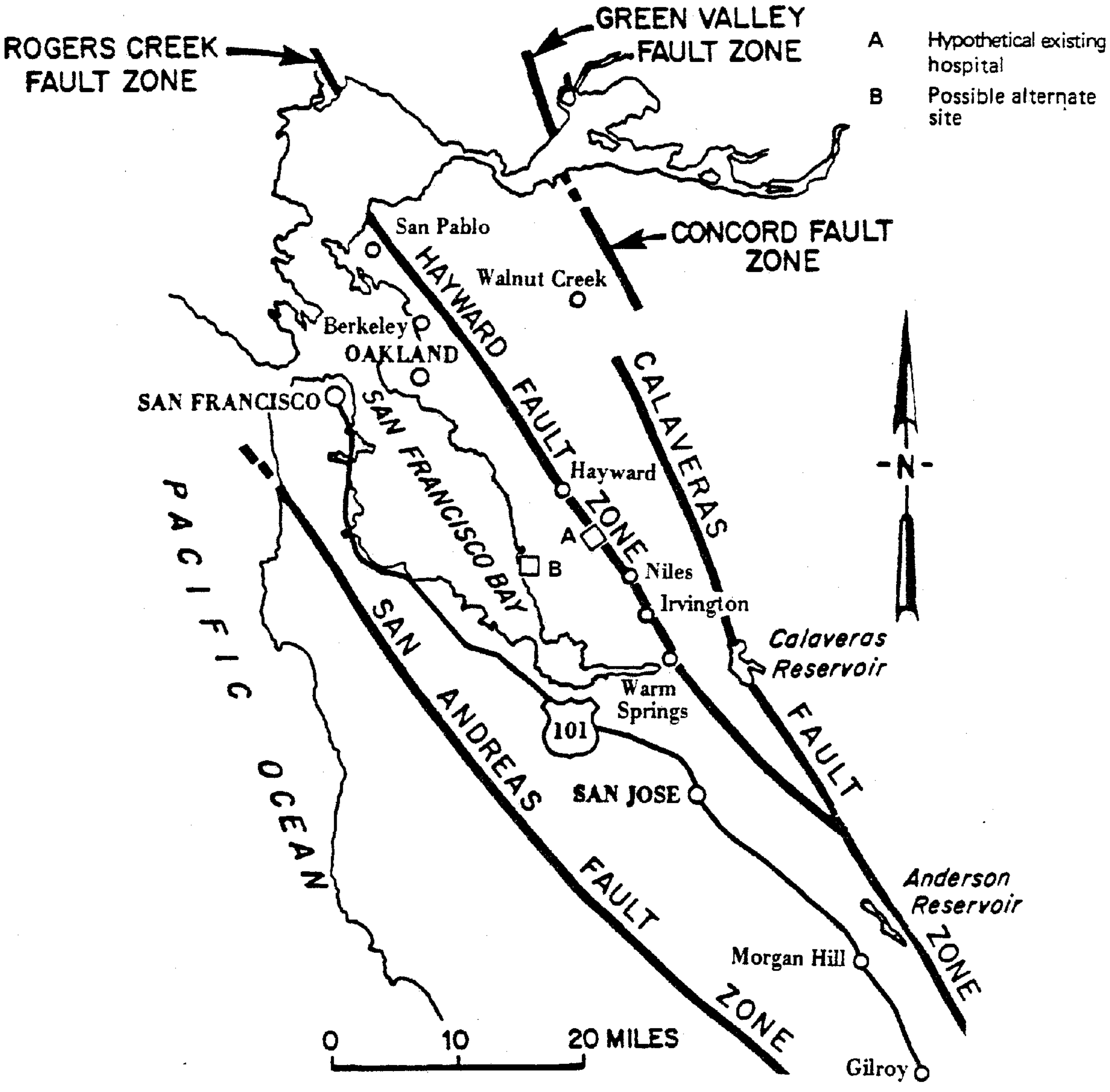
The continued functioning of a community after an earthquake depends upon how well utility and public service facilities function as systems having elements located at many different sites. The failure of an element can cause a total system to malfunction or be inoperative. Therefore, the design of system elements must consider the seismic performance characteristics required by the total system, not just individual elements. Both physically connected (water and utility distribution) and nonconnected (hospitals, clinics, and laboratories) systems must be considered. The location and design of systems, incorporating appropriate features to accommodate the earthquake hazards, are intimately related to local and regional planning. Such planning must consider both the direct impact of fault displacement and ground failure, as well as the indirect effects caused by disruption of utilities and public services.

In seismically hazardous regions, there must be a balance between seismic safety concerns and urban design concerns. The continued physical growth of cities in some regions has caused and is causing the use of "marginal" land, land that may have not been developed until now because of poor foundation conditions, fault zones, or steep topography. The need for land-use regulations for further development cannot be overemphasized. From a relative point of view, regulating future land use is fairly easy. A more difficult problem is the identification and mitigation of earthquake hazards traversing urban areas that have already been developed. The following example illustrates the seriousness of this problem.

Case History of A Critical Structure Located Across the Active Hayward Fault Zone

The following is a hypothetical case history based on combined data from several actual cases of structures that are located near or directly astride the Hayward fault. Figure 1 is a regional map of the San Francisco Bay area, which is traversed by several active faults, all capable of generating large earthquakes. A major part of the Hayward fault zone traverses the densely urbanized East Bay region. Important facilities have been constructed near and across the Hayward fault without knowledge that the fault is there or that it is active.

Approximately 60 years ago, a large hospital complex was located within the Hayward fault zone; the approximate location is shown in Figure 1. Since all the existing buildings of the hospital complex were built prior to 1972 (the time of the



GENERALIZED LOCATION OF HAYWARD FAULT ZONE WITH RESPECT TO REGIONAL FAULTS

Figure 1

Alquist-Priolo Act), there was no regulatory requirement to assess the earthquake hazards at the site. The board of directors of the hospital has now decided to modernize many of the existing buildings and to construct new buildings. These new buildings and modifications will come under the Alquist-Priolo Act, as well as the Safety of Construction of Hospitals regulations, both requiring detailed study and evaluation of the earthquake hazards. The first problem that faces the board of directors is: Will a study of the earthquake hazards jeopardize the existing facilities?

A compilation of published geologic maps (Figure 2) shows there may be numerous active fault traces traversing the hospital grounds. According to current California law, structures such as hospitals are not allowed to be built across an active fault (California Hospital Act). The act was primarily written for the purpose of guiding the selection of sites and building new hospitals; it did not seem in the best interests of public safety to allow a critical facility such as a large hospital to be located on an active fault. What about existing hospitals whose locations were selected many years ago without the benefit of knowing that the site is on an active fault? Do we proclaim that that is not a safe place, and close the hospital? Based on the information shown in Figures 1 and 2, it can be concluded that almost all the hospital buildings are located in a dangerous area and will be disrupted by future surface displacement along the fault. Should the hospital administrators abandon the present hospital site and find a new one? This case history gives some insight into a problem that is beginning to be faced by many important structures located near or across active faults. Let's examine the various options available to the responsible decision makers for the hospital.

Based on published geologic maps (Figure 2), most of the hospital buildings are located across an active fault. At this point in time, there are two basic options: (1) Assume the published data is correct, the faults are accurately located, and the consequences of future slip along the fault are unacceptable. One decision might be made to abandon the site; because the calculated life of the hospital (50 years) has been realized, without significant damage or any lives lost, this is an ideal time to take responsible action to move the hospital to a safer location. It could be argued that it is only a matter of time before a major displacement occurs along the fault; in fact, some claim it is presently overdue. Another decision would be to do nothing at all and wait for someone to force the issue. After all, the hospital has been located here for 60 years and no

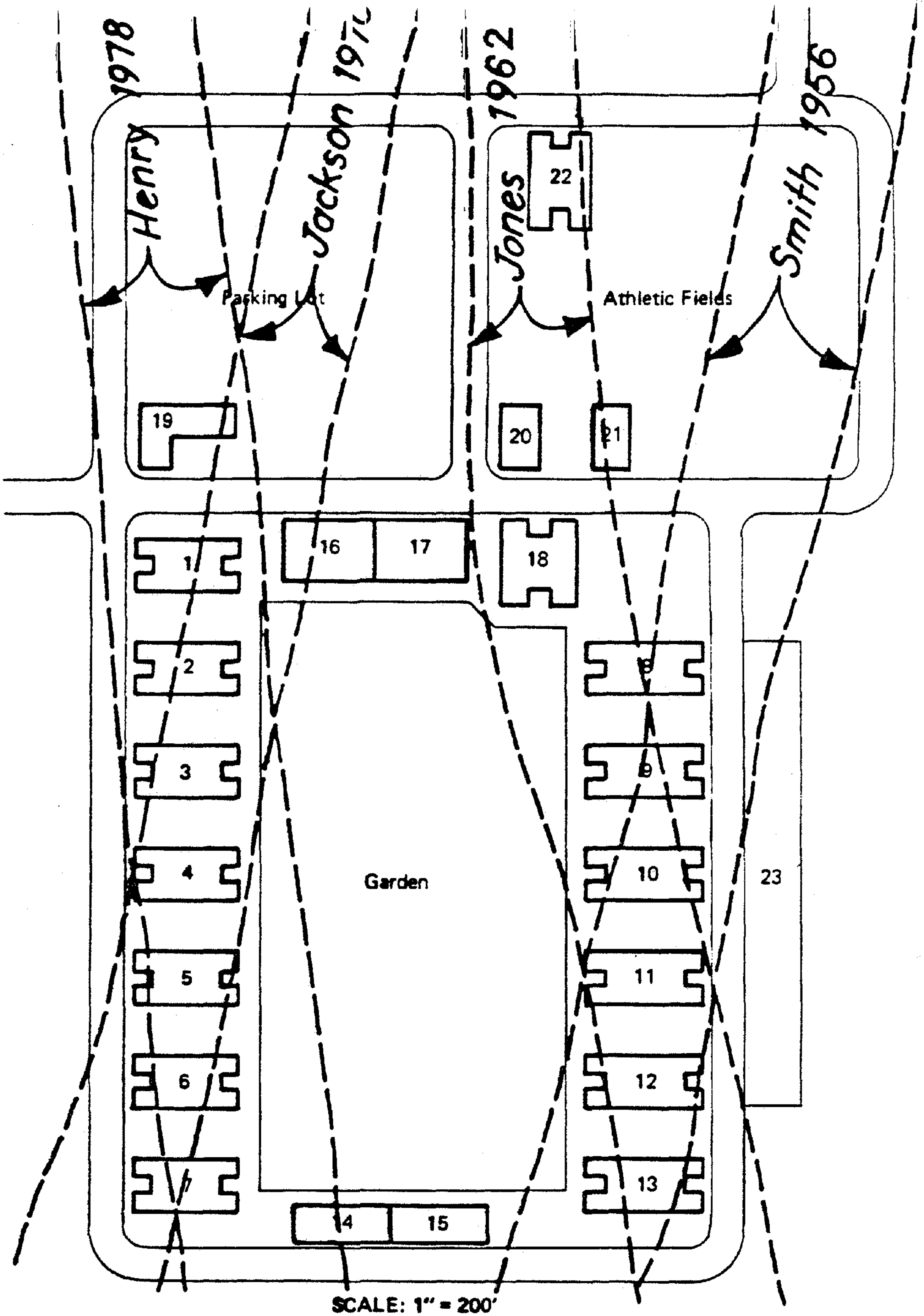


Figure 2. Map of Published Locations of Hayward Fault that Traverse Hospital Complex

lives have been lost due to fault displacement. The hospital has functioned without any mishaps associated with the fault or earthquakes. Even though the calculated, useful life of the hospital has been realized, it is a critical and essential facility; therefore, this is justification enough to allow the hospital to continue to function at its present location.

(2) It may be more appropriate not to take such final action until we reduce the uncertainty. Are the published locations of the fault accurate? Does an active fault traverse the hospital site? If so, what will happen should the fault slip? Will the surface rupture extend completely across the entire site, or be localized? If localized, is it possible to predict exactly where future surface displacement is most likely to occur? Is it possible to predict how much displacement is likely to occur and the width of the zone of distortion? What will be the consequences of future fault displacement? Is it possible to accurately delineate the location of the fault and then take steps to coexist with the fault? What about the other earthquake hazards: strong shaking, ground failure, and tsunami?

The responsible individuals in this case chose Option 2: to gather additional geologic and engineering data prior to making a decision so that the decision would be based on accurate information. The results of the additional studies showed that all the published locations of the Hayward fault were either misleading or inaccurate at the scale needed for decisions regarding individual buildings belonging to the hospital complex. The accurate location of the Hayward fault is shown in Figure 3.

Regarding the surface faulting hazard, it is clear that conclusions made relying on data from published regional geologic maps can be misleading. The detailed geologic studies conclusively showed that, rather than most of the hospital buildings being located across an active fault, only three buildings (nos. 7, 17, and 22, Figure 3) are across the fault and building number 6 is partly on the fault. The fault traverses mostly through the garden, athletic fields, and the parking lot. With regard to the shaking hazard, there is no question that all the buildings will experience strong ground motions when a future earthquake is released along the Hayward fault. However, the foundation conditions need to be taken into consideration. At this site, foundation conditions (Figures 4 and 5) are excellent. With regard to ground failure hazard (landslides, differential compaction, or liquefaction), the foundation conditions are not of the type to be susceptible to ground failure phenomena.

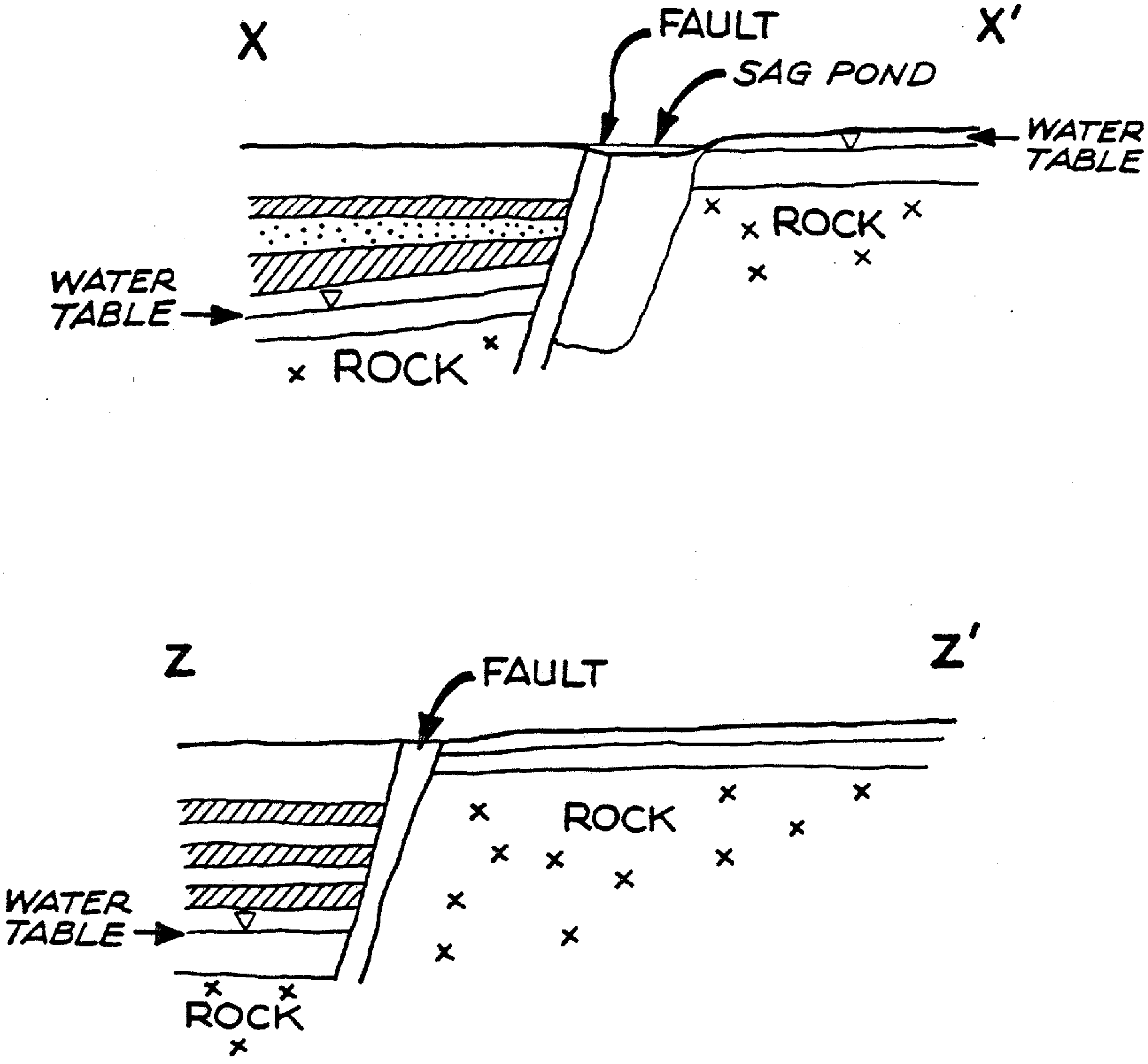


Figure 5. Geologic and Soil Cross Sections Across Hospital Grounds

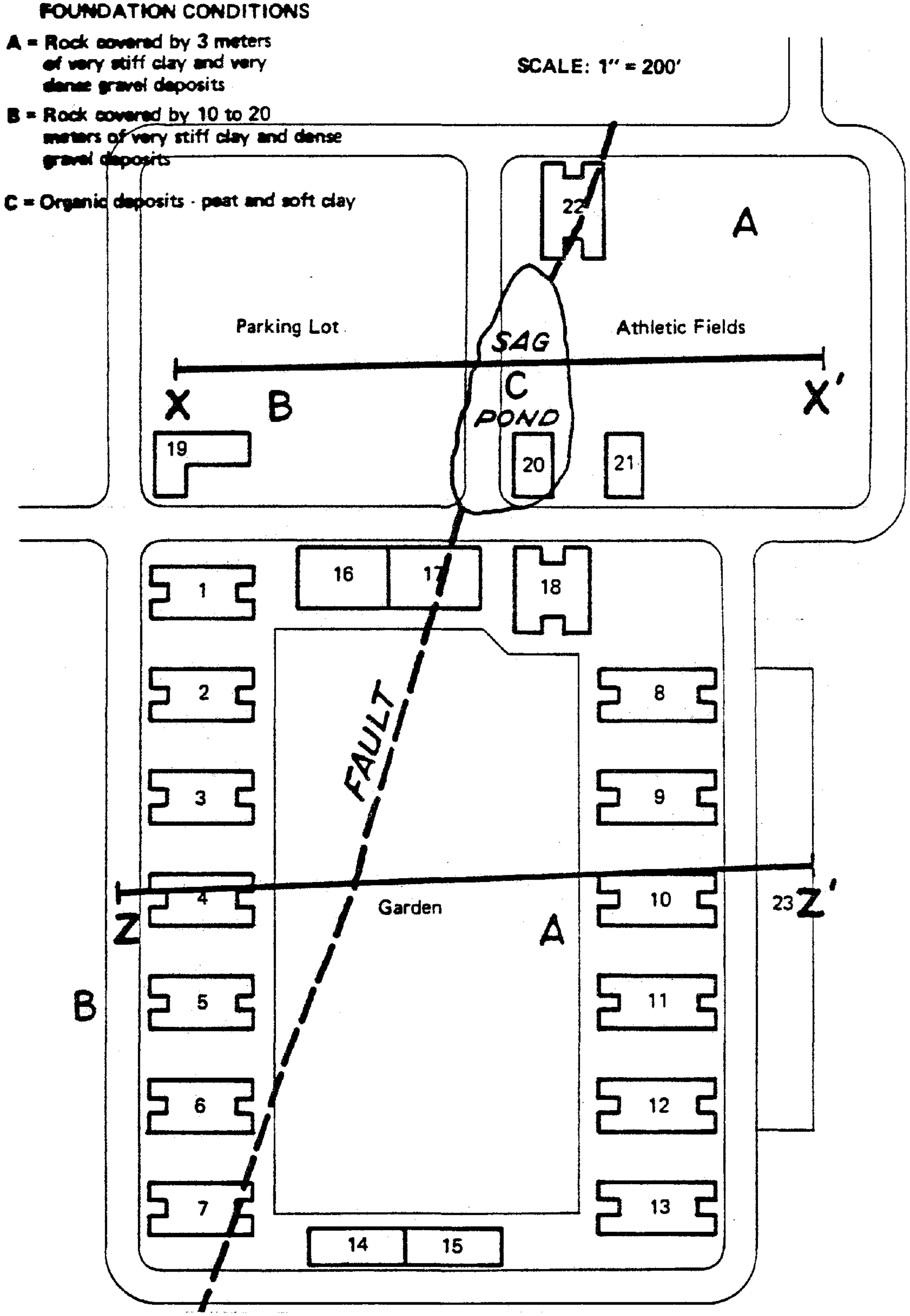
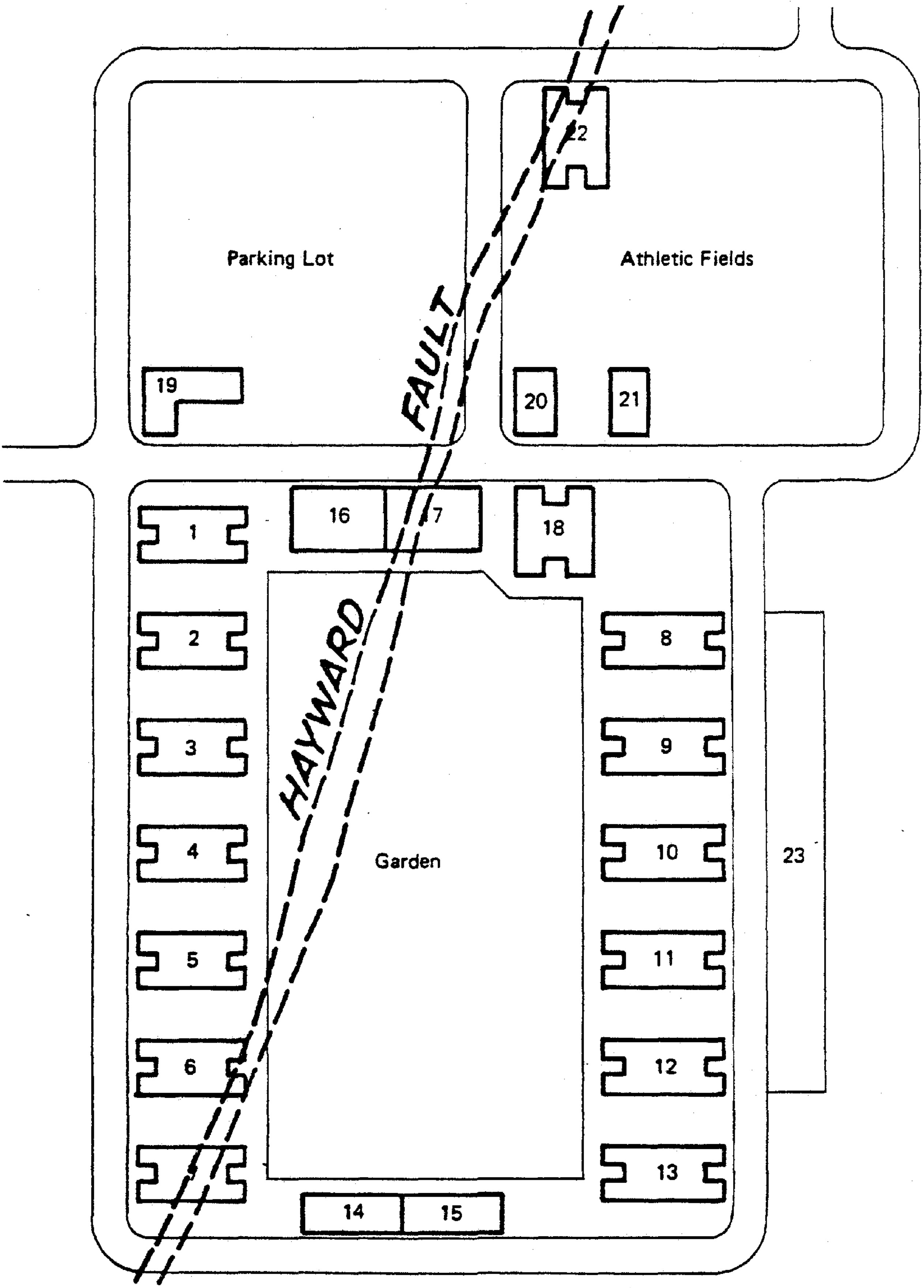


Figure 4. Map of Foundation Conditions underlying Hospital Grounds



SCALE: 1" = 200'

Figure 3. Map of Accurate Location of Hayward Fault Traversing Hospital Complex

Because the site is located away from the San Francisco Bay at an elevation of 50 meters, there is no tsunami hazard. Therefore, with the exception of the potential for surface faulting through four out of 22 buildings, the existing hospital site is located in a relatively much better location than many other possible sites throughout the Bay Area. Many other locations have a high potential for strong shaking, as well as ground failure that could occur as a result of earthquakes released on the Hayward fault or on one of the many other active faults shown on Figure 1.

If we examine the relative hazards between site A and alternative site B (Figure 1), it is clear that the probability of serious earthquake losses are higher at site B, even though site A is located on the Hayward fault. Site B is located at the edge of San Francisco Bay; therefore, it may be subjected to damaging tsunami waves that could originate in Alaska or even Japan, as well as from a local large earthquake. Site B is underlain by recent alluvial deposits. These are poor foundation conditions that will tend to amplify strong shaking, as well as fail due to liquefaction. In addition, the probability of liquefaction at site B during the life of the facility is very high because potential earthquakes will occur along the Hayward, Calaveras or San Andreas faults.

Conclusions

There is clearly a responsibility and an opportunity to influence earthquake safety by mitigating earthquake hazards through effective and intelligent urban design and appropriate legislation. This applies to new development or redevelopment of existing urban centers. There is an urgent need for accurate geologic and seismologic data at both the regional and local levels so that urban designers and legislators can make realistic decisions and value judgments regarding the many tradeoffs that exist when considering what risks are acceptable.

Our most serious problem is ignorance. This seminar should have an influence on that problem and the professionals that are involved in the planning and design of cities so that, through better communication between the many disciplines (geology, seismology, engineering, planning, and architecture) our cities will be safer during future earthquakes.

DISASTER PREVENTION PLANNING RELATED TO URBAN DESIGN

SUMINAO MURAKAMI

It is quite obvious that urban space should not be dangerous for the people to live in. However, it is not always safe because a lot of dangerous aspects exist in our life. Moreover, unbelievable danger may surface, threatening people's lives when an earthquake occurs. People are unaware of such dangers. They will not realize the danger which exists in urban spaces until they experience the misfortune personally. These dangers are not recognized as a social problem because people are not apt to face the matters which actually happen. For example, when disasters attack other people or other areas, they will feel they are the other people's affairs and don't pay much attention. This tendency seems to be a Japanese characteristic shared by Engineers and Planners. For example, when trouble occurs, they believe that it is because of the overlapping of a particularly bad condition, which was not their responsibility. They have mistaken confidence in believing that they will not encounter the same problem. The reasons for this tendency seem to be as follows: After the disaster or the accident occurs, they investigate only the cause of the crime. Nothing about the phenomena of the disaster or the accident and its social factors is examined any further. In such a social background it is quite difficult to address the problem of the safety in urban design. We especially need to address the disaster in terms of the problems with ourselves in order to make the urban areas safe against an earthquake disaster. In other words, we should not be Engineers or Planners who always find reason to rationalize disasters and are only concerned with the safety of the places they are concerned with. Engineers and Researchers must have courage and be prepared to consider disasters and accidents of other people or other areas and take responsibility as an engineer or researcher. In the old days, disaster counterplan in town construction was recognized as the problem of the whole city because of the undeveloped technology of each facility. The disaster counterplan which identifies the types of houses on a street and considers the human activities in relation to them was made. At that time, all people felt the same fear of the natural calamities such as earthquake, fire, flood, famine and so on. The people who lived in a city responded to the disaster together in order to save their city.

Today as the development of technology has removed many common problems, people in towns live their own way. It is true that most of the common problems of the past which they have fought against together are already conquered through modern technical developments. We still do not know or recgonize the fact that new problems are arising. The development of modern technology and economy are so rapid that one technique takes the place of another before it is fully tested. This means that the earthquake durability of modern technology is not confirmed by an actual earthquake. For this reason, the blame for modern disasters in facilities and buildings rests upon ourselves. When considering the problem of safety in urban design, an important point is the safety of 3 dimensional space where people live, framed by the urban facilities and buildings. The safety of the facilities and buildings themselves is the necessary condition, but may not be a necessary and sufficient condition. We can say that the earthquake durability covers only the durability of the facilities and structures. We should notice that the earthquake durability does not effect the safety of the space framed by the facilities. To consider the problem of safety in urban design, 3 dimensional space and time use (the difference of the urban activities, the difference of weather conditions, etc.) are complicatedly related to each other. Therefore it has a much more sophisitcated content than the case of a single facility. This complexity is the main reason that this problem has been ignored up to this date. It is impossible for an independent engineer or researcher to solve this problem no matter how conscientious he may be. This is the comprehensive research theme with which the entire society should wrestle.

In Japan, after the Kanto Earthquake in 1923, people paid an increasing amount of attention to disaster prevention planning (safety problem) in urban design and obtained some good results. After World War II broke out, it regressed. Most of Japanese cities including Tokyo and Osaka were burned. The reconstruction of Tokyo offered an opportunity to make the urban areas safer. But people were busy maintaining their daily lives and didn't have enough time to create a good city. Many people migrated to the city and the dangerous urban areas were reconstructed once again. Most of the people lived there without knowing its danger.

Isewan typhoon in 1959, made us realize the problems of living in a dangerous city. It made people recognize the danger of urban disasters and also the danger posed by an earthquake. After the typhoon, we began to study how and what kind of damage may occur if the earthquake struck the Kanto area. The main problems are large fires after an earthquake.

In 1964, the Niigata earthquake occured and Niigata city, where new economic activity had taken place after reconstruction from World War II, suffered the most damage. This earthquake forced us to think about the problem of urban disaster prevention. It is a matter of unstable ground and durable structure. At that time, we asked ourselves if our cities were realy safe when the earthquake occured, even if the buildings were constructed according to specifications. This opportunity allowed us to devise disaster prevention planning for the area which is below sea level in Tokyo. This was the beginning of the study of urban design and disaster prevention. For our plan, we consider disaster prevention planning with performance of the actual tasks. If actual constructions are performed, the planners, researchers and many other people of various fields have to join together and exchange information. Therefore, it is important to conduct discussions about disaster prevention on a wide scale. In the beginning, the social response to disaster prevention planning was quite low, but as planning and construction progresses the interest of society is growing. The educational effort of disaster prevention for the society is as important as the value of the building itself.

The redevelopment of the Koto Delta District in the eastern area of Shirahige, is the facility actually built as the result of 10 years of effort. The important points include: (1) the relation with existing developed area, (2) the large park which is not usually provided in an appartment-house complex, (3) the construction of Medical Center, Disaster Prevention Center and Schools which can continue their functions during and after an earthquake. Generally speaking, it is impossible to rebuild each structure in the city to be earthquake resistant. It is necessary to have some durable structures in the city and allow them to be the base of the disaster prevention. Now research and construction is being undertaken to minimize the earthquake disaster in an urban area. This research was begun because of the dangerous situation in Japan. This situation has not yet changed, because the activities to educate the public of disaster and disaster prevention problems have not been realized sufficiently.

DISASTER PREVENTION FOR YOKOHAMA-DISASTER PREVENTION FOR AN INDUSTRIAL CITY

AKIRA TAMURA

1) DISASTER PREVENTION IN URBAN AREA

Among many functions and values required of urban areas, disaster prevention is one of the most fundamental since even the most prosperous urban area can be reduced to rubble in one night, if the capability of disaster prevention is poor.

Large urban areas today are faced with a serious contradiction regarding disaster prevention. They contain huge populations at high density, increasing the dangers of disaster. Especially in Japan, where noncombustible residential buildings are in the minority. Merely to live in an urban area adds to the possibility of disaster. In the Edo Period, fires were so frequent in Edo itself, (as Tokyo was then known) that people spoke of fires in Edo as one of the distinguishing features of that flourishing city. Even without such arch-arsonists of today as kerosene and gasoline, the crowded housing, the prime means of protecting people against natural threats, was the greatest contributor to disaster.

Since then, this fundamental defect has not been improved, but aggravated with the increased variety and quantity of hazardous materials brought into urban life by technological development, and today, once a disaster is started in an urban area, the consequences are no comparison with the simple great fires of bygone eras. Any effective measures of preventing urban disasters in Japan today must start from the reorganization of the urban structure and revision of housing technology.

However, such fundamental measures as these involve some major problems: a) Who is to pay the enormous expenses involved? b) The comparatively lenient present legal restrictions on private buildings and land use must be greatly strengthened, and are citizens fully prepared to accept such restrictions? and c) To enforce sufficiently effective urban reconstruction programs, are municipal bodies capable of giving fully pursuasive directives to citizens, in place of bureaucratic forced order?

Another important consideration in dealing with the problem of urban disaster is that disaster prevention is not the total issue, but only a part of urban policy, although a fundamental and vital theme. For example, when designing river embankments, not only the structural capability to withstand the pressure of the expected maximum water quantity, but also the environmental and recreational aspects of the river must be taken into consideration. That is to say, values and functions incorporated in any disaster prevention plans should be maximized, and this is important for securing majority support for any such plans.

Prevention of urban disasters is a major issue involving many problems which require both immediate solutions and long-range measures. For this, both practical countermeasures and long-term fundamental studies are needed, which cannot adequately be described here.

2) AN INDUSTRIAL CITY - YOKOHAMA

In recent times, Yokohama has developed as the dominant international port of Japan and as the distribution center of western culture and technology in Japan. As early as the 1920's, the so-called Keihin Industrial Belt joining Yokohama with the neighboring industrial areas of Tokyo and Kawasaki was started, which has become one of the most important heavy and chemical industrial areas in Japan. During the high industrial growth period, especially in the 1960's, many petroleum-related plants such as petrochemical plants and oil refineries were built on the newly reclaimed land adjacent to the existing industrial area.

Accompanying this industrial growth, the population of Yokohama increased rapidly after World War II, and it is now the 2nd largest city in Japan with a population of 2.75 million, overtaking Osaka in 1978.

With many problems related to this industrial zone such as industrial pollution and industrial hazards, combined with the common disaster prevention problems mentioned earlier, Yokohama is now faced with the most urgent problem of typically modern urban issues, "heavy and chemical industries in urban areas".

Attempts to expel all industrial facilities out of the urban area do not solve the problem from a broad national viewpoint, because industries such as agriculture, forestry and fisheries as well as residents in the newly developed industrial area would be burdened with the same problems.

If the problem of overcoming the unfavorable influence of modern industry on urban residents is to be solved at all, Yokohama, where considerable experience is coping with this problem has been accumulated over the years, should be the place where efforts to this end should be made. Furthermore, Yokohama constitutes a large urban area where huge amounts of goods have to be stored or produced and eventually consumed. This also is an important factor in the industry in urban areas issue. This also means that Yokohama with its largest populated area comined with its largest industrial area and long experience in dealing with this issue, is an important testing ground in Japan for the urban issue specialists.

3) DISASTER PREVENTION IN THE KEIHIN INDUSTRIAL AREA

The problems that require fundamental review when dealing with the environmental issues of the Keihin Industrial Area are; industrial development siting, social obligation of enterprises, national industrial policy, urbanization policy of the greater Tokyo metropolitan area, existing land-use conditions and systems, the existing division of administrative and tax levy jurisdictions between state and municipalities, and safety technology.

In an industrial area with a long history and many established conditions like the Keihin area, all these fundamental problems must be studied. On the other hand, immediate problems must be dealt with, making whatever improvements are feasible on the basis of the existing administrative system, but not wholly restricted by such a system.

From the former viewpoint, the Yokohama Municipal Government has been making a long-term study of various items. A long-term joint study group of the Kanagawa Prefectural Government and Kawasaki Municipal Government and Yokohama Municipal government has been in operation for nearly 10 years. Although no satisfactory solution has been achieved for any of the problems under the rapidly changing economic conditions, the group has been making timely proposals and recommendations on fundamental issues.

a) In the Urban Environmental Belt, urban type industries should be introduced to replace heavy and chemical industries. At the same time, urban facilities, greenery, and recreation facilities should be created, so that this belt can play a leading role in the transformation of the Keihin Industrial Area into an urban environment and to improve the environmental conditions in the belt.

b) In the belt, greenery, open spaces, and non-combustible buildings should be effectively positioned to make the belt an effective disaster shieldand barrier. Possible changes of climatic conditions under major disaster conditions should also be taken into consideration.

c) In principle, the cost for the Urban Environmental Belt should be borne by private enterprises operating in the Keihin Industrial Area, with a portion borne by the state and the municipalities.

d) The Urban Environmental Belt should be fully compatible with neighboring urban areas in its developmental stage and in its functions.

4) CONCLUSION

Only a part of the problems and measures related to disaster prevention in the industrial city of Yokohama has been described, with all commonplace disaster prevention measures purposely omitted.

It must be kept in mind that disaster prevention should be conceived of as an integral part of urban environment improvement. Based on this concept, a long belt-like park, "Ohdori Koen" (Great Street Park) was created in the center of the urban area of Yokohama to serve as a disaster prevention zone. It acts as a place of relaxation, a site of cultural events of high quality, a site for other activities and as a strategic tool for peripheral area development. Securing more areas for multi-purpose community spaces such as this is an important target for the future. Their planning should be based not only on disaster prevention, but also on comprehensive and detailed urban management strategies involving the entire city area. Large municipal governments in Japan now definitely need full-scale planning sections and capable urban designers.

From the latter viewpoint, Yokohama has conceived and implemented many practical measures. They include:

1) Pollution prevention agreements with private enterprises. When there was no pollution control legislation, the Municipal Government started to conclude pollution control agreements in the form of civil agreements with major industrial companies. Now, these are being adopted by many municipal governments in Japan after the Yokohama pattern. These agreements have come to include various environmental quality improvement measures and disaster prevention measures as the responsibility of the enterprises. Supported by the laws and regulations enacted in the meantime, these private agreements are now fully enforced.

2) Land reclamation for industrial facility re-siting. Along with the transfer of polluting and potentially disasterous industrial plants outside the urban area, a large portion of these facilities have been re-sited on land newly reclaimed from the sea, south of the city. The evacuated land is being utilized for pollution and disaster control measures. With this measure, enterprises having important roles to play in Yokohama were retained within the city area but the residents were sufficiently protected from the harmful influence of these industrial facilities.

3) Outdoor oil tank research committee. Oil tanks are especially numerous in the Keihin Industrial Area, and their number has been increased enormously without sufficient safety measures being carefully studied. To improve this situation, a special committee was organized to study the structure of oil tanks from many viewpoints. The committee published large numbers of reports, on the basis of which appropriate administrative guidance was given to tank owners.

4) Establishment of urban environmental belt. The Keihin Industrial Area is enormous in size resulting from decades of development and cannot be changed overnight. The environment must be improved progressively towards a compatible coexistance of large urban areas and industry. For such a coexistance, the border zone between the existing coastal industrial area and the urban area should be treated as a special area designated as an "Urban Environmental Belt", and be assigned the functions given below:

NATIONAL EARTHQUAKE HAZARDS REDUCTION PROGRAM

JAMES LEFTER

INTRODUCTION

The National Earthquake Hazards Reduction Program which was announced last year, 1978, accomplished as its first task under Karl V. Steinbrugge's leadership, the study "Issues for an Implementation Plan." The National Earthquake Hazards Reduction Program evolved from that study.

UNDERLYING PRINCIPLES

Underlying principles for the program include:

1) Shared responsibility for earthquake hazard reduction among the Federal, state and local governments, private organizations, professional societies and private citizens. All must join in this effort if it is to succeed.

2) Mitigation activities will be keyed to assessments of relative risk and potential loss of life and property. Regional differences in the nature and magnitude of the risk require a flexible approach.

3) Hazard reduction procedures must be incorporated into existing organizations, institutions and regulations as part of established, ongoing activities.

4) The Federal government should set a strong example through its own construction programs and those constructed through federal financing and provide leadership in this national effort.

5) International cooperation and the exchange of information are a fundamental part of the Program.

PRIORITIES FOR IMMEDIATE ACTION

Recognizing that this Program will not be completed for many years, several areas have been assigned priorities for immediate action:

1) Indentification of an organization to provide national leadership for this Program.

2) Completion of several Federal, state and local contingency plans for responding to earthquake disasters in densely populated areas.

3) Development of unified seismic design and construction and encouragement of adoption of improved standards by state and local building codes officials.

4) A study of financial institutions and their responses to major earthquakes and other natural disasters.

5) A comprehensive research program for earthquake prediction and hazard mitigation.

ORGANIZATIONS

Several organizations will make important contributions to the success of this program:

1) The Earthquake Hazards Reduction Coordination Group has been leading the Federal effort. This role will soon be assumed by a new agency, Federal Emergency Management Agency, that will also have responsibility for emergency preparedness, disaster assistance, and insurance programs for flood and other natural disasters.

2) An Interagency Committee on Seismic Safety in Construction has been formed with representatives of all agencies involved in construction or the financing of constructions. Among its responsibilities are development of unified design and construction standards for federal agencies and of a strategy to identify potentially hazardous existing federal buildings.

3) A Building Seismic Safety Council has been formed to encourage the development and adoption of modern seismic design and construction standards. Member organizations include professional societies such as the American Institute of Architects, building code officials and materials producers and suppliers.

SUMMARY

I have discussed the National Earthquake Hazards Reduction Program in terms of its underlying principles, priorities and organizations. Some of the interrelationships sought in the National Program have been illustrated by other papers presented at this seminar.

1) Karl V. Steinbrugge discussed the issues in the National Program and the fundamental concepts of shared responsibilities in this effort.

2) William J. Duchek focuses on the "seismic elements" guiding the evolution of future development of a community and the concept of "special study zones" in areas of potential high seismicity.

3) Lloyd S. Cluff examines the nature of geologic investigations in a special study zone and the decisions that must be made in the assessment of geologic and seismic hazards.

4) George A. Agron describes the process whereby an architect, recognizing the problem, gathers information, and by creativity, imagination and meticulous attention to detail, develops appropriate design solutions.

URBAN DESIGN & SEISMIC SAFETY

DEVELOPMENT OF URBAN SEISMIC SAFETY ELEMENTS

WILLIAM J. DUCHEK

It is the objective of this seminar to link, for the first time, two seemingly disparate subject areas. This first effort at synthesis of these two urban planning concerns is an appropriate one. The inherent approach to the problems they address must be at a large scale--the urban scale.

However, in discussing seismic safety and urban design a fundamental problem arises--how does one define or conceive of them?

Seismic safety is the easiest of the two--fundamentally the need to reduce danger or risks from seismic hazards. Urban design on the other hand, defies an easy definition. It has become a popular "buzz word" especially for planners, architects, and some politicians, for at least a decade, and numerous essays and definitions have been published in recent years. Also, I suspect each individual present would render a different or at least varying concept of urban design. Therein lies the problem of any discussion involving urban design.

This lack of a common agreement is not to argue there is a right or wrong definition, but only that there is a need for a working definition, a basis upon which to relate to concerns. For purposes of this discussion on seismic safety plans, I will reference my comments to this definition of urban design:

> The objective of the "act of urban design" is to create a desirable visual, physical, and functional relationship of those infinite parts that together comprise an urban area. Urban design is the aggre-

gate of these parts and the continuity or counterpoint that is exhibited by them as they are resolved into the various systems of the urban area--buildings, streets, parks and open spaces, blocks, neighborhoods, and districts. The result is the three dimensional form and physical design of urban areas.

Comprehensive Planning and Seismic Concerns

Concerns for seismic safety have a long standing history, but only in the post World War II years have these concerns finally, in a significant way, begun to find their way into building codes and governmental funding for research. In more recent years, through increased legislative actions and funding for research the seriousness of seismic hazards is being acknowledged.

Likewise, comprehensive planning and urban design have roots that go back to the late 19th century beginning with the "city beautiful" movement. At that time, comprehensive planning and civic design began to be perceived as a way to achieve pleasant, livable and well ordered urban environments.

In 1916, the first comprehensive zoning ordinance was enacted by New York City. In the late 1920's the United States Department of Commerce drafted model legislation for zoning and city planning authority at the local level. The two model acts were the Standard State Zoning Enabling act and the Standard City Planning Enabling Act. These established the basis for governmental control of land use which continues to be used to the present day.

Most state legislation, however, was very general in outlining elements of the comprehensive plans, it was concerned primarily with public facilities, streets and open spaces. Moreover, preparation of plans by local governments was not mandatory. Seismic concerns were not related to comprehensive planning process.

One of the first states to require local governments to adopt comprehensive plans was California. Likewise, it became the first state, following the disastrous San Fernando earthquake in 1971, to require inclusion of a seismic safety element in local comprehensive plans.

In 1973, guidelines for the seismic safety element were prepared by the California Council of Intergovernmental Relations and stated:

> "The seismic safety element contributes information on the comparative safety of using lands for various

> purposes, types of structures, and occupancies. It provides primary inputs to the land use, housing, open space, circulation and safety elements."
>
> (California Council on Intergovernmental Relations, 1973, p. IV-27)

It is clear from the guidelines that seismic safety elements were not meant to stand alone, but to supplement and shape the other plan elements. Of note too, is that the guidelines did not specify precise content or structure of the elements, this was left for the local jurisdiction to adapt to its unique needs.

Seismic Safety Elements

The goal of incorporation of a seismic safety element in comprehensive plans is to reduce or eliminate deaths, injuries, and the economic and social costs resulting from the occurence of a seismic event.

The approach or emphasis that a community should take in preparation of a seismic safety plan will depend on a number of factors. Some of these would be the kinds of seismic hazards present, size of the community, age of structures, densities of population, and amount of developed land area. Also, of no minor consideration is the availability of staff and budgetary resources in the agency charged with preparation of a plan.

Although the general approach of plan preparation is subject to variable factors, a guiding principle for every plan should be the consideration of the implementation time-frames that are critical to the ultimate effectiveness of any seismic safety element. These are:

1) Pre-earthquake period.
2) Immediate post earthquake period.
3) Long term post earthquake period.

These time-frame considerations must be made at each of the two major phases of the planning process:

1) The policy formulation wherein general directions are established and guidelines determined--the "what wants to be done"; and
2) The implementation programs--the important "what actually gets done."

Policy Formation:

The policies of a seismic element will vary from community to community depending upon the critical issues identified in the analytical process. The process for analysis and evaluation should generally be:

1) Identification of the kinds of geologic and seismic hazards present in the community;
2) Identification of the critical urban systems and particular characteristics of the community that are of concern and how they will be affected by the occurrence of a seismic event.

   The critical urban systems are:

   a) Emergency power and communications
   b) Fire-fighting/protection
   c) Emergency transportation
   d) Police services
   e) Hospitals and emergency health/welfare services
   f) Utilities: electricity, gas/fuel, water supply, and waste disposal
   g) General transportation and communication
3) Identification of threats to life safety, and causes of economic or social costs.

Through this process, issues can be determined and priorities, based upon the levels of risks the community is willing to accept, can be established for the formulation of policies.

Basic issues every seismic safety element should address are:

1) The need for prevention of deaths and injuries--life safety; and
2) The need for adequate responses to the occurrence of a seismic event-emergency operations.

The principle concerns for safety from seismic hazards will fall under the umbrella of these two issues. Other major issues might also be addressed that derive from the unique characteristics or conditions in a community. The San Francisco plan addresses the issue of need for preservation of historic structures and of reconstruction needs that would follow a major destructive earthquake. Many issues identified in the "Issues for an Implementation Plan" are also of local importance.

Once the issues are identified, policies are easy to draft, but reasoned pragmatism should prevail. They should be drafted with an eye toward implementation feasibility. It serves no one to propose, much less adopt, a policy that for political or other reasons, will not be implemented in some form. On the other hand, should a policy be considered important that is presently economically or technically infeasible, it should not necessarily be discarded.

Implementation:

The key to the effectiveness of an adopted seismic safety plan is that it be implemented. To be effective, it must be accompanied by an implementation program or proposal. These should identify precise ways, and indicate feasibility, for carrying out the policies.

A broadly conceived seismic safety plan must also be implemented in a broad manner. Implementation of such a plan will not begin and end in modifications to land use zoning districts, changes to subdivision rules and regulations or amendments to construction codes. It will also include such activities as coordination of inter-jurisdictional programs, establishment of preservation or hazard abatement programs, intergovernmental coordination activities and public education efforts. I do not mean to imply that these will all be carried out by the agency drafting the plan and outlining the implementation program, but only that varied and imaginative actions will be needed to effectively carry out an adopted policy plan.

A National Approach?

As much as national awareness of seismic hazards is increasing, I suspect it will be many years before the California model has much following. If the United States is to be serious about incorporating seismic concerns in local planning efforts, it will almost certainly have to be mandated at the Federal level or--a seismic event of at least the magnitude of the San Fernando in 1971 will be required to jolt our inclination towards complacency. No one wishes the latter, but it is, historically, such occurrence that spurs action to remedy a hazard when its priority otherwise is rather low on the political ladder.

The California model, mandatory planning elements including seismic safety, is exemplary, but, as in all first efforts, has its shortcomings. It was mandated in 1971; guidelines were drafted in 1973; and a deadline for adoption of elements was set for 1975. To this date, there is not total compliance. The problem is common of codes and mandatory legislation--monitoring and enforcement.

Appendix IV of "Issues for Implementation Plan" documents the problems in California. To summarize briefly, there is little State review of the adequacy or accuracy of the document and little State monitoring of fulfillment of the requirement for the mandatory elements including the seismic safety element.

The state of California has taken the lead in requiring that cities and counties address seismic safety concerns during preparation of comprehensive plans. Although all jurisdictions have not yet complied, a significant number have. These constitute a body of knowlege and information as well as a positive increased awareness of seismic hazards at the local government level that did not exist as recently as 5 years ago. We now have this experience to build on. Evaluation of it is needed to determine potentials for broader application and for further local seismic safety planning.

Other related considerations might be:

1) Action at the Federal level to encourage or mandate seismic safety elements for all urban areas subject to high seismic risks.

2) Preparation of statewide or regional composite plans

3) Consolidation of plans for contiguous smaller communities

4) Preparation of areawide or urban region plans for those lifelines and critical urban systems that transcend local jurisdicitonal boundaries.

5) Evaluation of the urban design impacts of adopted seismic safety elements.

The Urban Designer

Where does the urban designer fit into this grand scheme of mitigating risks from seismic hazards? Probably after the fact, after the analysis has been done and the plan prepared and adopted.

In his role of urban designer--although as with most of us delving into urban design, his training and experience has probably been as an architect, landscape architect, engineer or planner--he probably has entered this secenario in one of two ways. Legislation may be pending pursuant to seismic policy, that will affect him or his colleagures or clients, or he may discover that the adopted legislation is affecting his project. He is just now finding that these seismic safety concerns can have a significant impact on the design of urban environments and the role he plays in shaping our urban areas.

Just as the seismic safety elements must supplement and interrelate with other elements of a comprehensive plan, and in ultimate implementation of that plan, it, like other elements of the comprehensive plan, will have an impact on the physical manifestation of the urban environment.

If the urban designer is to lend his expertise to that of other professionals, he must be aware of the seismic concerns. Moreover, he must understand them, be able to relate them to overall urban development, and participate in the decision-making process of actions to reduce risks of seismic hazards.

In his multi-professional role as broker or coordinator of many precise skills and areas of expertise, he is needed before the fact, not after, to creatively relate the varied aspects of physical urban development with seismic concerns. Some areas requiring the integration of urban design and seismic concerns are:

1) The design and location of streets and highways to also serve as evacuation routes.

2) The location of critical public facilites, police and fire stations, hospitals, and large places of assembly to safely serve emergency needs.

3) The design of park and open space systems to also serve as emergency refuge areas or to incorporate areas of geologic or seismic hazard that should not be otherwise developed.

4) The development of locational and design criteria for structures to minimize potential hazards to pedestrians and obstructions of critical streets in emergency situations.

5) Criteria for building types and densities to relate to the degree of seismic hazards.

6) The design of new urban areas of redevelopment of older areas in a mmaner to minimize seismic risks.

7) The design and location of transportation systems to also serve emergency needs.

8) Development of means to accommodate historic preservation concerns while increasing safety from seismic hazards.

These are but a few of the areas where seismic safety and urban design solutions may interface in mututally beneficial and cost-effective ways. Hypothetical and case studies should be undertaken to develop an information base for planning and decision making. There are urgent needs to analyze these interrelationships for the furtherance of the state-of-the-art for all professionals participating in urban design and seismic safety planning.

Conclusion

Comprehensive and ad hoc decisions are made on a daily basis which affect the physical urban environment. Inadvertently, as well as by intent, these are often urban design decisions. Increasingly, these decisions, in areas of high seismic hazard are including seismic concerns. Almost without exception the urban designer is absent from participation in these decisions and the processes by which they are made--both in implementation and in policy decisions which may be established by a seismic safety plan. He will continue to be absent until he becomes more aware of the seismic concerns and the impacts they have on the built environment. He must have this awareness and knowledge to be able to apply his talents to mutually achieve safety and urban design objectives. The creativity, skills and expertise of the urban designer is needed in this process if we are to optimize the livability and safety of our urban environments.

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OUTLINE - MAKING CITIES MORE RESILIENT TO EARTHQUAKES

WEIMING LU

What are some of the possible roles that urban designers can play to assist the city in recovering as quickly as possible after an earthquake? What are some of the possible roles urban designers can play to assist the city in the planned reconstruction of the city?

The former dealing with immediate recovery consists of short-range actions to restore essential services, getting industries back into production, and insuring that the city's homeless are provided with shelter and other basic necessities. The latter or planned reconstruction deals with long-range policies which are concerned with the future development of the community. One should be related to the other. The short-range actions shouldn't be allowed to interfere with the long-range policies. Yet, rarely has a city stricken by earthquake been able to avoid this pitfall. What appears most obvious is often not done. Both short-range actions and long-range policies should help the city to cope with future earthquakes.

The key question is how to design cities in earthquake prone areas with greater resilience. A city with this characteristic is more able to absorb sudden stress, avoid breakdown and recover quickly.

It is important to develop long-range plans that would help make the city more resilient. It is much more than merely making all the buildings in the city more earthquake resistant.

We need to think of every aspect of a city's physical environment, and consider not only the fundamental relationship between buildings and land in the city, but also how it varies in different parts of the city, how a city's transportation, communications and utilities, or so-called "lifelines," are laid out, and how they respond to sudden stress and destruction. It should also address land zoning and utilization in the region, open space distribution and the influence of community structures and neighborhood boundaries in the city. It should locate the vital community facilities such as fire stations, hospitals and emergency centers. These plans also deal with the protection of cultural heritage and historic landmarks from destruction. In other words, it touches practically every aspect of comprehensive planning, challenging us to think in terms of both micro and macro environments.

In terms of micro environments, we may have to take a new look at building coverages, open space distribution, street pattern and other elements. For example, we may need to examine cul-de-sac versus loop streets to see whether one pattern offers a distinct advantage over the other. As another example, we may also want to examine building setbacks and streets cross sections to see if some areas need wider streets in order to increase the safety of adjoining residents. The design of pedestrian systems should also be looked at. In Taiwan, for example, there are long debates among the urban designers as to whether pedestrian crossings should be above street level or below street level or both because the island is struck by typhoons every year and is in an earthquake prone zone.

In the macro environments, we are interested in how we may guide urban growth toward areas of less risk and stay clear of high risk areas. We would be interested in ways to render our transportation network less vulnerable to earthquakes. This means considering not only how bridges and roads are designed structurally for greater resistance to earthquake, but also how roads and transit networks may be planned differently. We should be interested in knowing if alternative routes can be found, should one part of the network be destroyed. This may require a totally new approach to the design of transportation corridors, stations and interchanges as well as the inter-modal transfer.

If seismologists can provide more reliable data on the probable location and probability of occurrence of future earthquakes, this data should be used in disaster prevention planning. The data can be used in determining optimum population size and distribution as well as land use activity patterns, which will in turn determine zoning patterns. Places where people congregate such as schools, theaters, churches and meeting halls should be located in the safest practical area with respect to earthquake danger. Critical community facilities such as hospitals, fire stations and emergency centers should also receive equal attention in terms of location. Backup systems should also be developed.

In order to avoid total destruction of the economic base of a community, we will have to rethink the employment distribution. In order to foster rapid recovery in case of an earthquake, we have to look at the location of new business and industry in terms of economic efficiency and seismic safety.

In terms of housing, we may need to re-examine different housing types and how their structural design performs in an earthquake, then redesign them accordingly to give them greater strength. A traditional Japanese house with its wooden structure, through centuries of adaptation to the Japanese geography, has shown to be more resistant to earthquake than a brick building. We may learn a great deal from close study of this adaptation as well as other types of structures which survive earthquakes.

Besides the structural approach, we may find that a different housing distribution from those used today will give a greater resilience. Will it be useful to stockpile prefabricated housing for emergency purposes? Will it be feasible to provide excessive housing capacity and distribute them in such a way that they will not be totally destroyed during an earthquake? Will satellite cities provide a metropolis better protection?

How do we design a city to make sure its cultural heritage and historic landmarks will not be destroyed in an earthquake? Perhaps, this suggests better documentation of cultural assets, or a selected decentralization of them. This may be difficult for historic landmarks. If so, is there any way to reinforce the landmarks without adversely affecting their cultural significance?

If landmarks are destroyed, how can they be properly restored. During the Second World War, 85% of Warsaw's buildings were destroyed. It was a remarkable testimony to the Polish people's vision and determination that they embarked on a reconstruction task which included some of the most outstanding and thorough restoration work ever completed anywhere in the world. How they reached their decision on historical restoration rather than merely new construction wasn't any easy task. Case studies on reconstruction in Poland may offer us some insight and lessons of great value.

Along the same line, case studies on how cities recovered from past earthquakes can be most instructive, for example, Skopji, Yugoslavia. The post-war reconstruction in cities destroyed by bombing offers another important lesson even though the cause of destruction was not an earthquake. Many European cities were rebuilt without adequate attention to long-range goals; as a result they have become inadequate far too soon afther their reconstruction. The urban renewal experience in the United States offer both successful and poor examples of reconstruction. Some aspects of the renewal process may also offer some indirect relevant lessons.

One related point should be made here. A news report noted that in making buildings safe, San Francisco building inspectors were singling out the cornices of many fine old buildings which might be safety hazards during earthquakes. They were considering forcing building owners to remove them. I think this would be unfortunate, if it were true. Hopefully, further study would show there are indeed ways to make these cornices structurally sound or reduce the potential hazards to a substantial degree so that no wholesale removal of the cornices would be necessary.

How do we help protect the ecology of an area, so that it will not be damaged during an earthquake? Area ecology was destroyed during severe earthquakes in Montana (1959), Alaska (1964) and Peru (1970), because these earthquakes caused major changes in the physical environment which in turn drastically altered ecology. The damage done may take years, decades or even centuries to repair.

Closely related to ecological issues would be how open space systems may be used to increase the resilience of a city. Can the system be designed in such a way which might offer more places for residents to escape from a disaster? Can open space be developed that would reduce flood danger, landslides and other hazards after an earthquake?

Although the spatial aspect of city growth pattern and how urban design may be able to increase the seismic safety of the city is important, the time dimension of city activities and how they affect seismic safety should also be considered. During the day, a typical American city has a high concentration of population in its downtown area. This is the time when downtowns are most vulnerable. Eighty percent of the urban traffic is composed of trips to and from work. During rush hours, obviously, the transportation network, particularly the radial corridors may be most vulnerable. For example, the loss of lives in the 1971 San Fernando quake would have been much greater had it occurred several hours later, when the freeways would have been crowded with normal rush hour traffic. On the other hand, during holidays more people are normally away from the city, which makes the city relatively less vulnerable. Perhaps we can think about various parts of the city in terms of its vulnerability during different times of the day, different days of the week and different seasons of the year and develop a plan to help the city be in different degrees of preparedness as required.

Having said so much about making cities more resilient, I should add quickly that it is not the only goal in designing a city in an earthquake prone zone. Other goals such as accessibility to jobs, adequate housing, school and recreation facilities, shopping and other amenities, diversity of environments, sense of community, protection of natural environment, preservation of landmarks, legible visual image for the region and other socio and economic goals should also receive our attention. We need to make certain that we maximize all these goals as we design a city, rather than maximize resilience goals alone.

In addressing the above and other related questions, we have defined a highly complex urban planning and design problem. It will require the efforts of an interdisciplinary team to address the problems adequately. Urban designers, architects, landscape architects, planners, civil engineers, seismic geologists, sociologists, economists, lawyers, ecologists and many others all can make important contributions to help solve the problems. Most likely, we shall also need the assistance of system analysts and computers to help us simulate possible earthquakes and calculate risks for different city designs. From these a preferred comprehensive plan can be devised with seismic safety fully integrated with other considerations.

In a democratic society like America, advances in planning are not made simply because the prefessionals know more about how to do a specific job better. It also depends upon the public awareness and support as well as civic leadership and vision. Only then can proper legislative mandate be provided, administrative mechanism set up, and financial resources mobilized to address the question. In other words, the technological advances in any field may not be used to solve the problems in that same field, unless they are interpreted and adopted in policies by that level of government which normally decides upon those issues.

For example while significant advances were made in cognitive psychology (which deals with legibility of visual forms) there was little application of this knowledge in helping cities develope more scientifically based sign ordinances. It was not until approximately eight years ago, when one United States city ran into great controversy in dealing with the preparation of a new sign ordinance that the professionals and the citizenry in that city were able to obtain enough local resource, get enough study time and retain outside consultants (including cognitive psychologists and others) for assistance. A scientifically based sign ordinance was drawn up for the first time. After two and a half years of hard battle with the sign industry, the community was able to marshal enough broad community support, including businessmen and environmentalists, to get their city to adopt the ordinance.

Thus, in dealing with urban design problems we are not merely concerned with the product of design, but the process as well. We're not only concerned with the specific design framework we may have devised for a city, but are also deeply concerned with urban design mechanism, including legislative framework, administrative organization and the staff capabilities, which can help to carry out the design framework. Otherwise, the design may remain on the shelf as has happened so often. This brings me to my final point -- unless and until we have developed strong urban design mechanisms in local governments, our effort in getting better city design will not be successful.

Increasing numbers of American cities such as Baltimore, Minneapolis, Dallas and Seattle are now strengthening their design mechanism. These are also the cities which benefit the most from better design. In these cities, urban designers often play a multiplicity of roles. They are able to work as members of the city management team and influence the city's decisions in many diverse areas--from environment management to preservation, from streetscape to sign ordinance and from neighborhood conservation to downtown revitalization. Cities in the earthquake prone areas may learn from these cities with effective design mechanism, and then add the specific function of earthquake hazards reduction as one of their basic design concerns. Only then can the plan drawn be more comprehensive and effective; and a living city of beauty and charm, of opportunities and resilience be created.

In summary, let me make four points:

1) Seismic safety shouldn't be addressed in isolation from other urban issues. Seismic design elements should be part of the city's comprehensive plan and urban design framework.

2) "Structural approach" alone will not be adequate; we need to have a balance between structural and non-structural approaches to reduce the risk. The structural approach

relies primarily upon making existing structures more earthquake resistant, which the "non-structural approach" relies on various means in making cities more resilient to earthquake and other disasters.

3) Much advancement has been made in urban analysis, land use, planning and environment management in the last ten years. We don't need to reinvent the wheel. What's needed is to integrate risk analysis with urban analysis.

4) We need to build up urban design capabilities in local government. Experiences in the U. S. and Japan have shown those cities with built-in design capabilities are more likely to provide more effective responses to seismic or other urban design concerns.

IDENTIFICATION OF URBAN DESIGN ISSUES FOR ACTION

RONALD A. STRAKA

INTRODUCTION

Urban Design and Architecture are "Arts of Context". They deal not only with the natural and man-made physical characteristics and infra-structural elements, but also with traditional and cultural contexts including social, economic and political forces which determine and shape the character and quality of life in our communities and regions. The area of Seismic Concerns is also contextual in nature as it impacts these same elements. It is therefore essential that we have a basic understanding of the scope, inter-relationships and potential opportunities that exist in these contextual fields of study. It is necessary to identify the commonalities and differences that exist between participating countries and cultures so that the appropriate linkages can be explored and delineated. Thus a meaningful transfer of ideas and information can be made, and joint research opportunities identified.

Although the basic foci of Urban Design & Seismic Concerns have different and varying roots, each has an important impact on the other and can determine the physical form of our cities. Their impacts deal with a wide range of issues including; a) large scale regional policy, b) local social economic considerations and decisions, and c) building techniques for our cities and places of residence. However, analysis of these areas of study reveal that both countries share similar experiences, namely:

1) There is no common awareness, acceptance or support at a large scale for these concerns by government, federal agencies, design professions or by the common man in the street because they are not high priority issues.

2) These concerns, although national in scope, are regional (applicable to areas of the country which are prone to earthquakes) and long-range in nature. They are also policy-oriented, and somewhat out of phase with more pressing economic, social and political concerns.

3) Reactions are usually short term and single-purpose in nature.

4) They are not exact sciences and therefore have no set formulas, rules or cookbook approaches which can be applied across the board. Rather, general frameworks have been established which respond to regional and local concerns.

Therefore, in dealing with Urban Design & Seismic concerns, some basic questions must be addressed in order to identify potential linkages and common ground. These two disciplines may collectively approach the issues of a) how we deal with the concerns of both, but not at the expense of the other, and b) how to create a quality environment in which we can live with safety and peace of mind. Some of these questions are:

1) What can Urban Design do regarding seismic concerns?

2) How can Seismic Concerns contribute to the urban form and quality of life within our cities and environments?

3) How can these two disiplines work together and share their knowledge, ideas and resources to give direction and assistance in the various phases of potential disasters?

THE URBAN DESIGN PROCESS: FOCUS OF OPPORTUNITY AND ACTION

The interdisciplinary approach of the "Urban Design Process" offers us a method of combining the resources and expertise of two fields to establish a framework and a context for urban design and seismic concerns. It will also help to identify the context and criteria by which alternative approaches and options are delineated and the appropriate actions and strategies for implementation. This open-ended, on-going process utilizes design as a creative tool for problem solving, focusing on a) learning what to do rather than creating a built artifact, and b) meaningful citizen involvement at key points to build an awareness for the issues and a base for action. The process is ultimately shaped by the issues to be addressed and the people who are affected by its actions, maintaining the flexibility to respone to: 1) regional and local differences and uniqueness, 2) a variety of scales and contexts, 3) participation and feedback from the various groups within the public and private sectors, 4) professional organizations, 5) general public and 6) communication and education of the people involved in the larger context of the issues and opportunities available to them in approaching the problem.

The urban design process is not an end in itself. It leads to direction or action on issues addressed, which may in turn lead to products in the built environment. With this brief general description of the Urban Design Process, one can see some of the basic linkages and connections that can be made from the specific local level urban design concerns that could help to determine appropriate larger scale policies and programs.

OPPORTUNITIES FOR ACTIONS

To identify potential areas of research, one must first have a feel for a) current state of the art, b) previous research efforts in these areas of study, c) research opportunities available, d) differences between research efforts in urban design and seismic concern and e) applications of research efforts to the various phases of disaster (pre-disaster, during-disaster and post-disaster).

Historically in America there has been an imbalance in the amount of research efforts and opportunities between the sciences and the design fields. Currently this imbalance holds true in the relationship of seismic/natural hazard research and urban design research especially in the effort to establish the linkages between the two concerns. It is important to understand the context in which urban design research must be carried out and how it is different from research in other fields. Research that exists has been marked by common deficiencies of being irrelevant, out-of-date, inaccessible and un-shared. It also ignores the needs of local government and lacks both the use by government and a coherent framework from which the various research findings can be evaluated and related.

The nature of urban design research is contextual. The urban designer must be concerned about the consequences of everything he does. Therefore, experimentation done in urban design must be of a type that allows corrected failures to eventually become workable. This type of applied research must be done by people in the field or by an integrated, inter-disciplinary team of professionals and researchers who understand the context of the urban design process and what can change as; a) the experiment changes, b) goals change and c) feedback indicates new possibilities or needs. Many urban designers are not researchers and vice versa. In order to implement effective Urban Design Research and insure a means by which the research findings are used by practitioners and local government officials, it is necessary to make the needed linkages with a) the disciplines that deal with the aspects of the problem, b) the levels of government that might implement the recommendations and c) research institutions and federal agencies which fund research programs and determine public policy.

In order to address these research needs, we must develop a "Culture of Applied Research", not just a research effort or program. We must change some of our attitudes towards research. In dealing with the concerns of Urban Design and Seismic Safety the research effort breaks down into two or three distinctive areas where different types of research and assistance might be required.

The first area of concern and perhaps the longest range effort deals with the preventive measures in the pre-disaster time frame. They range from large scale issues of where and how to build in various earthquake zones, to scenarios and guidelines for future settlement patterns. Mitigation treatment of existing settlement in fault areas and locational decisions on facilities to measure the seismic controls of building codes on individual buildings should also be examined.

The second area of concern is to determine if there is a role for combined research effort in the during-disaster period. This may include a Red Cross type effort to provide safety, health, shelter, etc.

The third area of concern involves the reconstruction and redevelopment of the disaster area. In this period, major decisions are made to build back in the same area and in the same way or to evaluate previous decisions and rebuild in a different manner or possibly in a different place. Disaster Assistance and a framework or process for decision making would be most helpful to communities who experience all forms of disaster.

In order to relate previous research efforts and concerns of the various groups, a context and framework for this research effort should be established. Overall research management strategy that will coordinate the effort 1) gives direction, 2) defines roles and levels of quality, and 3) establishes a network for communication of the research findings with policy formulation; and funding should be established.

The following recommendations for consideration as potential major research categories are made in order to identify areas of joint research. Some of these urban design research efforts would apply to all natural disasters and some specifically to seismic:

A) Awareness/Communication/Education

Currently there are a number of public/private, national/regional agencies and programs that deal with many aspects of a disaster. Unfortunately these efforts are unknown, uncoordinated and in some instances, a duplication of information.

Actions

1) Develop a context, framework and research management plus assistance program strategy for urban design and natural hazard research. Identify on a national basis for appropriate linkages with the Federally Assisted Programs that are working in the area of pre- and post-disaster planning.

2) Identify appropriate roles, programs and new partnerships for the various organizations and "actors" which are involved in the urban design process and seismic research. Combine and utilize their resources and talents:

    a) Government agencies: Federal, regional and local government level (i.e. Federal Emergency Management Agency.)

    b) Public and private organizations and special interest groups

    c) Professional organizations: international, national and local component groups (AIA, APA, ALSA, ULI, etc.)

    d) General public and volunteer organizations

3) Develop a network of international, national and regional research and communications centers for urban design and natural hazards to serve as a focus for applied research. (A center for data and resources of facilities unique to the area and a center for educational and technical assistance programs.)

4) Develop a simple and quick way of communicating urban design and seismic concerns to professionals, citizens and decision makers.

Education

In schools of architecture, design, engineering, landscape architecture, behavioral science, etc., interdisciplinary courses should be taught as part of the core curriculum to deal with the issues of "contextual architecture". The necessary connections between the natural hazards and the natural and built environment as determinants of urban form should be made.

Professional Organizations

The two national professional organizations of architects, the American Institute of Architects (AIA) and its Japanese counterpart, should develop their own programs, identifying areas of concern and developing programs that respond to needs and deficiencies at a national and local level.

B) Urban Design Research Issues

1) Investigate new urban forms and infrastructural determinants which relate urban design concerns to seismic concerns (i.e. development, redevelopment and reconstruction; transportation, energy, settlement patterns, land use and human values, etc.)

2) Identify areas of commonality between urban design and seismic concerns by delineating the framework establishing a common ground for future research and information sharing.

3) Identify methods for mitigating or re-structuring existing environments to accommodate urban design and seismic concerns.

4) Develop prototypical design guidelines for various natural hazards for different regions of the country, with appropriate policies, strategies and actions.

5) Develop criteria for the location of new settlements, growth and key facilities within hazard areas.

6) Develop a series of case studies and scenarios using existing US/Japanese cities as examples of the type of urban design issues, tools and mechanisms that may be considered in various phases of disaster.

C) Urban Design Management Tools

1) Develop a series of management tools and models for local and national governments to coordinate various public programs which directly or indirectly relate to urban design and seismic issues.

2) Develop, coordinate and manage a program of interdisciplinary technical assistance to local and regional governments.

3) Develop policies, programs and mechanisms on an international national, regional and local basis to respond to the various phases of natural hazards.

4) Develop the proper strategies, criteria and incentives for urban design/seismic development/redevelopment.

5) Develop a process for evaluation of urban design and seismic concerns before the reconstruction and redevelopment process begins.

6) Monitor and evaluate the cost, benefits and impacts of such measures.

These suggested actions are not intended to be all-inclusive, but a starting point to investigate our collective knowledge and creativity to reach some acceptable solutions to the issues of urban design and seismic safety.

POTENTIAL RESEARCH PROJECT:

Select two cities, one in the United States and one in Japan (i.e. San Francisco, Tokyo, etc.) that lie in major fault areas and use these cities as research case studies and laboratories for interdisciplinary teams of professionals (Japanese & American):

1) Delineate an urban design process for research and evaluation of the results.

2) Establish a framework plan for each city to identify the major infrastructural elements (i.e. social, economic and political contents and an appropriate set of goals for the community).

3) Develop a series of conceptual alternative action scenarios and the accompanying results that the community might consider in case of a seismic disaster.

    a) If nothing was done, the potential cost in lives and property.

    b) If preventive measures were taken within the existing context to reinforce or relocate certain facilities/ provide refuge areas, etc.

    c) Should reconstruction occur in the same place and manner as before.

    d) Should reconstruction occur in a new place with different building forms, settlement patterns and a different technology.

4) Evaluate and measure the positive and negative impacts of these actions.

5) Develop appropriate design guidelines, policies, strategies and actions for each scenario.

6) Develop a process which addresses key reconstruction issues and a time table for the reconstruction. Identify the type of assistance program that might be required and when it might be most effective.

7) Compare and evaluate the results of the project and readjust the research and urban design processes as required.

8) Publish and communicate the results of the effort. Identify what variables exist, what items might be transferable and further research efforts.

POTENTIAL NAIA AGENDA FOR URBAN DESIGN AND SEISMIC CONCERNS

Building upon the recent experiences of the Johnstown (Pa.), flood, the Louisville (Kentucky), Xenia (Ohio) and the Wichita Falls (Texas) tornadoes, the NAIA needs to recognize the growing concerns of the primary and secondary impacts of disasters upon the natural and built environment. It should also address the issue in a positive manner by incorporating these concerns into its policies, education and communications programs at the national and grass-roots levels, and also in its budgeting process. Many of the mechanisms exist to implement these recommendations but priorities and direction and primary requirements/concerns. Some of the recommendations are sequential and some can be carried on concurrently.

1) Research:

    a) Expand the AIA's effort "Architects and Earthquakes" which primarily deals with individual buildings. Look at the larger issues of urban design and seismic concerns and how they effect the design of neighborhoods, communities, regions and infrastructural elements.

    b) Work with other professional disciplines (i.e. sociologists, economists, engineers, geographers and etc.) to determine the impacts of some of the building code recommendations regarding seismic concerns.

    c) Define future research areas.

2) Communications/Publications: Develop a series of simple and to-the-point publications which communicate to a variety of audiences the urban design and seismic concerns (natural hazards). A series of techniques and medias may be used and should be distributed to elementary schools, colleges, volunteer groups, civic organizations and interprofessional groups.

3) Disaster Assistance: Expand the current effort of the Disaster Assistance Committee of the AIA's Urban Planning and Design Committee into Phase II of its program, by establishing and funding a task force centered around the Disaster Assistance program building on the Xenia, Wichita Falls and Texas Society of Architects (TSA) experience.

It should:

a) Determine what different types of assistance is needed and at what time.

b) Establish a process for giving assistance to communities who ask for it.

c) Develop and mobilize the resources required.

d) Determine a methodology for implementing assistance to communities.

e) Organize a process for communicating these programs and resources to the local grass-roots components.

f) Assist in setting up a network of regional assistance programs which coincide with the AIA's regional structure or the federal government program.

g) Devise a process of evaluation and monitoring of the assistance program.

4) Education: Incorporate these concerns into the AIA continuing education program, recertification etc.; through workshops, seminars, films, etc.

5) Policy:

a) Adopt an urban design policy statement which addresses these disaster issues along with other concerns of energy, transportation, etc.

b) Develop a "white paper" or issues-type paper (8 pages) on a Disaster Policy Statement for the AIA (similar to the Housing Policy Statement). This can be a further deliniation of the policy statement.

CRITICAL PROBLEM AREAS & RESEARCH NEEDS

FREDERICK KRIMGOLD

The Earthquake Hazards Mitigation Program of the National Science Foundation is part of the Problem Focused Research Division of the Directorate for Engineering and Applied Science. Earthquake engineering research was originally initiated in the Engineering Divison of the Foundation in the early 1960's. With the occurrence of important damaging earthquakes in Alaska (1964) and San Fernando, Califorinia (1971) research interest and the national importance of earthquake mitigation research increased.

In the fall of 1977, the President signed into law the Earthquake Hazards Reduction Act of 1977.

The purpose of the Act is to reduce the risks of life and property from future earthquakes in the United States through the establishment and maintenance of an effective earthquake hazards reduction program. The objectives of the program include the development of technologically and economically feasible design and construction methods and procedures to make new and existing structures, in areas of seismic risk, earthquake resistant. Emphasis is placed on the development of research on A) ways to increase the use of existing scientific and engineering knowledge to mitigate earthquake hazards; B) the social, economic, legal and political consequences of earthquake prediction and C) ways to assure the availability of earthquake insurance.

The two agencies of the Federal Government which have had major responsibility for the research component of the Earthquake Hazards Mitigation Program have been the National Science Foundation and the United States Geological Survey. The Geological Survey has had primary responsibility for the basic geological and seismological research relating to hazard mapping and earthquake prediction. The U. S. Geological Survey has had primary responsibility for the basic geological and seismological research relating to hazard mapping and earthquake prediction. The National Science Foundation has had primary responsibility for earthquake engineering research and research on societal response to natural hazards.

The Earthquake Hazards Reduction Act includes research elements relating to development of information and guidelines for zoning land in light of seismic risk in all parts of the United States and preparation of seismic risk analysis useful for emergency planning and community preparedness. It also specifically emphasizes research for development of methods for planning, design, construction, rehabilitation, and utilization of man-made works so as to effectively resist the hazards imposed by earthquakes. In the area of social science research, the Act calls for exploration of possible social and economic adjustments that could be made to reduce earthquake vulnerability and to exploit, effectively, existing and developing earthquake mitigation techniques.

The Act has provided the basis for a significant expansion of earthquake required by the Federal Government over the past three years. Every important part of this expansion has been the extension of topic areas for research to include architectural and planning research. The NSF program is now structured under two headings: "Engineering, Architecture and Urban Planning" and "Societal Response."

The Engineering, Architecture and Urban Planning Element is subdivided into fifteen subtopics as follows:

1) Analysis of destructive earthquake ground motions.

2) Instrumentation for strong earthquake ground motion.

3) Geotechnical earthquake engineering.

4) Analytical methods for structural response.

5) Structural properties for experimental tests.

6) Existing hazardous buildings.

7) Non-structural and architectural systems.

8) Architectural and planning influences on earthquake vulnerability.

9) Seismic effects on coastal and inland waterways.

10) Seismic effects on lifeline facilities.

11) Post-disaster earthquake studies.

12) International cooperative research.

13) Information transfer.

14) Dam Safety.

15) Earthquake effects in relation to other natural hazards.

Of these subtopics, six are of particular relevance for Architecture and Planning researchers:

Existing Hazardous Buildings. The greatest threat to life safety in earthquakes is associated with the expected failure of those structures which predate the establishment of modern aseismic regulations. Many of the residential and commercial buildings in older downtown areas of cities such as Los Angeles, San Francisco and Seattle on the west coast are considered highly vulnerable to earthquake shaking because the first regulatory approaches to aseismic construction date only from 1930's. East of the Rocky Mountains, the existing building problem is even greater because, though the level of seismic activity is relatively lower than in the west, actions to improve construction for earthquake resistance have only been initiated in the past decade. The strong trends toward historic preservation and recycling of existing structures stand in direct conflict with the ambition of earthquake hazard reduction. Considerable research is necessary to resolve this conflict and to develop safe and economical retrofit techniques.

Non-Structural and Architectural Systems. The great bulk of earthquake engineering research in the past has been directed to avoidance of structural failure or collapse as this was considered the major threat to life safety. However, it has been demonstrated in recent earthquakes that major economic loss has been incurred as well as severe injury in buildings which did not suffer significant structural failure. In the San Fernando Earthquake, it has been estimated that the greatest dollar value of damage was suffered in non-structural elements of buildings.

These findings indicate that considerable research must be directed to reducing the failure probability of building components, electrical, mechanical and architectural systems.

Architectural and Planning Influences on Earthquake Vulnerability. The disciplines of architecture and planning combine understanding of the physical and natural science aspects of construction and resource management as well as the social and behavioral aspects of occupants and users. Architectural configuration must accommodate both the intended socially determined uses of buildings as well as the physically determined structural system. As these objectives often appear in competition for limited resources, means need to be developed for guiding design decisions to provide maximum safety at feasible cost. At the larger scale of Urban Design and Urban Planning much research remains to be done for the reduction of damage to lifeline systems and other threats to the survival of urban services following earthquakes. At the scale of urban and regional planning methods must be developed for introducing geotechnical information in to land use management and to the direction of development patterns to minimize further earthquake exposure.

Seismic Effects on Lifeline Facilities. Concern for seismic effects on lifeline facilities has expanded significantly in recent years. While early work in earthquake hazards mitigation was confined to the avoidance of structural failure in individual buildings, it is now recognized that the secondary effects of urban systems failure may be as great or greater than direct losses due to earthquake shaking. Fire following earthquake in the absence of water and power supply systems poses a very serious problem. Lifeline facilities by their nature as extended network systems suffer a higher probability of experiencing earthquake effects. Furthermore, it is the nature of network systems that the failure of a single element will impair the function of the entire system. Particularly important in the evaluation of seismic risk in lifeline systems is the understanding of expected social and economic impacts of failure. Such evaluations require a thorough understanding of the complex interactions of urban systems and the social consequences of systems failure.

Learning from Earthquakes. The analysis of damage following earthquake has provided the most important data for improvement of understanding of earthquake effects and structural failure patterns. The structural engineering research community has made extensive studies of earthquake damage around the world.

To date, there has been only very limited participation by architectural and planning researchers. Post earthquake damage analysis is possibly the best source of insight into the patterns and mechanisms of non-structural failure. It also provides an understanding of how systems interact in the real world where materials and construction techniques may vary considerably from those of the laboratory. Architects and planners working in conjunction with social science researchers should also be able to develop a better understanding of the social significance of damage impacts.

International Cooperative Research. Fortunately, earthquakes are relatively infrequent in any particular country. However, this makes them difficult to study. In order to accumulate adequate data earthquake researchers must utilize an international network of data collection. As much as possible in the way of new knowledge must be extracted from each earthquake experience. Bilateral research programs are currently being developed with Japan, China and the Soviet Union. Efforts are also underway to facilitate the development of cooperative research efforts with researchers in Europe and the Middle East. Proposals are currently under consideration for expansion of cooperative research efforts for earthquake hazards mitigation in developing countries.

For Architecture and Planning researchers these international cooperation research activities have added importance. Not only is there the potential of significantly expanding the data base for non-structural failure studies; there is also a great deal to be learned from the earthquake mitigation policy approaches developed in other countries. There is a general benefit to be derived from establishment of cooperative research agreements between planning and design researchers in this country with their counterparts abroad.

The National Science Foundation Earthquake Program will receive unsolicited proposals at any time. The proposals should follow the format provided in the Guidelines for Preparation of Unsolicited Proposals. Proposals are subject to peer review and program evaluation. The processing of proposals generally requires six to nine months.

For further information, please contact:

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SECURITY OF CITIES & EMERGENCY ACTION

KIMIO TAKANO

PREFACE

Edo, now called Tokyo, was noted for frequent fires. It was said that Edo merchants were always ready to order construction materials for rebuilding due to destruction by fire that occured every three years. Most citizens lived with resignation, regarding fire as unavoidable. Streets were filled with beggers and street-girls trying to avoid starvation. It is reported that the misery of these people remained the same for about 3 years after the fire; whereas the houses were rebuilt and Edo was renewed within 2 years. The history of Edo seems to be a series of destructions by earthquake and fire and recoveries from them.

In the 20th century, Tokyo experienced two disasters which caused great loss of life and property. One was the Kanto Earthquake of 1923 and the other the bombing attack of World War II. Tokyo recovered from the war and now faces a predicted seismic catastrophe that may occur in the near future.

Because the present state of urban life increased the vulnerability of a community that has undergone great change, it can easily be imagined that the destructive power of an earthquake would disrupt life-support systems, causing confusion and possibly triggering a secondary disaster.

COUNTERMEASURES

In general, a disaster is considered in terms of loss of life and property, but in a broader sense, it includes also the destruction of life-support systems. Therefore, when thinking of countermeasures against seismic disasters, we should place more emphasis on this aspect. The following are three fundamental countermeasures against seismic disaster.

1) Reduce damage to living spaces
2) Secure the safety of inhabitants and life-support systems
3) Assure the early restitution of living conditions

These countermeasures may be considered from various standpoints and will be addressed here from the viewpoint of a city planner.

LIVING SPACE DESTRUCTION AND EMERGENCY PLANNING

1) When existing social functions collapse, people need substitute agencies to keep social order.
2) When the living environment is on the brink of ruin, people need safer places to shelter themselves.
3) Before and during an earthquake, people try to defend themselves from the disaster. Space, property, human relations, etc. will become important factors.

The three patterns mentioned above appear at the moment of disaster, creating various needs on different levels. We need a new approach (emergency plan) based on human relations, space, property, etc. In other words, an emergency plan is a total policy for defending ourselves against the disaster and for maintaining life-support systems. In case of emergency, we should provide all the measures and services necessary to replace the existing ones, and should also take into the consideration the maximum use of facilities and space which have escaped destruction. The emergency plan can also be regarded as a basis of city planning and a safety standard for securing civic life in case of disaster. Each region and city should have its own emergency plan. The following viewpoints are important in studing an emergency plan.

1) How the existing structure is protected against disaster
2) How the existing structure could be improved to cope with future disaster

CONSIDERATIONS FROM CASE EXAMPLES OF DISASTER

In order to clarify the concept of an emergency, three examples of disasters that have recently occured in Japan will be examined.

1) SAISEIKAI HOSPITAL, 1973

Thirteen patients were burned to death, by a fire that broke out at night, while 224 others were rescued. The fire at the Saiseikai Hospital was a lesson in city planning as well as disaster prevention in high buildings. The help provided by inhabitants of the vicinity in the rescue operations suggested a question of mutual relations in the community. Since the fire occured at night, there was only a small staff on duty. The hospital was in a densely built-up area, which could not facilitate a prompt rescue, nor provide enough relief and protection for the victims. Under this situation, the cooperation of local residents played a key role. They offered their houses, inns and public bath house as first-aid stations. The bath houses, in particular, received many patients, and was said to have been very useful.

The Saiseikai Hospital Fire was a good example of an aspect of an emergency plan. Destruction by the fire was held to a minimum by the cooperation of local residents. This was possible because the hospital had been in close contact with the local residents during ordinary times. The human relations in the community during ordinary times is a decisive element in the dimensions of damage. If there had not been mutual relations like this, the Saiseikai Hospital Fire would have been much more serious with a large number of deaths.

2) THE SAKATA FIRE, 1976

The Sakata Fire, considered one of the biggest fires of the postwar period, occured 3 years ago. 22.5 ha of the center part of Sakata city was burned down, and 1016 families (3270 people) lost their houses. One person, a fire chief, lost his life. In the case of this fire, in spite of serious damage to property, the life of the citizens did not fall into utter confusion and resumption of normal life was comparatively smooth. The Sakata Fire broke out in the evening, and an all-out effort to fight the fire continued until the next morning. The fire occured in October, with a severe winter expected to follow shortly. The city authorities and regional societies, taking a leading role, devoted themselves to the relief of the victims, and received assistance from all over Japan. The following measures were taken by the city authorities during the 90 days after the outbreak of the fire.

The moment the fire spread, the city authorities designated six buildings as shelters. Since the number of users was small, the shelters were closed only 6 days later. After

20 days, construction of prefabs was undertaken, with commercial activities reopening at temporary stores 30 days later. 290 families, or 39% of the total victims, used these facilities, while the rest either found shelter with friends and relatives or provided for themselves.

A feature of the Sakata fire is the fact that despite heavy material damage, the life of the citizens was not thrown into chaos. This could have been attributed to the following:

a) It as a limited disaster in comparison with the dimensions of the city. The disaster-stricken area was comparatively small and therefore, facilities, space, lands and administrative agencies that had been spared the destruction could continue their functions during the relief and reconstruction work.

b) The municipal office survived the fire, and important documents relative to the residents and their estates remained safe. The reconstruction work was carried out promptly and without trouble.

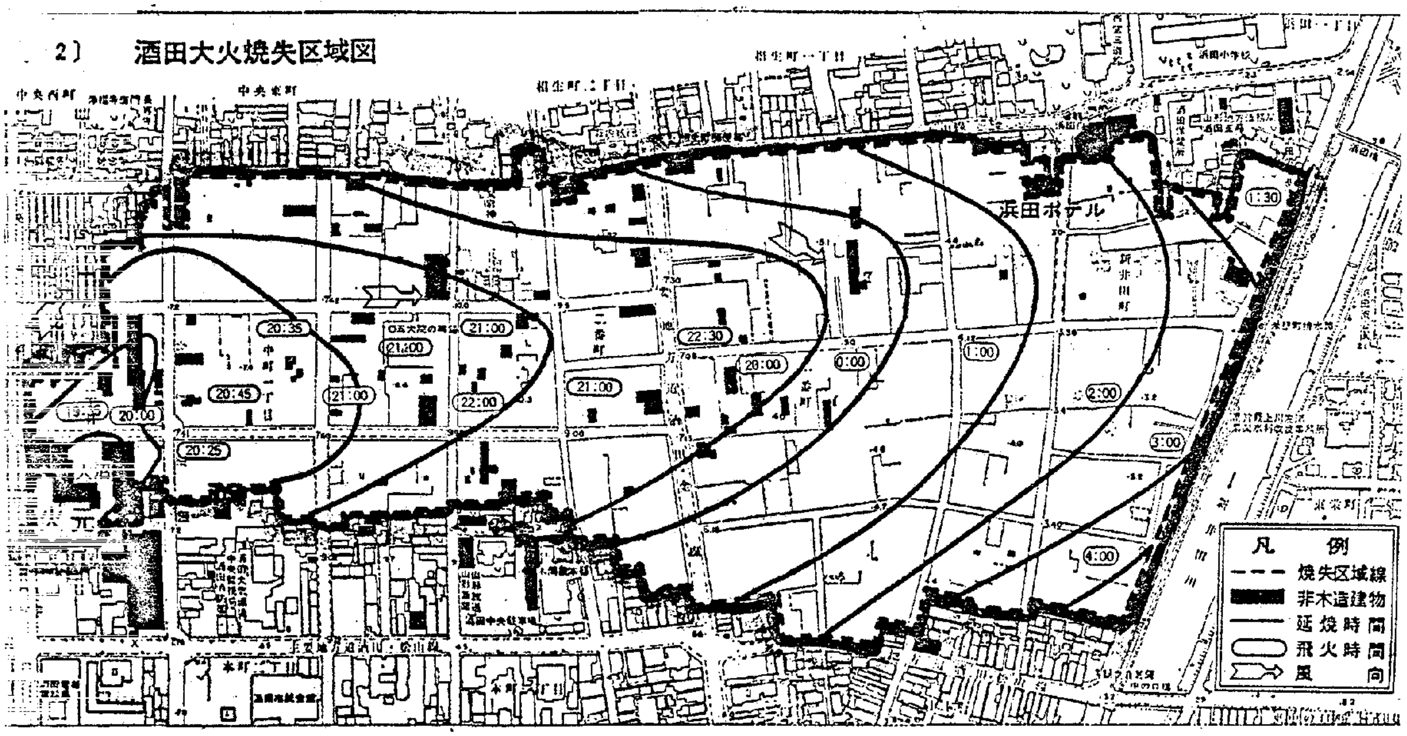


chart 1. Burned down area of the SAKATA FIRE

The prompt restoration of Sakata city was due to its structure and to human relations within the community. The mutual concern for security brought within the territorial society as a trait of local city as were the large superficies of unused lands.

3) THE MIYAGI PREFECTURE OFF SHORE EARTHQUAKE, 1978

Last year in June, an earthquake (of 7.4 magnitude, the 5th degree on the seismic scale) hit Sendai city, and caused damage to both the city itself and the lives of its citizens. The following is a summary of the features of this seismic disaster.

a) The destruction was concentrated in newly developed hill areas, lowlands and a portion of the urban district. Serious damage was not registered in the center of Sendai city.

b) Water and electric supplies were stopped, and the railroads were immediately paralyzed but were restored in a day or two. However, gas service took more than 20 days to be restored.

c) Detailed information about the disaster over the radio was very useful in calming the citizens during the disturbance.

d) Of the several fires that broke out, none developed to levels of serious proportion.

e) A traffic jam in the center of the city lasted for 4 hours. No other problems were reported after this incident.

f) Of the 13 deaths reported most victims were crushed to death under fallen walls made of cement blocks.

The damage caused by the Miyagi Prefecture Off Shore Earthquake was relatively light relative to its magnitude. If an earthquake of the same magnitude were to strike another metropolis, it is difficult to estimate the extent of damage that might occur.

<u>OBSERVATIONS</u>

Chart 2 is the result of research on damage to principal residential areas, showing the process of recovery. The damage to each area has its own unique features. A month after the earthquake, all areas regained their original status. The results of the investigation are as follows:

1) The urban district built on the solid ground suffered only light damage.

2) Damage, building destruction and casualties, in the lowland area was heavy.

3) When the earthquake struck, nearly all the people were at home or remained in the vicinity.

4) A number of residents of apartmenthouse complexes spent the night outdoors. Many cars were used as shelters, and the car radios served as sources of information.

5) Residents of apartmenthouses felt more fear of the earthquake than others.

6) Community activity was more energetic in the public housing compounds.

7) Citizens made little use of public facilities, even in the area that was badly damaged. They did make use of gathering places in the vicinity, such as little squares and friends' houses.

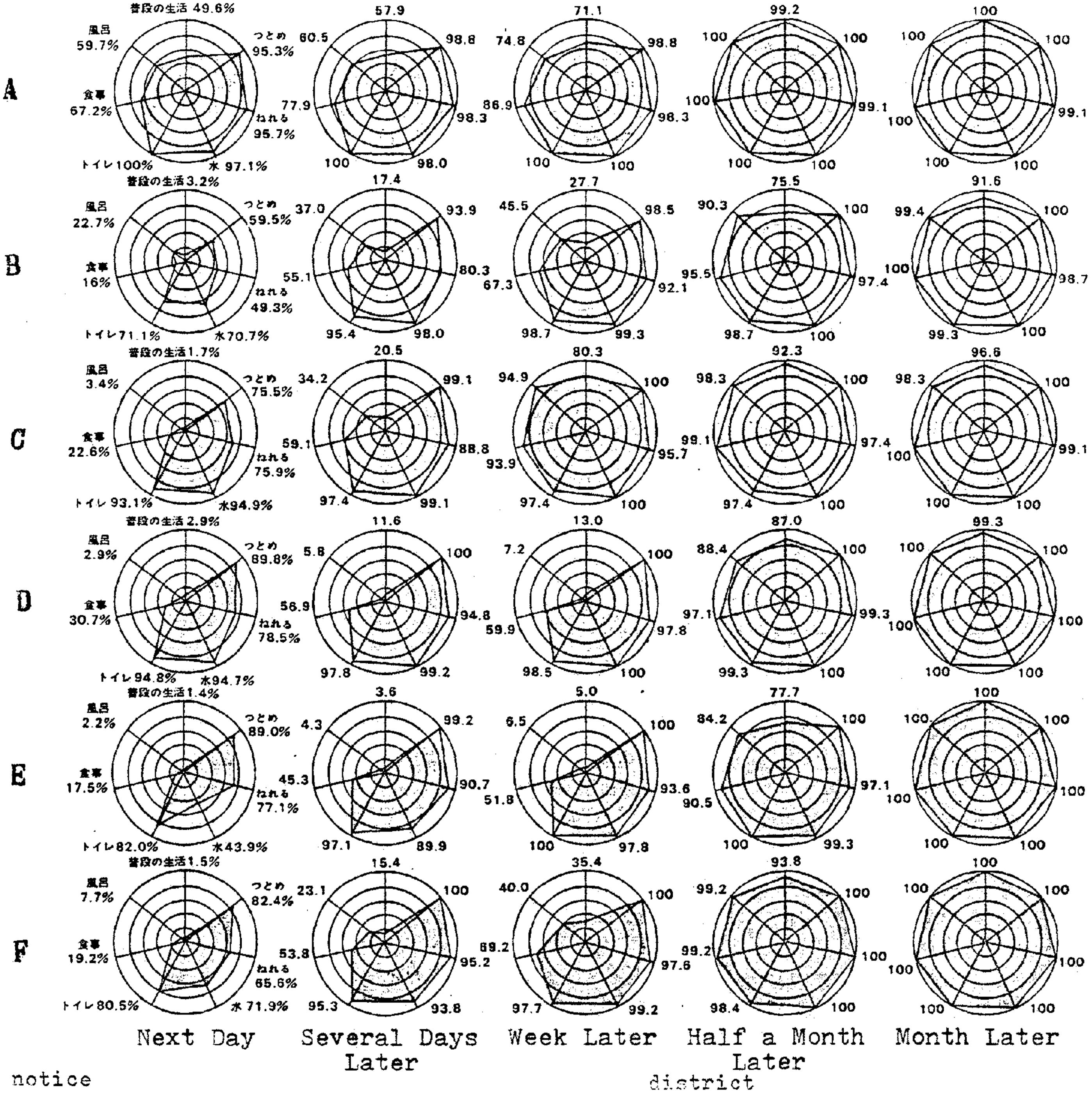
8) The news that the homes for the aged would be open to the public relieved the old people of their anxiety.

9) In a portion of the central area, water supply was inadequate. Residents made up the shortage by using water left in the tanks of high buildings and banks.

10) The shortage of water was a cause of problems especially for families with sick persons and babies.

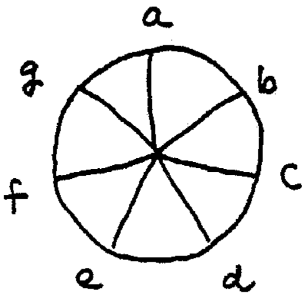
11) Learning from past experience, the citizens felt that water supply, neighboring open spaces, help from local authorities and mutual cooperation as necessities for safety.

12) They regarded their own family, themselves, and neighbors as the most important in the human relationship.



notice

district



a normal life

b work

c sleep

d potable water

e toilet

f meal

g bath

A. first-class residential area

B. downtown (lowland old quarters)

C. multistoried building area

D. suburban residential area

E. "

F. central area of multistoried buildings

chart 2. THE DAMAGE AND THE PROCESS OF RECOVERY

CONCLUSION:

The earthquake triggered various problems, but on the whole civic life was saved from confusion for the following reasons:

1) Damage to life lines such as water supply, electricity and traffic was light, with normal service resuming quickly.

2) Mass communications and administrative agencies could cope with the needs of citizens without delay.

3) Mutual reliance and social solidarity had existed among the citizens before the earthquake.

4) Sendai city is well-planned and spacious and also has a long tradition. These fundamental factors did much for the public safety.

SEVERAL PROBLEMS OF LARGE CITIES

Taking into account the 3 cases the following questions dealing with safety of metropolises in the seismic disaster (assuming an earthquake of the same or slightly greater magnitude as the Miyagi Prefecture Off Shore Earthquake) would be of concern:

1) Is the plan against damage to the so-called life lines, water, electricity, etc., sufficient? Is short-term resumption possible?

   In the case of Sendai city, citizens ran out of the water in the tanks within one day. If the suspension of water supply extended over a long period, the inhabitants, in particular those of the city center, would not be able to live there.

2) Can the radio offer detailed and accurate information?

   In Sendai, the detailed information put on the air was effective. However, the same cannot be expected in a metropolis, for they are too large and too complicated. Therefore, the shortage of information would result in more serious disturbance and confusion.

3) Are administrative agencies capable of acting promptly?

Under the present situation, prompt action is doubtful, because nearly all the public servants live outside large cities (absence of staff at night) and because the vertical structure of administrative agencies would be an obstacle to prompt action.

4) What about countermeasures against the outbreak of disaster in the wintertime?

Places to sleep, heat sources and so on will become serious problems. It as June when Sendai was hit by the earthquake. If it had happened in the wintertime, finding shelter would have been much more difficult.

5) Is it possible to gather social solidarity akin to the case of the Saiseikai Hospital Fire and the Sakata Fire?

Can the present life in a metropolis bring forth mutual aid and mutual reliance among the people?

As mentioned above, a metropolis is faced with serious danger, even in the case of medium-sized earthquakes.

COUNTERMEASURES AGAINST SEISMIC DISASTER AND SOME PROPOSALS

1) Lay emphasis on the mutuality of the society.

Human society is made up of various mutual relations among people and the life space itself is a complex of various elements. Even under normal conditions, society is complicated in structure. In the attempt to tackle the seismic disaster, we should not forget this complexity and mutuality that our society has. Each problem that springs up in the emergency should be solved independently as well as in relation to the whole. Social solidarity and mutual reliance in the community are prerequisites for the systems approach.

2) Concrete measures for emergency plan.

The second point is concrete measures for emergency use of space and facilities, including places of refuge, sleeping accommodations, meeting places, first aid stations, information sources, temporary administrative agencies, fire fighting equipment and water storage. These are the minimum conditions for safety, and each area should be equipped with them. The following are some examples of important facilities.

1) Public facilities such as schools, facilities for community activity, homes for the aged and preschools,etc.
2) Private facilities such as assembly halls, public bath houses, private dwelling, offices, supermarkets, etc.
3) Little squares, unused lands, areas surrounding shrines and temples, tec.

When civic life suffers great damage, public facilities as well as a few private facilities play an important role, and are also required for emergency use. An inventory of the buildings that can be used as shelters is one step for safety.

3) District as a unit for the emergency action.

In mapping out the emergency plan, we should fix the boundaries to set up fundamental units. I think that a zone the size of a school district is desirable. As I mentioned before, in case of an emergency, the mobility of people is limited. We should put emphasis on space, facilities and human relations within the community.

4) Specific problems of emergency use.

Each district has its own vulnerabilities, according to the character of the area. For example, the central part of the city, suburb, overpopulated area, mixed area, old quarters, newly developed area, lowlands and hills are problems which differ from one another. Emergency use should be adapted to meet the needs of each area.

5) Forecast of disaster

In order to have the countermeasures cover all the problems, we should forecast in advance, the damage that would be caused by the disaster. In this case what we need is not general estimation, but specific one that is rooted in the community life. Everything we have at present lacks comprehensiveness and is fragmented. Since we are making the estimation on the assumption of giant earthquakes, it is not suitable for all cases. Each district has to know what damages will occur. This is necessary for carefully thought-out measures.

6) Scenario simulation

The "Scenario Simulation" is a method of estimating the future damage. This is a literary technique often used in writing a novel. First assume the magnitude of earthquake, and follow the action of certain characters in certain districts over the course of time. It is very useful for spotting problems. This technique was developed in 1973 and 2 case-studies using this method have been conducted. The results of the investigation of the Miyagi Prefecture Off Shore Earthquake came out closely akin to this study.

7) Medium-sized earthquake

In the process of Scenario simulation, one must consider the case of a medium-sized earthquake. These earthquakes are frequent and the damage they cause will give us enough materials to study. It will help to take more concrete and accurate measures, particularly in connection with emergency use. The present measures are being planned, based on a giant earthquake, but this may not be fruitful. We should set the medium-sized earthquake as the starting point.

CONCLUSION

Countermeasures against disaster from the point of view of the emergency action have been discussed. Of course, for the preservation of life, there should be various approaches. What we lack so far is an approach aiming at establishing a plan for a unit district. The earthquake is the fate of Japan, and urbanization is the fate of our time. The safety of life will not be obtained in a day, but should be realized step by step. As the first step, emergency action should be given primary status.

SEISMIC SAFETY & URBAN RENEWAL

MASAAKI SHIBATA

Seismic safety is an important motive for urban renewal in Japan, especially in urbanized areas. Urban renewal in Japan descended from "fire protection". Since 1919, when City Planning and Urban Area Building Laws designated fire-protection districts, the idea of "fire protection" has been perpetuated. This can be seen in many ways, including the following: The amount of wood buildings built with upper floor areas from 1955 to 1965 to 1975 decreased from 82% to 49% to 47% of buildings per 1000 square meters. During that same period, the amount of non-wood buildings increased from 18% to 51% to 53%. In a typical urbanized area (urban renewal project area) approximately 62% of the buildings are wooden. One of the necessary conditions of the "Urban Renewal Law" was that "The building area of 3-or-higher storied fireproof buildings is less than one-third of the building area of all the buildings in the project area."

Legislation of urban renewal has three areas of concern: Land Readjustment, Housing Improvement, and Fire Protection. Briefly, they include the following for Fire Protection:

1) Fireproof Building Promotion Law 1951-61 -- Fireproof Building Belts were built 38.88 km. (frontage width) in 83 cities

2) Fireproof Building Street Formation Law 1961-69 -- Fireproof Building Blocks were built at 643 blocks in 105 cities

3) Public Facilities and Reformation of Related Urban Areas 1961-69: 15 districts were redeveloped

4) Urban Renewal Law 1969: The following are examples of the Urban Renewal Laws passed:

Arable Land Adjustment Law of 1909

City Planning Law of 1919 and the Urban Area Building Law

Special City Planning Law 1946

Interior Housing Area Improvement 1927

Building Standards 1950

Land Readjustment 1954

Fireproof Building Promotion 1951

Housing Area Improvement 1960

Development of Public Facilities and Reformation of Related Urban Areas 1961

Fireproof Building Street Formation 1961

New City Planning 1968

Urban Renewal 1969 (current)

For seismic safety, escape roads and wide space for escape maps have been prepared. These roads and spaces are chosen for their safety, while their surrounding areas should be resistant to fire. To achieve a fireproof conditions, urban renewal projects should be put into effect. Problems hindering realization of urban renewal projects include:

How to reach an agreement with people living in the areas

How to plan the project to be profitable

How to implement the project

Besides the above, there are other techniques which include the financing of cooperative buildings for commerce, the controlling of the private activities of building constructions, etc.

SEISMIC SAFETY IN JAPAN

URBAN DESIGN & SEISMIC SEFETY-
AN OUTLOOK FOR SEISMIC SAFETY IN JAPAN

SACHIO OTANI

The west coast of the United States and Japan are both situated along the so-called Circum-Pacific seismic belt, and have suffered frequent large earthquakes in their metropolises.

Since the beginning of this century, many major earthquakes have occurred, including the San Francisco Earthquake of 1906, the Kanto Earthquake of 1923, the Niigata Earthquake of 1964, the San Fernando Earthquake of 1971, and the Miyagi-oki Earthquake of 1978. These major disasters illustrate the importance of concern for seismic safety by both countries.

Because it is impossible for anyone to intercept ground crust activities, seismic safety depends primarily on the strong structure of our cities and of those buildings which compose a city. As a result of long technical studies, man has invented various solutions and has succeeded in constructing skyscrapers and buildings spanning large spaces. It must be recognized, however, that this kind of progress will not always spare us from the destruction caused by an earthquake. Indeed, these technical developments even provide a source of a new type of disaster never before experienced. In Japan's past, primary destruction due to earthquakes was caused by fires accelerating through wood-constructed structures in high-density cities. Today, although many buildings are built of concrete, which is considered fireproof, we, nevertheless, cannot expect to eliminate the possible destruction due to fire following an earthquake.

Over the past decades, and continuing today, the growth of cities has increased greatly due to migration and a centralization of industry. An explosion in the size of cities is inevitable, and high-density areas have become a familiar phenomenon. This has forced conversion of open areas to highly populated ones, reducing the safety area.

It is not only the explosion in city size that makes us less safe from any menace, but in our surroundings, a great amount of inflammable and other dangerous materials are stored for the working efficiency of an expanding city. By virtue of the high productivity and efficiency peculiar to our modern lives, we face a new crisis in our environment. Furthermore, rapid city expansion has been partially achieved by placing buildings on geologically poor land or, even worse, on so-called "sinking land." In this context, the fundamental reality must be recognized that a city today is not safer than before and even more complicated problems must be solved for our security.

In Japan, the disorder and danger of our cities is historically due in part to the process of restoration following World War II, and in part to the industrial revolution. In ruins just after the war, Japan was forced to accept the pragmatic view that the people must be first fed for minimum survival, and only after this was achieved, offered a basic housing facility (most often a shantyhouse). Well-organized development of cities was neglected for rapid economic growth exclusively focusing on the above needs. Even after adequate restoration, the tendency to build a strong and efficient economic base has remained, resulting in disorderly cities and inhuman surroundings in which we are forced to live. Over the last quarter century, gigantic land development, mass production, and mass consumption have been realized. Under these conditions, city planning has been regarded as a tool to stimulate greater economic growth and activity.

Despite this fact, however, some measures have been taken for our security, but they were limited to concern for individual building's structural aspects. A number of fireproof materials and earthquake-proof techniques of structure were created and started to be commonly applied. It can be said that our efforts to obtain security applied solely to individual units and not to the city as a whole, ignoring the correct methods of arrangement, of city planning. There is no question that we have highly developed construction techniques and have enjoyed theoretical progress in the design of buildings, but greater danger remains in our cities, because the security of each component can by no means automatically contribute to the safety of a whole city.

What must be done at this stage is to study the right way of planning our cities, to make them safer from any menace, especially of earthquakes. All planners need to bear this in mind to assure public security, and architects, too, are morally obliged to design more safely. Collaboration among specialists of each field is necessary for our future security.

We know by now that well-organized and well-informed communities always tend to be less confused in any disaster, and as a result tend to recover from destruction. This emphasizes the need for more advanced information and organization to create a public awareness of disaster precautions.

A number of huge blocks of buildings, unseen before, have been constructed by means of newly achieved technology. Concerning the earthquake menace, unexpected problems have emerged because each huge building, each skyscraper, has numerous occupants and more complex interior systems, comparable to a town of the past. Once attacked by a destructive earthquake, the chaos in these crowded super blocks would be an incomparably appalling experience and would involve much greater destruction than before. A study limited to each building is clearly no longer useful for our security from possible future earthquakes.

Instead there must be an overall consideration to make the situation safer. Only then will a public security system be acquired, not only for each carefully designed unit but for a well-organized whole. In this sense, each professional ought to determine safer design from the point of view of the macrocosm as well as the microcosm. The destruction caused by a huge earthquake is incalculable. The right preparation for a disaster must be an essential requirement for any specialist in planning a future city.

No modern city has been completed in a manner to insure total security from seismic destruction. This is mainly due to the fact that few regions have experienced destructive earthquakes occurring more than once in a lifetime, or with even less frequency. Nevertheless, adequate preparation for a future earthquake should not be neglected, and should derive not only from one's own experience but from the past experience in general, despite the fact that the infrequency of the occurrence and rapid changes in our cities make it impossible to predict the exact consequences of the next earthquake.

The long intervals between massive earthquakes does not provide enough information for us, so sharing the experiences of others will more easily determine proper methods of reducing the possible losses due to earthquake destruction.

In Japan, a Tokai district earthquake is being forecast for the very near future. Urgent measures will be needed to make our megalopolises safer from destruction. It is therefore of the utmost importance for the Japanese to begin the discussions at this Seminar with American specialists whose various backgrounds have equipped them for this purpose. We hope this occasion will also help you to improve American cities, and make them more secure from the menace of earthquakes.

URBAN DESIGN & SEISMIC SAFETY IN JAPAN

KUNIHIKO HIRAI

1) HISTORY

We must still evacuate our cities because of large fires caused by earthquakes even today, so close to the 21st century. Earthquakes cannot be separated from large fires in Japan because of the crowded condition of wooden houses. The fact that large fires will occur when large earthquakes strike such crowded areas of wooden houses is a kind of tacit understanding, if wood is the main material of city construction in our country. Therefore "Escape from large fires" may rank first in many counterplans for earthquake hazards in the sense of urban planning. Medical care, maintenance of living, public peace, restoration and so on are the things of major importance after the disaster. But it is the case that only after the safety of the people's lives are guaranteed, that these actions are put into effect. As a large fire is quite dangerous to human life, the evacuation plan should be the primary concern in any counterplans. This point of view is the basis for the counterplan in urban planning. The actual plans involve securing large open spaces and planning evacuation routes to these areas. This idea is common in every large city in Japan. Evacuation is the most serious problem in Tokyo. The people know which city areas will be burned once a large earthquake occurs in Tokyo. The fact that there are many crowded wooden houses creates an ironical point of view toward urban design.

2) FUTURE

The situation mentioned above is changing slowly, because the Japanese are becoming accustomed to "Concrete" as a material used to form our houses. To date, the concrete material has mainly been used for commercial buildings, factories and a few houses. Although the houses in most urban areas are generally made of wood, because of the small cost difference between wooden house construction and concrete house construction and the development of air conditioning equipment, concrete materials are gradually being employed more often as the materials for house construction.

The use of concrete has been further facilitated by the promotion of fire resistant construction as the urban planning policy in disaster prevention. Promotion of fire resistibility of urban areas has been one of the problems in urban planning policy in Japan. Even the necessity of the promotion of fire resistibility has also been stressed for a long time. There were two opportunities to promote the need for fire resistivity in the Tokyo area. One is the Kanto Earthquake in 1923, the other the Tokyo Air Attacks during World War II. The promotion of fire resistibility was not realized in these two situations, but it is now in our hands. According to the advancement of fire resistance, the large fires will become independent from the earthquake. When this happens, earthquake counterplans and urban design will be recognized quite differently compared to the present day recognition.

Japanese people have thought that large fires after an earthquake is an extremely big bomb wich affects the whole city after many small bombs were exploded in urban areas. In other words, if we know the extremely big bomb certainly will blow up the whole city, it is nonsense to fight the small bomb. "Well, evacuation is the only way, isn't it?" However, if that big bomb does not come, fighting the small bomb is worth our effort in saving people's lives and property. Urban design is really required when we are free from the menace of large fires.

3) SUBJECT

What kind of urban circumstances and life environment do we wish to have. Can we create a valuable space by using concrete material in case of earthquake when land prices are rising, and usable space for each house becomes narrow and small?

The subject of the future urban design is how to answer these questions.

CHARACTERISTICS OF HAZARDS

CHARACTERISTICS OF HAZARDS IN JAPAN'S URBAN AREAS

MASUTERU MUROZAKI

INTRODUCTION

This paper will discuss the characteristics of and conditions related to hazards occurring in Japanese cities, especially the dangers associated with earthquakes in urban areas.

1) The Conditions Related to Hazards in Japanese Cities

The location, climatic conditions, geology and geomorphology of Japan make the country highly vulnerable to natural hazards. Japan is located in the Western Pacific typhoon zone and is also located on the circum-Pacific volcanic-earthquake belt. As a result of its location typhoons and earthquakes attack the country. In addition, due to the rugged, steeply sloping topography and the brittle nature of the geology, the land is highly vulnerable to landslips, landslides, rock falls, etc. In addition to these natural conditions, there are many problems related to cities in Japan. The lag in fire-prevention and location of densely populated areas on unconsolidated fill etc. makes the danger of hazards in these environments particularly high. One good example would be the large urban fires that occur as a result of the high concentration of wooden structures in cities.

Tables 1 to 3 show typical hazards that occur in urban areas in Japan, such as earthquakes, typhoons and large fire-related hazards and damage.

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Table 1 Main flood disasters in urban in Japan (since 1946)

		deaths	injuries	buildings collapsed	b.half collapsed
Kitty Typhoon	1949.9	160	479	3733	13470
Jane Typhoon	1950.9	539	26062	19131	101792
West Japan Heavy rain	1953.6	1013	5819	7704	2125
Isahaya Heavy rain	1957.7	722	3860	1564	2802
Kanogawa Typhoon	1958.9	1269	1138	2118	2175
Ise Bay Typhoon	1959.9	5098	38921	80838	113052
Heavy rain	1961.6	357	1320	1758	1908
Muroto Typhoon (the 2nd)	1961.9	202	4972	15238	46663
Heavy rain	1967.7	118	152	163	169

Table 2 Main earthquakes in urban areas in Japan (since 1946)

		Mag.	deaths	buildings collapsed	b.half collapsed	buildings burnt	fires occured
Nankai	1946.12	8.1	1432	13042	23476	2598	?
Fukui	1948. 6	7.3	3895	35420	11449	3691	57
Niigata	1964. 6	7.5	26	1960	6640	402	12
Tokachi Bay	1968. 5	7.9	52	673	3004	13	52
Miyagi Bay	1978. 6	7.4	27	578	5171	0	11

Table 3 Famous city fires in urban areas in Japan (since 1946)

		deaths	injuries	burnt buildings	devastated area (m^2)
Iida	1947. 4			3742	481985
Noshiro	1949. 2	3	874	2238	210411
Atami	1950. 4		3277	1461	141900
Tottori	1952. 4	3	3963	7240	449295
Niigata	1955.10	1	275	892	115051
Noshiro	1956. 3		19	1475	178933
Oodate	1956. 8		16	1344	156984
Uozu	1956. 9	5	170	1677	175966
Sakata	1976.10	1	964	1774	225000

Hazards in cities can be divided into two major types: (1) those related to typhoons, earthquakes and floods, i.e. "natural hazards", and (2) those caused by accidents and operations mistakes, i.e. "man-caused hazards". Nevertheless, it goes without saying that there are many cases of damage resulting from a combination of both types of hazards such as the spread of fire by strong winds or flooding caused by high tides in subsidence areas. These combined hazards can be divided into four types: (1) Those due to ground instability or subsidence (buildings and structures collapse, etc.) are called "ground-collapse hazards"; (2) Those due to tidal waves, high tides and river overflow are called "flood-related hazards"; (3) Those due to fire or explosion are called "fire-related hazards", and (4) Those where damage to facilities allows the escape and diffusion of toxic materials are called "pollution-related hazards".

Ground-collapse Hazard

Land subsidence and land failure are two typical examples of this type of hazard. Subsidence generally occurs either due to earthquake seismic ground movements or the removal of ground water, natural gas, etc. from subsurface strata. In Japan, land subsidence due to the pumping-up of ground water is remarkable, especially in the coastal areas of large cities such as Tokyo and Osaka in which large areas of coastal land have subsided below sea-level. The result of such subsidence is damage to subsurface gas and water pipes, cracks in coastal floodwalls and levees, and damage to buildings and oil storage tanks due to uneven settlement. The oil spill that occurred at the Mizushima oil refinery in 1974 was caused by uneven settlement beneath an oil storage tank.

Land failure generally occurs due to earthquakes and abnormally heavy rainfalls. In Japan, only 10% of the land area is flat. As a result, a considerable amount of development occurs on the surrounding mountainlands as well as on land reclaimed from the coastal waters by landfill. It is in these areas that the danger of land failure is highest. One example of land failure is the collapse of sloping land due to heavy rainfall. The city of Kobe has a very small area of flatland resulting in development spreading uphill. When abnormally heavy rainfall occurs, the collapse of developed slopes is not uncommon. Slope collapse also occurs during earthquakes. In the 1978 earthquake that occurred off the coast of Miyagi Prefecture in northeastern Japan, many of the developed slopes in the suburbs surrounding Sendai City collapsed causing considerable damage to buildings and structures located there.

There is an direct relationship between land failure and building damage caused by conditions of the ground on which these buildings are built. There appears to be a increasing tendency for building damage to occur in areas with unconsolidated sediments or sandy ground conditions. During the great Kanto Earthquake of 1923, there was a clear causal relationship between the depth of the alluvial plain and rate of collapse of wooden structures in Tokyo. Also during the Niigata Earthquake of 1964, liquifaction of coastal landfills occurred causing many reinforced concrete buildings to collapse or tilt and fall over.

Flood-related Hazard

The main causes of flood damage in urban areas are the high tides caused by typhoons, floods caused by heavy rainfall and tidal waves caused by earthquakes. Many of Japan's cities are located in coastal areas making them vulnerable to high tides and tidal waves. For example, Typhoon Kitty which passed through the Tokyo-Yokohama area in 1949, Typhoon Jane that hit Osaka in 1950, and the Ise-Bay Typhoon that struck Nagoya in 1959 brought with them extremely high tides that caused substantial damage to these coastal urban centers. The dead or missing amounted to over 5000 people in the below-sea level coastal areas of Nagoya City.

Table 4 shows the yearly change in large scale damage caused by high winds, high tides and river floods. However, there appears to be a declining tendency for these large scale calamities to occur. Recently however, flooding and damage caused by levee collapse along smaller rivers appears to be on the increase. The damage caused by flooding in and around such smaller rivers is small compared to that caused by high tides and large river floods. However, the number of incidents of such flood-related damage have been increasing along with expanding urban development, as is shown in Table 5.

Table 4 The number of flood disasters
(more then 50 deaths)

deaths	50-99	100-	total
1946-50	4	8	12
51-55	5	13	18
56-60	8	8	16
61-65	2	5	7
66-70	2	4	6
71-75	4	2	6

Table 5 The ratio of loss caused by high winds, high tides and river floods

	high tide, large river floods	inland waters floods	land slide, land slips etc.
1962	64.7 %	12.2 %	23.1 %
63	69.7	19.4	10.9
64	84.0	4.6	11.4
65	74.8	24.1	1.1
66	49.6	41.9	8.5
67	88.4	8.0	3.6
68	73.7	21.7	4.6
69	60.6	19.4	20.0
70	34.6	26.2	8.1
71	48.3	43.6	8.1
72	57.6	35.0	7.4

This kind of hazard also occurs when there is an earthquake. For instance, during the Niigata Earthquake, the levee of the Shinano River was breached flooding the surrounding countryside. The coastal area was also flooded by the tidal wave following the quake.

Fire-related Hazards

Roughly 80% of all buildings in Japan are made of wood, increasing the potential of large fires occuring in cities and spreading to unprecedented scales. Figure 2 shows the change in the number of city fires in Japan in which more than

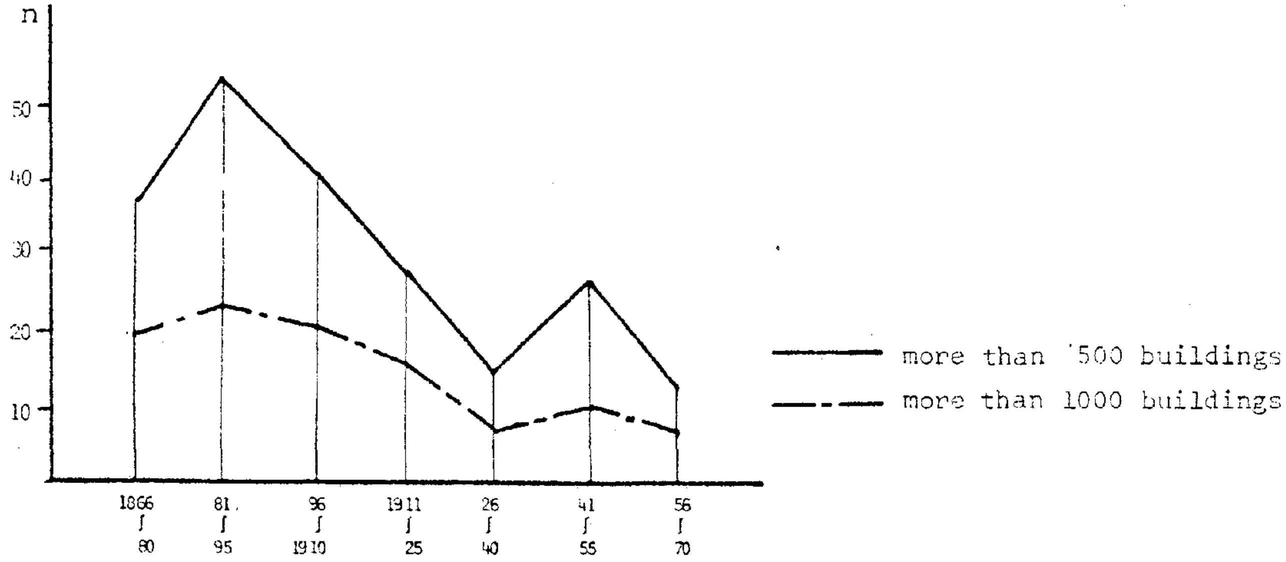


Figure 2 The number of city fires(more than 500 buildings burnt)

500 buildings were damaged or destroyed. It is clear from this figure that like large floods, large fires in cities are also on the decline. However, the great Sakata City fire of 1976 shows that the danger of large city fires has not been eliminated. this fire which was not successfully controlled at its outset and fanned by very high winds, was able to spread over a large part of the city's central business district.

Earthquakes are also a major cause of city fires. In the great Kanto Earthquake, fire broke out in 134 places. Of these, 77 spread to consume most of Tokyo itself. Large fires of this type also accompanied both the Nankai Earthquake of 1946 and the Fukui Quake of 1948.

While the incidence of large urban fires is decreasing, the number of urban building fires has been increasing. Table 6 shows that the number of fires that occurred in Tokyo in buildings more than 4 stories high has shown a tendency to increase. More than 100 people died in the Sennichi Department Store fire of 1972 as well as in the Taiyo Department Store in 1973.

Table 6 Fires in buildings more than 4 stories high (Tokyo)

	the number of fire	the ratio on total fires (%)	deaths	injuries
1966	251	5.2	3	48
7	354	6.9	2	61
8	369	7.5	9	91
9	418	8.3	10	91
70	517	9.4	5	86
1	572	10.9	7	105
2	586	11.8	7	122
3	684	12.7	17	108
4	686	14.2	9	144
1975	778	16.2	16	168

In the city, there are a large amount of gasoline, kerosene, propane gas and other dangerous volatile liquids. In Tokyo alone, there are more than 30,000 facilities in which such highly combustible liquids are used or stored. Table 7 shows that accompanying the increase of such dangerous items there has been an increase in damage caused by fires related to high pressure gas as well.

Table 7 Fires related to high pressured gas in Japan ( );LP gas fires

	number of fire	death	injuries
70	327(240)	63(48)	440(301)
71	316(232)	41(34)	381(308)
72	398(316)	62(53)	452(415)
73	484(384)	73(59)	453(405)
74	651(562)	77(76)	726(692)
1975	595(520)	43(41)	594(564)

In 1970, a large fire broke out at a subway construction site in Osaka in which 78 deaths and some 300 injuries resulted. This fire demonstrated the inadequacy of the safety equipment and procedures for fires in underground spaces.

Many fires related to the movement of dangerous volatile materials such as liquid propane gas (LPG) by railway tank cars have occurred in Japanese cities.

In Japan, industrial complexes and oil refineries are located in or close to many large cities. Fires that break out in such industrial zones often spread, threatening the surrounding residential and other high density urban areas. For example, during the Niigata Earthquake, oil tanks caught fire and spread to nearby homes, etc. resulting in considerable fire damage to the city.

Pollution-related Hazards

The rupture and leakage of tanks or facilities containing poisonous gases frequently occur in Japan. During the last ten years, there have been eleven cases in which people were harmed by leaking toxic gas fumes. The presence of dangerous facilities and oil tanks in Japanese cities attests to their danger and demands relief.

2) Recent Earthquake Damage

Large earthquakes cause extremely great damage in urban areas. There are, as we have seen, a wide variety of hazards in Japanese cities, but when there is an earthquake, these dangers are compounded in an instant resulting in great damage. Since a great earthquake is thought to be able to destroy a city or cities, considerable effort has been put into developing countermeasures for such events in Japan, i.e. predictions of damage expected from hypothetical earthquakes in Japanese cities have been made. These have been used as major inputs in the development of anti-earthquake calamity policies. The process of predicting damage from hypothetical earthquakes involves "learning from past calamity" by analyzing the damage caused by past quakes. We will consider some of the conditions surrounding recent earthquakes and examine some of the problems related to safety in cities.

1) The first problem involves the outbreak of fires caused by earthquakes. The amount of dangerous volatile materials and combustibles found in cities today is extremely high when compared to conditions that existed when the great Kanto Earthquake struck Tokyo over 55 years ago. This indicates that the danger of fire breaking out in a quake has greatly increased. The Tokachi Bay earthquake was responsible for no less than fifty fires, 40% of which eminated from kerosene space heaters. Also, the Izu Peninsula earthquake caused numerous propane gas fires. Kerosene space heaters and propane gas tanks are thus judged to be highly dangerous and are especially vulnerable to increasing the danger of causing fires in the time of earthquakes.

2) The next problem involves the fire dangers inherent in oil refineries and other such volatile facilities. In the Niigata quake, oil tanks exploded and caught fire causing great damage, as was also the case in the Miyagi Bay earthquake. Oil refineries are particularly vulnerable to earthquakes being highly likely to become enveloped in flames when a large quake strikes.

3) The third problem involves the ability of reinforced concrete buildings to withstand seismic shocks. As in the Tokachi quake of 1975 and Oita quake of 1976, reinforced concrete buildings were greatly damaged by the Miyagi Bay quake. Much of this damage occurred in 3 and 4-story high R/C buildings built on unconsolidated sediments. The same thing occurred during the Niigata quake demonstrating the clear need to think more about building for earthquake-resistance.

4) The fourth problem involves the damage caused to urban utilities and the subsequent impact this has on urban activities. In the Niigata earthquake, 68% of the water mains were ruptured requiring five months for service to be restored to normal. In the Miyagi Bay quake, gas, electric and water facilities were damaged causing considerable disruption of urban life (table 8). In order to avoid such disruptions strengthening of urban utilities to resist strong quakes is necessary.

5) The next problem involves development for housing and industry on weak or unstable ground. In both the Niigata and Miyagi Bay earthquakes, the collapse of or damage to buildings on such soils was conspicuous, as was damage to industry located on landfill. There is a great need to give more attention to ground conditions when planning urban development. In addition, the damage caused by the collapse of block fence-walls, falling glass and roof tiles, etc. has been brought to the foreground by recent quakes in Japan. These and other problems need to be given sufficient consideration in the development of anti-earthquake policies.

Table 8 Recovery time (days) and rate of urban utilities

	Niigata (1964)		Miyagi (1978)	
water facilities	15 days	50%	6 days	100 %
electric facilities	5	100	2	100
gas facilities	15	20	27	100
communication facilities	15	50	2	100

3) Characteristics of Urban Hazards in Japan

a) In addition to the damage caused by earthquakes themselves, high winds, floods and large fires round out the major hazards most prevalent in Japanese cities. As a result, the prediction of damage to cities is being done similar to hypothetical quake calculations.

b) Large damage formerly caused by high tides and great fires are showing a tendency to decrease, but smaller floods and building fires have tended to increase showing the continuing everyday nature of urban hazards.

c) The potential danger of urban calamity is increasing. The high density nature of cities, the concentration of dangerous volatile objects and facilities, and the appearance of large scale spatial concentrations, etc. have expanded. There has also been a great increase in the conditions favorable to calamity caused by earthquakes. Today, earthquakes are expected to cause many times more damage to cities than in the past.

d) Oxygen-depletion hazards, the gushing of ground water caused by changes in urban construction methods, underground street fires and numerous new and more terrible calamities are expected to occur in modern Japanese cities in the future.

e) The chain-reaction multiplication nature of hazards is increasing cases of building fires causing panic, automobile fires causing fires in other places nearby, or ground subsidence causing tanks to rupture.

f) The inherent weakness of geological conditions under cities increase the danger of calamity in those cities. Also ignorance of ground conditions related to development is a cause of the spread of urban damage.

Conclusion

The nature of urban hazards and calamities in Japanese cities has been discussed in this paper. In addition to requiring that these hazards and characteristics be thoroughly considered in the establishment of urban anti-calamity policies, we are also asking that urbanization and urban construction methods be thoroughly re-examined.

NATURAL CALAMITIES & DISASTERS IN BUILT UP AREAS

YASUSHI KIJIMA

Most cities in Japan have histories of frequent disasters such as floods, typhoons, earthquakes and fires. Kumamoto is such a city. It dates back from the feudal era and has been the prefectural capital for a century. Located in Kyushu, the largest western island in Japan, it has a population of more than 500,000, and has been destroyed by disasters many times during the past one hundred years. When Japan entered into diplomatic relations with foreign countries and was modernized at the end of the last century, Kumamoto's population was about 40,000. At that time, built-up areas covered about 500 hectares (about two square miles) of the total land space of the city.

In 1877, ten years after the beginning of the Meiji Era, a civil war broke out in Kyushu and the anti-government forces made a final stand in the city. This battle continued for several months and most of the central part of the city was reduced to ashes. The old castle was burned by the government army before being shelled by the enemy. Following the war the city was restored almost as it had been previously.

In 1889, frequent earthquakes occurred in Kumamoto city. Hundreds of tremors shook the city from July 28 to the end of August. The residents were forced to live outdoors. Since these quakes occurred during the summer, the residents were not troubled by the cold but suffered instead from bad drinking water. There was no public water supply at that time. Some residents had their own wells, and others used common wells. Some of the wells ran dry and unsanitary running water leaked into other wells.

The physical damage from the earthquakes was not so serious. A breakdown of the damage follows:

Completely destroyed housing units	31
Partially destroyed housing units	17
Collapsed bridges	3

Kumamoto is 30 kilometers from the famous active volcano, Mt. Aso. Another volcanic mountain, Kimposan, is located on the western side of the city. Although there have not been any strong seismic tremors since that time, slight ones occur very often. It can be said that most of the inhabitants in the city do not fear seismic tremors, because none of them have had an experience with a severe earthquake.

The Second World War also damaged the city considerably. Thirty percent of the built-up area was burned by air-raids in 1945. The bombed area totalled 362.9 hectares (about one and a half square miles) and the area raised to protect against fire was an additional 11.8 hectares. At that time the population was about 205,000 and of those 169,000 people lost their housing units in the bombing. The whole urban area of 473.7 hectares was replanned by the Land Lot Adjustment Law after the war, and was continued up to 1975.

In 1953 an exceptionally disastrous flood damaged the city. More than 500 persons died or were missing and about 2000 houses were destroyed. The center of the city was covered by water for a week. Even after the water receded an enormous amount of sand and volcanic ash was left as if it were the debris from an earthquake. The central part of the city was cleaned by the energetic labor of the people, but the historic moat of the castle and vast areas of ricefields were reclaimed by the earth.

A flood control plan was inaugurated after the flood but it has not yet been completed. Trees growing on the banks are to be cut down to enlarge the width of the river, creating the possibility of increase in the water entering the heart of the city in time of heavy rain fall. If any portion of the retaining bank should fail, we can expect more serious damage than before, due to an increase in the population and houses concentrated on both sides of the river.

Our ancestors should have designed a bypass canal outside the central city. We now have the technology but lack a sense of comprehensiveness in our city planning.

How have these disasters affected the development of Kumamoto? Has the development of any district been strongly obstructed by these disasters? The most prosperous area of the city has been damaged many times.

Another tragedy struck the city November, 1973. There was a big fire in the Taiyo Department Store, which was situated in the heart of the city. More than 100 customers and clerks were killed. As a result of the fire the prefectural office ordered the building remodeled under supervision of the central government. The improved part of the building consists primarily of the staircases where many open-air steps were added and the shopping areas reduced.

The remodeled department store was opened three years later, but closed in 1978, due to bankruptcy. I believe the basic reason for bankruptcy was excessive expense required for safety. There was too much space for staircases and completely enclosed escalators which kept the customers from seeing the goods. Imagine a shopping space without visual contact (from the outside).

Most people in Japan believe that a building which meets the Building Standard Laws and Regulations must be completely safe, so they do not take care to keep it safe. Taiyo Department Store was a product of this attitude. There were so many display cases on each floor that two customers could hardly pass each other. The layout of display cases is not controlled by law and not considered to be the responsibility of an architect. On the other hand the amount of goods sold per square meter in the store was high when ranked in comparison with other stores. This meant that too many goods were displayed on the floors and too many clerks were employed. A store cannot prevent the entrance of customers so it is almost impossible to avoid the same disaster once more when many customers crowd inside.

Every government official feels his responsibility to guard against these kinds of accidents, and has a strong belief that rules must protect the public at all times. The bureaucratic dogma, which is always general and abstract, neglects the individual situation in which architects work. I believe that the most important thing is presenting these facts to people who follow materialism and mechanism and obey the rules blindly. Bureaucrats take advantage of the public in this way.

There are some inconsistencies in planning policy such as the building regulations that cover every detail of design. For examply, the width and length of corridors are decided according to the type of building, not according to the real situation. But the width of many streets or sidewalks is often narrower than doorways. The distance from buildings to the public open spaces designated for refuge is often quite far.

There are daily traffic jams in Kumamoto just as in bigger cities. A comparison of the traffic volume estimated from the person-trip census with the capacity of the street, suggest the possibility of terrible chaos in the event of a seismic disaster. All trips outward from a district must pass through one of the streets which surrounds that district. From the highest level of floor area permitted by law, the maximum trips exceeds the capacity of the streets. It is quite possible that many from a broad area will crowd at one point in the event of an earthquake. An analysis comparison shows that there are not enough broad streets around the center, and indicates that great suffering may result as people seek refuge in a disaster situation.

In conclusion it can be said that the present method of design according to official regulations does not insure safety. We need reliable standards, but must be free from predetermined measurements and fixed mechanisms. The present laws contribute considerably to the increase in large scale buildings which are generally owned by thoughtful men and wealthy companies. For ordinary people and small scale private proprieters the building standards are too severe and entail great expenditure. After buildings are completed according to the rules they are often changed to suit their owners' immediate needs, thus negating the basic purpose of the codes under which they were constructed. It is meaningless to attempt to control all construction in Japan by a single system, and also impossible to make diverse rules to meet every situation. Japan is still a dual society, being very civilized and at the same time quite uncivilized. Under such a varied structure we should strive for a case by case study and design for each building.

DAMAGE TO LIFELINE SYSTEMS IN THE CITY OF SENDAI

TSUNEO KATAYAMA

INTRODUCTION

An earthquake of magnitude 7.4 struck the northern portion of Honshu Island on June 12, 1978. The epicenter was about 100 km to the east of the city of Sendai and the focal depth was 40 km. The shortest distance from Sendai to the source area was 50 to 60 km. The intensity in the Sendai area was V by the JMA scale, which roughly corresponds to VIII on the Modified Mercalli scale. The peak horizontal acceleration recorded on the ground surface or in building basements in Sendai and its surrounding area generally varied between 200 and 300 cm/s^2.

Sendai, the 14th largest city in Japan with a population of 617,000 on 237 km^2, is situated at almost the center of the JMA intensity V area, and a variety of damage was sustained by a number of different structures and systems. The overall damage was estimated at some 200 billion yen. More than sixty percent of this was sustained in Sendai, where some 700 homes were reported totally collapsed, 3,400 homes appreciably damaged and 74,000 homes received minor damaged. Six reinforced concrete buildings and nine steel frame structures reported to have completely collapsed. Damage to highway and railway structures was also extensive. Twenty-eight persons lost their lives (thirteen in Sendai) due to damage caused by the earthquake. It was noted that sixteen were killed by collapsing gatepost, masonry or concrete-block walls.

One of the particular features of this earthquake was the damage sustained by various lifeline utility systems of electric power, water supply, sewerage and city gas and the processes of their restorations.

ELECTRIC POWER SYSTEM

Prior to the occurrence of the earthquake, the Tohoku Electric Power Company was delivering 4,900 megawatts to the northern portion of Honshu Island. Approximately 1,500 megawatts drop in demand after the earthquake, including the interruption of some 1,130 megawatts of supply. System frequency momentarily fluctuated from 50.00 Hz to 50.58 Hz, then returned to normal in five minutes.

An estimated 681,600 customers were affected by powere outages caused by seismic damage to power system facilities and by the operation of relays triggered by the earthquake. These relays were reported to have operated normally to protect the equipment from electrical faults in the system prior to the structural damage.

Generally speaking, generating facilities sustained minor damage. Two steam power plants serving most of the customer load in the Sendai area sustained some equipment damage. Damage at these plants was not severe, but it took several days before generating units at these plants resumed running. This caused a shortage of power in the Sendai area and necessitated curtailment of customer service. The Sendai Steam Plant No. 1 unit was placed in service by June 16. The Shin-Sendai Steam Plant Nos. 1 and 2 units resumed running on June 18 and 19, respectively.

There was no major failure of overhead and underground transmission lines except for some fissuring near footings and minor cracking of the retaining walls of transmission towers.

A total of eighteen substations sustained equipment damage of varying degrees. There was major damage to nearly every type of electrical equipment. However, the primary cause for the extensive power outrages in the Sendai area was severe damage to electrical equipment at two of the key bulk power substations which disrupted the company's artery 275-kv transmission line. Most of the equipment damage at these substations was associated with failures of porcelain components. Damage caused by inadequate anchorage was minimal.

Early restoration of the 275-kv lines was judged impossible because of the damage to the two steam plants and the Sendai Substation as described above. Emergency service was recovered by connecting intact lower voltage (154 and 66-kv) lines. Service was restored to about 90 percent of the customers within the same day of the earthquake occurrence, and all distribution substations in the Sendai area received power supply during the early hours of June 13. However, power outages to about 80,000 customers remained on the following morning mostly in the city of Sendai and several surrounding cities. The number of customers without power decreased until emergency restoration was completed about 38 hours after the occurrence of the earthquake. It has been reported that the total restoration required some 19,400 man days and 3.22 billion yen.

WATER SUPPLY SYSTEM

The Sendai City Bureau of Water Supply provides potable water to some 200,000 customers (out of a total population of 620,000) by three treatment facilities having a maximum daily capacity of 320,000 m^3. The fourth treatment facility was in the process of expansion and not in full operation. Facilities for collection, storage, transmission and treatment came through the earthquake without any substantial damage, since the Sendai water supply network uses gravity flow for most of its service area and pumping facilities. Power required at treatment facilities was obtained from emergency power units so the power outages did not affect service to customers. These three treatment facilities regained normal operations at 0:15, 0:35 and 7:30 on June 13.

Minor distribution piping sustained considerable damage. A total of 215 breaks occurred in the water distribution mains having diameters equal to or greater than 50 mm. The summary of damage to distribution pipes with diameters equal to or greater than 75 mm is shown in Table 1. There were 98 breaks in 50 mm pipes (lengths not determined). The statistics in Table 1 should be carefully interpreted because damage to buried pipes is strongly related to subsurface site conditions.

Figure 2 shows the general geological setting of the Sendai area (Okutsu, H., 1975). The distinct NE-SW line passing near the center of the map is called the Rifu-Nagamachi tectonic line. The Sendai Plain developes to the east of this line and is bounded by the Pacific Ocean. This alluvial plain is mostly sand, silt and gravel. Its depth to the Tertiary basement rocks varies abruptly near the tectonic line but is generally between 30 and 60 m. There are several areas in this plain covered with 2~5 m thick, very soft peat or mud. The general topography of the area to the west of the tectonic line is characterized by hilly terrain and several levels of terraces. The central part of Sendai composed of office and business quarters and older residential districts is located on the terrace structure to the north of the Hirose River. The surface deposit of this terrace is loam with its thickness rarely exceeding 2 m. This surface deposit is underlain by gravels or sand and gravels with the standard penetration N-value varying from 20 to 60. The Tertiary basement rocks, mostly of tuff, is usually found at a depth of 5 to 7 m. The hills are either of very hard andesite or agglomerate, or of workable tuff, shale , mudstone or sandstone. At serveral places, the tops of hills are covered with loam deposits. A number of residential districts have been developed in the last 30 years on the slopes of the hills with softer workable rocks.

Damage to buried water pipes was generally slight in the central part of the city located on geologically stable terrace. Pipe failures concentrated in the newly developed residential districts where large-scaled cut and fill have extensively altered the original ground profile. In these areas, because of inherent instability of artificial slopes, insufficient densification of fills, and abrupt change in subsoil properties between cut and fill, strong seismic shaking easily produced fissures, local settlement, slippage, and relative displacement over short horizontal distances. These were the main causes of buried pipe breaks.

The emergency operations immediately following the earthquake were primarily concentrated on stopping any uncontrolled flows of water from broken mains. Consequently, about 7,000 services were without water on the following morning. The restoration of water service in Sendai was generally fast and the number of customers without water decreased to 800 by June 15, during which normal service was restored in the city of Sendai except for several newly developed residential districts where the stability of fills and slopes came into question. Over 4,000 breaks to service connections, meters and domestic pipings were reported to the Bureau during June.

Trucks were used to supply water to the areas which were completely out of water. On June 14, thirty-seven trucks made 213 deliveries to various locations. Most of the vehicles were rented ordinary trucks which carried the Bureau's 1 m^3 water tanks. It is noted that an average of 8~10 litres per person was distributed during the days that shortage of water was most acute in a number of localized areas.

A total of some 650 man days was required for restoring water mains, and an additional 1,100 man days for repairing facilities on customers' premises. The overall damage to the Bureau's facilities has been estimated at some 255 million yen.

SEWERAGE SYSTEM

The sewer system of Sendai servies approximately 60 percent of the city's total population. The length of sewers amounts to about 700 km with diameters varying from 250 mm to 2200 mm. The system has eleven main pumping stations where sewage is boosted to a single treatment plant. This plant treats a daily amount of about 260,000 m^3 of sewage before it is discharged off shore.

Although various types of damage were inflicted upon the sewerage system, the single most important seismic effect was the disablement of several pumping stations caused by power outages. Table 2 summarizes the seismic effects on the eleven pumping stations. Normal operation was continued at two of the stations without interruption by using emergency power units. At the rest of the pumping stations, sewage had to be temporarily discharged to rivers or other estuaries, and in one case to the adjacent down-stream station. It is particularly important to note that emergency power units at five stations were disabled by a shortage in the cooling water supply. Most of the disabled pumping stations resumed normal operation within two days after the earthquake due to resumption of power and/or completion of emergency repair work. At one of the stations, however, where equipment damage was most severe, discharge of sewage into a river continued for eleven days.

When pumping was resumed, it was discovered that no major sewer line had completely collapsed. A damage survey was concentrated on those areas where damage to road, water and gas pipes had been reported. A total of 702 manholes were visually inspected and 299 manholes were found to have been damaged to varying degrees; of these 82 manholes received sufficient damage to warrant some repair. A damage survey of buried pipes was made in those areas where manholes were severely damaged. A total of about 2 km sections of pipes was inspected. About 1.6 km sections were inspected by using television camera and supporting video tape equipment. Based on this damage assessment, some 190 m sections of 250 mm and 300 mm vitrified clay and concrete pipes were replaced. Although the Sendai sewer system has not encountered any major trouble since the earthquake, undetected damage is anticipated to cause maintenance problems in the future.

There were several sections of large-diameter sewer mains which had been completed but were not in use at the time of the earthquake. Pipes were of concrete with diameters varying from 1650 mm to 2200 mm. They were buried in the alluvial plain shown in Fig. 4. A total of 62 manholes and 2,845 joints were visually inspected for the sections of 7.42 km, and 51 manholes and 533 joints were found to have been damaged. Cracks in pipe body were also found, notably in the circumferential direction near the junctions between pipes and manholes. Although it is difficult to generalize this result to uninspected used pipes, there may be many, probably minor, undetected pipe failures in the present sewer network.

The overall damage to the Sendai's sewerage system has been estimated at some 370 million yen.

CITY GAS SYSTEM

The city of Sendai and parts of several surrounding cities were supplied with city gas by the Sendai City Bureau of Gas. City gas was served to about 136,000 customers from the Bureau's two factories, one of which produced more than 90 percent of the total supply. Damage to production facilities was generally light although an old water-sealed gas holder suffered structural damage and was eventually destroyed by the ensuing fire at the smaller factory. All of the three production units at the larger factory stopped due to power outages but equipment damage was slight. Service to customers was maintained for nearly an hour after the earthquake by using the reserved gas in holders. During this period, however, a number of calls were received from customers about gas leakage. Supply was closed down at 18:15 to all 136,000 customers. This was the first instance in recent years in Japan that service to such a large number of customers was closed down at one time.

Medium pressure (1~10 kg/cm) transmission lines were mostly of arc-welded steel pipes, and low pressure (less than 1 kg/cm) distribution mains were mostly of screw joint steel pipes or mechanical joint cast-iron pipes. Screw joint steel pipes were also used for service pipes and pipes on customers' premises.

In approximately 240-km length of arc-welded steel pipes, only four minor failures occurred. All of them were associated with loosenings of flange joints in pits caused by the settlement of surrounding soil. It is significant that arc-welded steel pipes sustained the stresses of the earthquake remarkably well although substantial portions of these pipes were buried in soft alluvial soil.

A cross tabulation was made for damage to low pressure buried pipes with respect to various items and categories. The low pressure pipes included distribution mains, branches, services and pipings on customers' premises. Damage to medium pressure transmission lines was not included. Six items selected are failure mode, pipe classification, pipe material, pipe size, type of joint and type of soil. Each item was divided into two to five categories. For example, failure mode was divided into breaks, cracks, slipping out of joint, loosening of joint, and others. The result is shown in Table 3. A number on the diagonal shows the simple sum of failures under each respective category. A total of 552 failures have been reported in the low pressure pipings. The uppermost diagonal element shows that 409 of them were classified as breaks. Then by tracing the numbers along the horizontal direction, the breakdown of these 409 breaks can be seen. Breaks were observed most often in small-diameter steel pipes with screw joints used for distribution branches, services and pipings on customers' premises. Breaks at screw joints seem to be the most common type of damage to buried gas pipes.

Another interesting feature observed in Table 6 is the effect of site subsoil upon pipeline damage. The site condition was very roughly classified into three categories, i.e. terrace, alluvium, and cut-and-fill. 397 out of 552 failures were sustained by the pipes buried in newly developed cut-and-fill residential districts.

By the morning of June 13, valves at all 141 distribution regulator stations had been shut down. Damage survey was first made for medium pressure transmission lines. Damage to these some 200-km sections of arc-welded steel pipes was slight as described before, and repairs had been completed by the noon of June 14, some 40 hours after the earthquake occurred.

During the afternoon of June 13, the first restoration program was established by employing six subisolation areas. On June 16, this program had to be altered to adopt eight subisolation areas since the original program was found inadequate as the distribution of damage was eventually disclosed. Leakage surveys and repairs started on a full scale from June 16 for some 1,200 km distribution lines. Four days beginning from June 15 were required to close customers' meters. As surveys and repairs progressed, however, damage in several newly developed residential districts was found to be much heavier than earlier estimated. Several subisolation areas had to be further divided into smaller areas to efficiently facilitate the location and repair of leaks. All 38 subisolationareas had to be employed, with the number of customers varying from 77 to 21,638. Distribution mains had to be cut and bulkheaded at 155 locations in order to create subisolation areas.

The first 400 customers had service restored by June 16. Accumulated percentages restored were 30 percent by June 22, 50 percent by June 24, 70 percent by June 26 and 90 percent by June 28. It was about four weeks after the earthquake that all restorable meters were returned to service.

Restoration was accomplished in four phases. During Phase I from June 12 to 15, all supply was closed down. A damage survey was made for key facilities, such as production facilities and transmission lines. Transmission lines were repaired and the original restoration program for distribution lines established. During Phase II from June 16 to 21, surveys and repairs of distribution lines were initiated according to the original restoration program. Uncertainty involved in the damage estimate made in Phase I necessitated revision of the program including subdivision of subisolation areas. Work efficiency is seen to fluctuate during this period. From June 22 to 29 (Phase III), restoration progressed smoothly with stable and high work efficiency. Then in Phase IV, surveys and repairs in most heavily damaged areas were made, and consequently efficiency of restoration work became very low.

The four phases described here seem to be one of the typical restoration processes following seismic damage to lifeline utility systems. The period of suspension of lifelines will be shortened if the length of Phases I and II is minimized. To achieve this, it is important to protect key facilities within the system from an earthquake and to have a well-organized and developed emergency planning for handling seismic disasters. It seems to be particularly important for utilities to be prepared with a macroscopic damage estimate in case of a future earthquake disaster including information on the distribution of damage within their service areas.

The total cost of restoration for the city gas system of Sendai has been estimated at some 850 million yen.

CLOSING REMARKS

Although damage to the city of Sendai caused by the 1978 Miyagiken-Oki earthquake was not devastating, numerous lessons have been learned from this experience, especially on the seismic effects upon lifeline utility systems in a modern urban area.

It was clearly demonstrated that buried utility pipelines are very vulnerable to seismic effects. Alteration of the original ground profile by large-scaled cut and fill was found to be potential seismic-disaster areas unless proper geological and engineering considerations are made. The closing down of city gas supply to a large service area causes extremely tedious and time-consuming restoration work. The importance of emergency planning was reconfirmed. Preparation of an adequate damage estimate in case of future earthquake disasters was found to be important.

It should be also pointed out that emergency planning must be made by assuming several different levels of seismic disaster. The level experienced by Sendai during and after the Miyagiken-Oki earthquake seems to be one of the typical levels to be considered. In comparison with a catastrophic disaster, a moderate level of disaster should occur more frequently. Utilities should be able to deal with such a disaster quickly and efficiently so that the period of inconvenience to human activity in a major metropolitan area is minimized.

ACKNOWLEDGEMENT

The author wishes to express his appreciation of the assistance given by Y. Masui, R. Isoyama and I. Jin-nai in preparing this report. The assistance given by Professor K. Kubo of the Institute of Industrial Science, University of Tokyo, is also acknowledged.

Table 1. Damage to Water Distribution Pipes With Diameters Equal To Or Greater Than 75 mm (The Sendai City Bureau of Water Supply).

Diameter of Pipe (mm)	Material of Pipe								Total	
	Cast Iron*		Steel		Asbestos Cement		Polyvinyl Chloride			
	Length (km)	Breaks	Length (km)	Breaks	Length (km)	Breaks	Length (km)	Breaks	Length (km)	Breaks
75	18.4	3	1.1	1	7.0	32	114.4	21	140.9	57
100	183.6	15	1.7	0	29.1	5	207.2	22	421.6	43**
150	205.0	4	1.4	0	7.0	0	-	-	213.4	4
200	118.9	2	1.4	0	1.5	1	-	-	121.8	3
250	39.9	3	0.7	0	1.3	0	-	-	41.9	3
300	70.0	2	3.7	0	2.1	1	-	-	75.8	4***
350	2.0	0	0.1	0	-	-	-	-	2.1	0
400	27.6	2	3.5	0	-	-	-	-	31.1	2
450	1.7	0	0.1	0	-	-	-	-	1.8	0
500	20.0	1	6.6	0	-	-	-	-	26.6	1
550∿1100	16.3	0	50.2	0	-	-	-	-	66.5	0
Total	703.4	32	70.5	1	48.0	39	321.6	43	1143.5	117

* Including ductile cast iron pipes.
** Including one break of isolating valve.
*** Including one break of hydrant.

Table 2. Damage to Pumping Stations in Sendai.

Pumping Station	Drainage Area (ha)	Capacity (m^3/s)		Effects of the Earthquake							Amount of Sewage Discharged into Waterways (m^3)	Normal Operation Resumed at
		Sewage	Storm Water	Power Outages	Suspension of Water Supply	Faults in Emergency Power Units	Faults in Electrical and/or Mechanical Systems	Damage to Discharge Pipes	Damage to Inlet Pipes	Damage to Buildings and Other Equipment		
A	55.84	0.134	0.860	X				?		X	Normal Operation Continued	
B	16.60	0.014	--	X							Negligible	0:30 on June 13
C	243.54	0.510	--	X	X →	X		X			2,000	1:30 on June 13
D	158.78	0.067	--	X					X		2,000	16:00 on June 14
E	920.00	0.419	7.687	X			X	X		X	450,000	16:25 on June 23
F	121.52	1.007	3.620	X		X	X	X		X	10,000	17:30 on June 14
G	139.30	0.135	--	X	X →	X		X	X	X	5,500	10:00 on June 14
H	168.00	0.149	--	X	X →	X					Negligible	10:00 on June 13
I	320.42	0.236	2.118	X					X	X	Normal Operation Continued	
J	53.96	0.033	--	X	X →	X					*	10:00 on June 13
K	108.00	0.151	--	X	X →	X	X			X	3,000	9:00 on June 13

* Discharged to Station K by gravity flow.

Table 3. Cross Tabulation of Gas Pipe Failures in the Sendai Area.

		Mode of Failure					Classification of Pipe				Mate-rial		Size of Pipe				Type of Joint					Site Geological Condition		
		B	C	S	L	O	M	B	S	D	S	C	D_1	D_2	D_3	D_4	W	M	S	B	O	A	B	C
Mode of Failure	Breaks	409	0	0	0	0	3	127	129	150	409	0	276	132	1	0	0	0	408	0	1	45	73	291
	Cracks		43	0	0	0	1	14	8	20	43	0	29	14	0	0	0	0	43	0	0	2	18	23
	Slip Out			60	0	0	11	46	2	1	49	11	1	51	7	1	0	11	48	0	1	0	2	58
	Loosening				13	0	4	5	2	2	11	2	2	11	0	0	0	2	9	0	2	5	2	6
	Others					27	1	6	7	13	26	1	19	7	1	0	0	0	24	0	3	4	4	19
Classi-fication of Pipe	Mains						20	0	0	0	6	14	0	11	8	1	0	13	4	0	3	2	6	12
	Branches							198	0	0	198	0	16	182	0	0	0	0	196	0	2	3	14	181
	Services								148	0	148	0	142	6	0	0	0	0	147	0	1	18	32	98
	Domestic									186	186	0	169	16	1	0	0	0	185	0	1	33	47	106
Mate-rial	Steel										538	0	327	210	1	0	0	0	532	0	6	55	98	385
	Cast Iron											14	0	5	8	1	0	13	0	0	1	1	1	12
Size of Pipe	D_1	$D_1<50$ mm											327	0	0	0	0	0	324	0	3	47	73	207
	D_2	$50 \le D_2 \le 100$ mm												215	0	0	0	5	207	0	3	9	24	182
	D_3	$100 < D_3 \le 200$ mm													9	0	0	7	1	0	1	0	1	8
	D_4	$200 < D_4$														1	0	1	0	0	0	0	1	0
Type of Joint	Welded																0	0	0	0	0	0	0	0
	Mechanical																	13	0	0	0	1	1	11
	Screw																		532	0	0	52	97	383
	Bell & Spigot																			0	0	0	0	0
	Others																				7	3	1	3
Site Geolog-ical Conditn	A	Terrace (Old City Area)																				56	0	0
	B	Alluvial Plain																					99	0
	C	Cut and Fill																						397

Table 4. Equipment Damage at Eighteen Substations.

Type of Equipment	Number of Damage Sustained by Equipment for			Total
	275-kv	154-kv	66-kv or Lower	
Transformers	4 (2)	3 (1)	6	13 (3)
Gas Circuit Breakers	3 (3)	-	-	3 (3)
Air Blast Circuit Breakers	3 (3)	16 (3)	6 (3)	25 (9)
Porcelain-Clad Circuit Breakers	-	-	3	3
Disconnecting Switches	2 (2)	1	3 (1)	6 (3)
Porcelain-Clad Current Transformers	10 (10)	12 (2)	2 (1)	24 (13)
Capacitance Potential Devices	3 (3)	-	-	3 (3)
Lightening Arresters	6 (6)	8 (2)	-	14 (8)

Numbers in brackets show damage to the Sendai Substation (275-kv).

Table 5. Data on Emergency Water Service.

Date	Number of Customers Without Water	Number of Persons Affected	Number of Trucks Employed			Number of Men Employed			Number of Deliveries Made	Amount of Water Delivered (m^3)	Service Hours
			Bureau's	Rented	Total	Bureau's	Contractor	Total			
June 12	?	?	5	0	5	20	0	20	7	7	20∿24
13	7,000	21,000	7	22	29	50	22	72	165	180	6∿23
14	5,800	17,600	7	30	37	60	30	90	213	230	6∿22
15	800	2,400	7	20	27	50	20	70	120	130	6∿21
16	300	900	7	10	17	40	10	50	60	65	6∿21
17	250	750	6	4	10	26	4	30	26	30	6∿19
18	200	600	6	4	10	26	4	30	18	20	6∿19
19	200	600	5	3	8	15	3	18	18	20	6∿19
20	60	200	4	0	4	9	0	9	7	14	8:30∿19
21	30	100	2	0	2	5	0	5	3	6	--
Total	--	--	56	93	149	301	93	394	637	702	--

Table 6. Cross Tabulation of Gas Pipe Failures in the Sendai Area.

		Mode of Failure					Classification of Pipe				Material		Size of Pipe				Type of Joint					Site Geological Condition		
		B	C	S	L	O	M	B	S	D	S	C	D_1	D_2	D_3	D_4	W	M	S	B	O	A	B	C
Mode of Failure	Breaks	409	0	0	0	0	3	127	129	150	409	0	276	132	1	0	0	0	408	0	1	45	73	291
	Cracks		43	0	0	0	1	14	8	20	43	0	29	14	0	0	0	0	43	0	0	2	18	23
	Slip Out			60	0	0	11	46	2	1	49	11	1	51	7	1	0	11	48	0	1	0	2	58
	Loosening				13	0	4	5	2	2	11	2	2	11	0	0	0	2	9	0	2	5	2	6
	Others					27	1	6	7	13	26	1	19	7	1	0	0	0	24	0	3	4	4	19
Classification of Pipe	Mains						20	0	0	0	6	14	0	11	8	1	0	13	4	0	3	2	6	12
	Branches							198	0	0	198	0	16	182	0	0	0	0	196	0	2	3	14	181
	Services								148	0	148	0	142	6	0	0	0	0	147	0	1	18	32	98
	Domestic									186	186	0	169	16	1	0	0	0	185	0	1	33	47	106
Material	Steel										538	0	327	210	1	0	0	0	532	0	6	55	98	385
	Cast Iron											14	0	5	8	1	0	13	0	0	1	1	1	12
Size of Pipe	D_1	$D_1 < 50$ mm											327	0	0	0	0	0	324	0	3	47	73	207
	D_2	$50 \le D_2 \le 100$ mm												215	0	0	0	5	207	0	3	9	24	182
	D_3	$100 < D_3 \le 200$ mm													9	0	0	7	1	0	1	0	1	8
	D_4	$200 < D_4$														1	0	1	0	0	0	0	1	0
Type of Joint	Welded																0	0	0	0	0	0	0	0
	Mechanical																	13	0	0	0	1	1	11
	Screw																		532	0	0	52	97	383
	Bell & Spigot																			0	0	0	0	0
	Others																				7	3	1	3
Site Geological Conditn	A	Terrace (Old City Area)																				56	0	0
	B	Alluvial Plain																					99	0
	C	Cut and Fill																						397

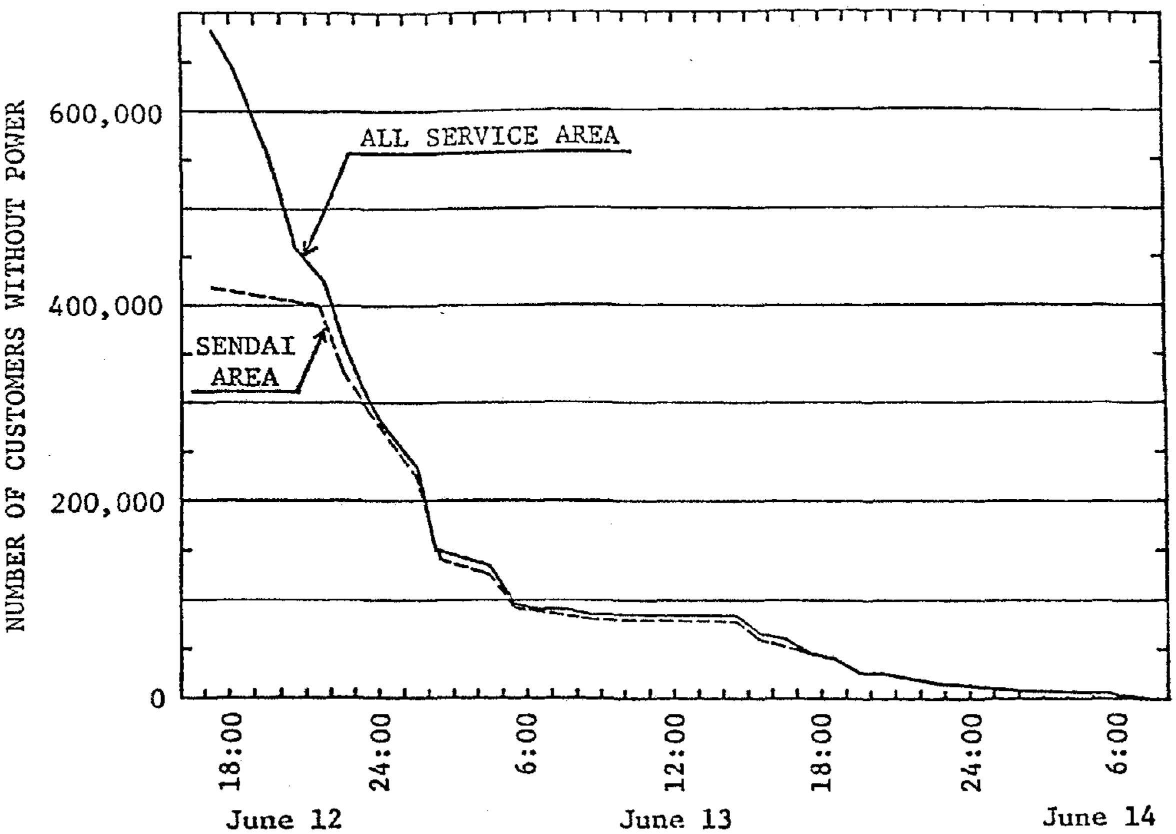


Fig. 1. Number of Customers Affected by the Earthquake in the Tohoku Electric Power Company's Service Area.

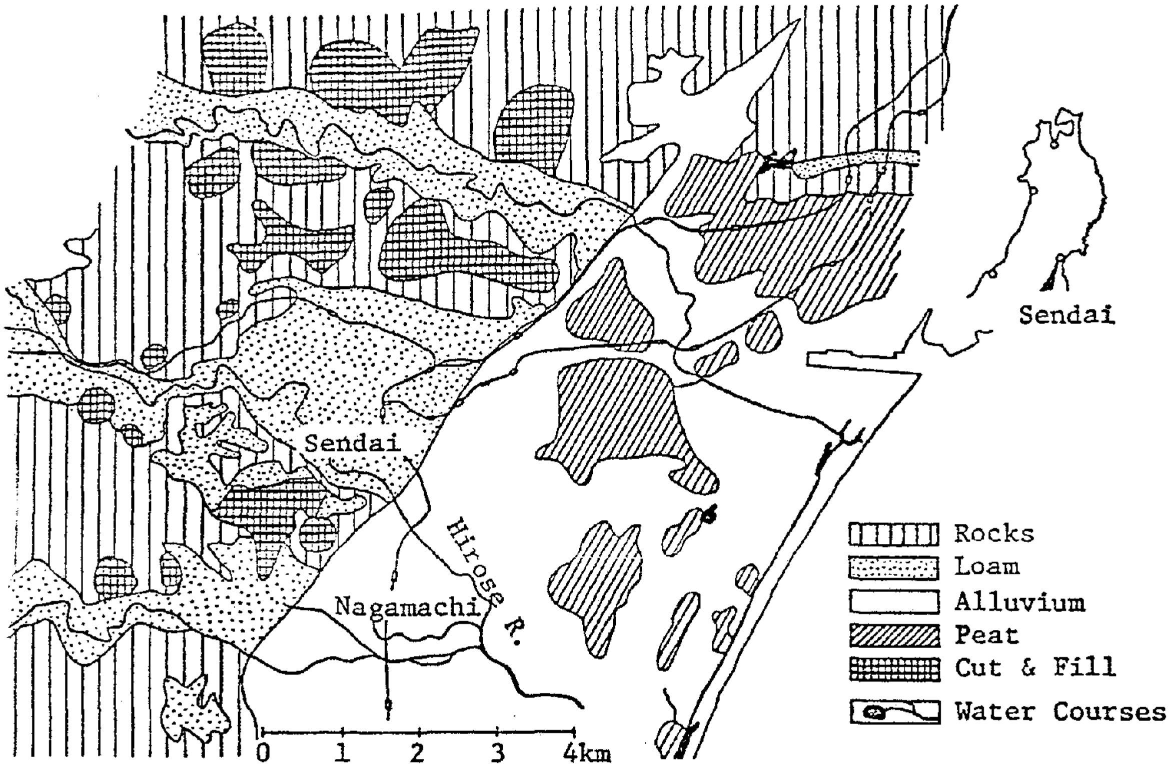


Fig. 2. General Geologic Setting of the Sendai Area.

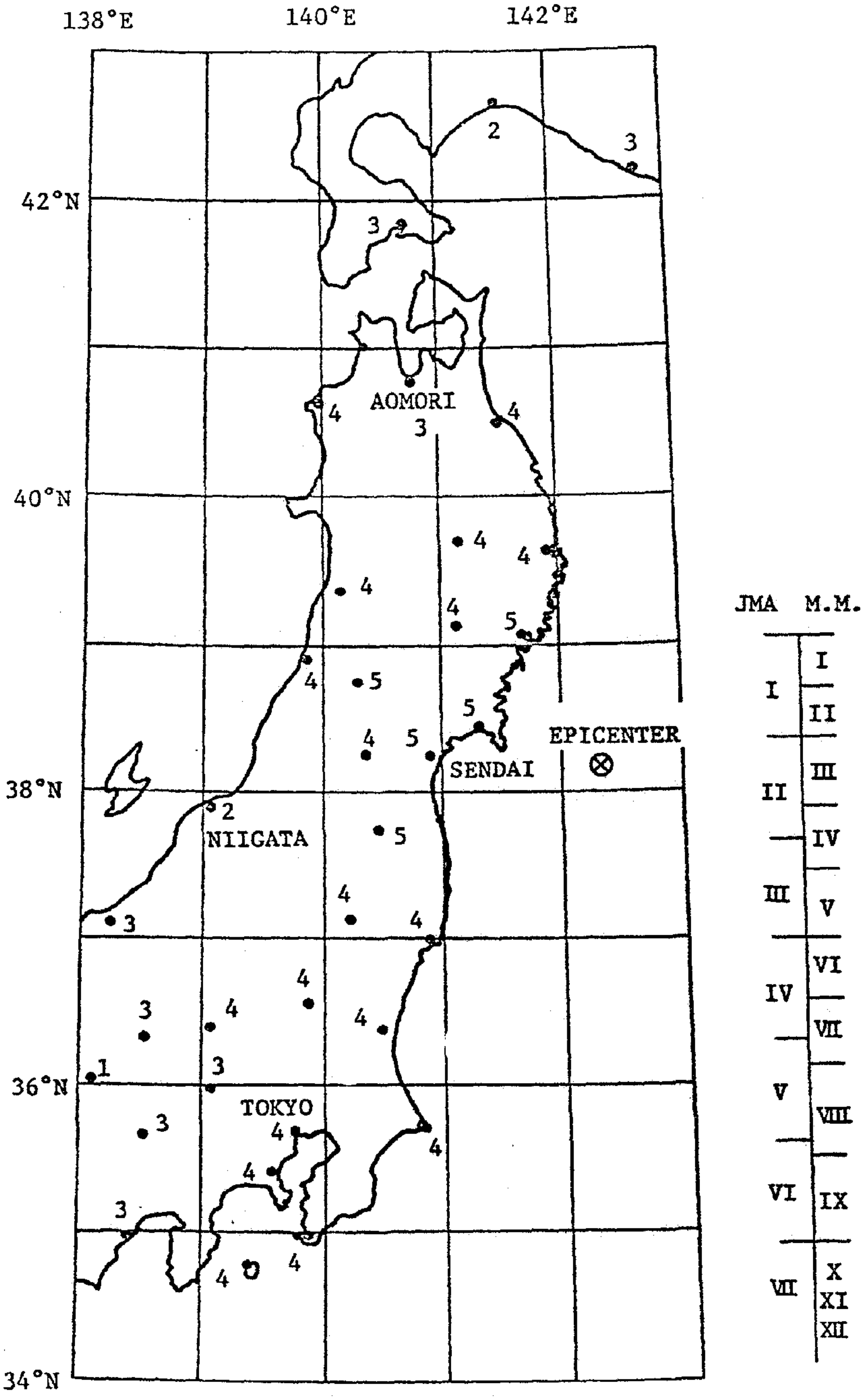


Fig. 3. Location of Epicenter and JMA Intensities at Various Places.

SAFETY & RECOVERY OF URBAN LIFELINES

GAKU YAMADA

I. DEFINITION OF 'LIFELINE':

In order to clarify the boundaries of the study, it is necessary at the outset to define the object termed "Lifeline". As there is no precedent for such a definition, the author intends to consider it as follows:

The Lifeline may be considered to be one of the systems comprising a city and it is, in itself, comprised of 3 further sub-systems, viz:

<u>Sub-system 1</u>: Enables the maintenance of activities pertaining to daily life;

<u>Sub-system 2</u>: Enables the protection of life and property;

<u>Sub-system 3</u>: Enables post-disaster recovery, reorganization and growth.

A) <u>Sub-system 1</u>:

1) Facilities for the supply (and disposal) of the following:
    - a) Energy - Electrical power, Gas, Liquid fuel pipelines, etc.
    - b) Water - For domestic use, for industrial use.
    - c) Food - Wholesale markets, refrigeration, retail outlets
    - d) Waste - Garbage, sewerage

2) Transport facilities
   - a) Roads
   - b) Railways
   - c) Waterways (including ports and canals)
   - d) Airways (including airports, guidance systems)

3) Information systems:
   - a) Telephone
   - b) Data transmission
   - c) Broadcasting

B) <u>Sub-system 2</u>:

1) Life protection facilities:
   - a) Emergency aid-medical facilities and ambulance services
   - b) Emergency escape - Escape routes on land, water, air disaster relief areas guidance systems

2) Property protection facilities:
   - a) Fire fighting
   - b) Flood relief
   - c) Police

This sub-system falls mainly within the jurisdiction of the Fire Department, the Police and Medical Services. While 1 is relatively more important than 2, in order to realize 1, the importance of 2 should also be recognized.

C) <u>Sub-system 3</u>:

The components of this sub-system, which enables the recovery, reorganization and growth after the occurence of a disaster, are the same as those described in Sub-system 1. Therefore, conclusions will be drawn by considering the components, or elements, described in Sub-systems 1 and 2.

II) THE BREAKDOWN OF THE LIFELINE:

The Lifeline in itself is considered as an integrated system. Therefore, the functions of the sub-systems that constitute the Lifeline are not independent, but interdependent upon each other. However, up to the present time, these sub-systems have largely been considered independent of each other, and a large number of studies concentrate on a description of the disaster as perceived after its occurence. Such descriptive studies are useful if similar disasters were to occur. It is felt that research should also be directed so that disaster situations which have never been experienced before may be imagined and preparations made for appropriate countermeasures, if such disasters were to occur.

Let us consider the fact that urban systems have become increasingly complex and inter-dependent. On the one hand, this complexity shows instances were the city has come to increase its resistance to disasters, but, on the other hand, instances where the city has developed weaknesses may also be seen. The latter may be seen if we were to imagine what would happen if the centralized control systems employed in a city were to breakdown. Even if only a part of the city was to cease functioning, the ill-effects of this tend to spread over a far wider sphere of influence than the immediate problem area. This is to say that there is a need for us to imagine an instance where, for example, the power supply is cut off and the telephone system also ceases to function. Also, even for cities which are not dependent upon such complex artifical systems, there is a need to imagine the worst conceivable disaster that could occur. Hence, the need exists to construct, by deduction, images of the most hazardous disasters that could possibly occur across the spectrum of the globe. It is also necessary to relate these constructed images to actual occurences in order that we may refine our forecasts and be better prepared to meet such disasters. Let us consider how such images may be constructed.

First, the requirements of each system would have to be considered under conditions of: A) Ordinary, day-to-day use; B) Temporary use, during recovery from a disaster; and C) Improved use on recovering from the disaster.

A) Requirements for Ordinary use:

- A1) Natural environment
- A2) Structures, plant and equipment
- A3) Control equipment
- A4) Operators
- A5) Energy inputs
- A6) Waste and effluent disposal.

B) Requirements for Temporary Recovery

- B1) Natural environment
- B2) Finances for recovery
- B3) Layout plans, drawings and diagrams of the affected systems
- B4) Repair materials stock

B5) Stock of repair tools and equipment
B6) Technicians and repair workers
B7) Energy inputs
B8) Waste and effluent disposal

C) Requirements for Improvement

C1) Natural environmental Data
C2) Finances for improvement
C3) Optimum Design
C4) Materials Stock
C5) Stock of tools and equipment
C6) Technicians and repair workers
C7) Energy inputs
C8) Waste and effluent disposal

Ordinarily, for the system to function effectively, requirements A1 to A6 would have to be satisfied, i.e, the condition $\phi = A1 \cap A2 \cap A3 \cap A4 \cap A5 \cap A6$ must exist.

The occurance of a breakdown may be considered as something that inverts the "and" ($\cap$) in the above equation into "or" ($\cup$). Therefore, even if there is a breakdown with respect to only one of the requirements (A1 to A6) the system will cease to function. The details of such breakdowns may be elaborated as follows:

(A1) → A2: Breakdown of structures, or plant and equipment
→ A3: Control equipment breakdown
→ A4: Cessation of the operator's function (eg. due to the sudden death of the operator, sabotage, etc.)
→ A5: Cessation of energy inputs
→ A6: The disposal of wastes and effluents becoming impossible.

In addition, it is also possible to conceive of instances where a chain of breakdowns may occur, e.g., (A1) → A4 → A3 → A2, resulting in A2 to A4 ceasing to function. Situations are also conceivable where the starting point of such a chain reaction may not return to the original state it was in before the occurence of the disaster. Ground subsidence resulting from an earthquake (which may be taken as an example of (A1)) is one such instance.

Such breakdown effects may be represented in matrix form, the elements comprising the matrix varying with the system being considered.

$$\begin{array}{cccccccccc} & & & & \text{effect} & & & & & \\ & & A1 & A2 & A3 & A4 & A5 & A6 & & \\ & A1 & 1 & 1 & 1 & 1 & 1 & 1 & & \\ & A2 & 1 & 1 & 1 & 1 & 1 & 1 & & \\ \text{cause} & A3 & o & 1 & o & o & 1 & 1 & = & A \\ & A4 & o & o & 1 & o & o & o & & \\ & A5 & o & 1 & o & o & o & o & & \\ & A6 & 1 & 1 & o & o & o & o & & \end{array}$$

The direct, or primary effect may be considered to be represented by the notation A, with A^2 representing secondary effects.

A system such as the one described above is vulnerable, but if some alternate elements (A1' to A6') are considered to exist for the elements A1 to A6, we may be able to reduce this vulnerability. This is the usual approach to resolve such a problem.

Therefore, we may say that the conditions that should exist for, say, Anti-seismic Systems are:

1) Improved efficiency of the Damping/Buffer factor;
2) The elements of Matrix A should be made to tend towards zero (0);
3) Total transfer of functions to the Alternate/Standby elements should be possible.

Let us consider an example where the breakdown of one sub-system affects other sub-systems by looking at the earthquake that occurred in Miyagi prefecture in 1978. As shown in the illustration in figures 1 and 2, the effects of the breakdown of the telephone and road systems were next in order of inconvenience. However, it may be said that the effects of the breakdown of other systems was relatively slight (breakdown of the gas and water supply systems caused great, but localized inconvenience to the effective functioning of households).

In the case of the earthquake that occurred in Niigata Prefecture (1964), the collapse of the breakwater, coupled with ground subsidence on the landward side, resulted in floods caused by the sea flowing in, thus delaying the recovery of the Lifeline system. In much the same manner, in the Miyagi example, in areas where landfill and earth retention works had been carried out, ground collapse resulted in the breakdown of most of the roads and pipelines concentrated in these areas in low lying areas too, several hundred areas experienced accidents similar to those described here. Such a pattern of disasters appears to be efficient each time a major earthquake occurs.

Next, concerning the sub-systems that caused the breakdown, as well as those affected, the following observations may be made:

El-El: The supply to the Sendai Area Power Station was cut off. The headquarters of the Tohoku Electric Company continued to function using a Standby Generator. As the Sendai Area Power Station did not possess a stand-by generator, mobile power generators had to be transported in order to enable recovery functions to proceed.

El-Gs: Due to power failure, the gas supply system also suffered breakdown. In addition, because the Stand-by generator would not function, normalization was delayed.

El-Wl, W2: These did not cease to function, even though power was cut off because the stand-by generator functioned. However, as the period during which power was cut off was rather long, the stand-by generator suffered from a shortage of fuel supply.

El-Fd: Due to power failure, the electrically operated shutters of the wholesale warehouses could not be opened. Thus mobile power generators had to be brought into operation before the shutters could be opened.

El-Sw: Due to power failure, the sewerage system ceased to function. The standby generator could not be put into operation because its cooling unit failed to function.

El-Gb: Equipment breakdown as well as power failure were responsible for the ceasing of functions. There was no stand-by generator.

El-Rd: Traffic Signals and Control systems ceased to function because of power failure. Mobile Generators were dispatched to major traffic intersections to enable the traffic signals to resume their function.

E1-Rw: Stopped functioning temporarily due to power failure. However, as the Standby Generator at Sendai Station took over functions, and also because other power supply requirements (e.g., to train motors) were restored, the ill-effects were minimized.

E1-T1,T2,Bc: Function ceased with the cut off of power supply, but the stand-by generator restored function, thus minimizing any ill-effects.

E1-M1: Lack of power supply to the Control Board resulted in the inability to direct Ambulances by radio.

E1-M2: Hospitals also suffered from power failure. In some instances, standby generators took over function while in other, mobile generators were dispatched.

E1-Fr: Power failure affected these functions, but radio communication was restored by switching over to batteries. However, due to inadequacies in such power supply, the Control Board did not function. Also, fire fighting equipment in high-rise buildings ceased to function in instances where it was dependent upon a motor to pump water up from a sump at ground/basement level.

E1-P1: Stand-by generators were put into use when power supply failed, but in instances where these did not function, mobile generators had to be dispatched.

W2-Gb: Due to broken pipelines along the way, water supply to garbage disposal plants were stopped and their function ceased as a consequence.

W2-Rd: Roads were flooded because of damage resulting in industrial water supply pipes.

Rw-Fd: Where rail freight was stopped/delayed, the fresh food being carried required the continuous provision of refrigeration (e.g., using dry ice) to prevent putrefaction.

Rd-Rt: Where detours were possible, bus services continued to operate, whilst where such re-routing was not possible, bus services came to a halt at the points where road damage had occurred.

Rd-M1,Fr: Due to the resulting traffic congestion, it took about twice the usual time to gain access to the affected areas.

Rd-(Pl): As traffic signals ceased to function, police officers had to be dispatched to direct traffic.

Rw-(Rt): Passengers had to be transferred to the bus system in areas where the railway system had ceased to function.

Pr-Gs: As the Tohoku Petroleum Company could not supply Naphtha for the manufacture of Gas, the gas supply system was affected.

*[Tohoku Petroleum, which is located along the seafront, is assumed by virtue of its scale and function, to be equivalent to a Port (Pr)].

Tl-Gs,Wl,Rd,Rw: There were problems with respect to the collection and dissemination of information concerning gas and water supply as well as Road and Railway services due to the jamming of the telephone system caused by a heavy overload of communications traffic directly after the occurrence of the disaster.

T2-W2: Some telemeter transmission of data and information ceased to function.

3) IN CONCLUSION

In this report, an attempt has been made to define the boundaries of the Lifeline System, and to illustrate the cause-effect relationships among the elements constituting its sub-systems by carrying out a review of the earthquake which occurred off Miyagi Prefecture in 1978. The author chose not to engage in a detailed account of the contents of each sub-system because it was felt that efforts towards improving the disaster prevention, or disaster handling, capabilities of the separate sub-systems would be better left to researchers concerned with and personnel responsible for those specific fields. Hence, it was felt that it was more pertinent to concentrate upon the structure and inter-relationships of the whole Lifeline System, although this is not to imply that the separate elements of each sub-system could be overlooked. Also concerning the optimum dispensation of resources (especially finances), there appears to be a need for establishing priorities, based upon an assessment of the disaster prevention capabilities required of each sub-system. The author considers this aspect of the efforts required to fall within the boundaries of Urban Planning Research.

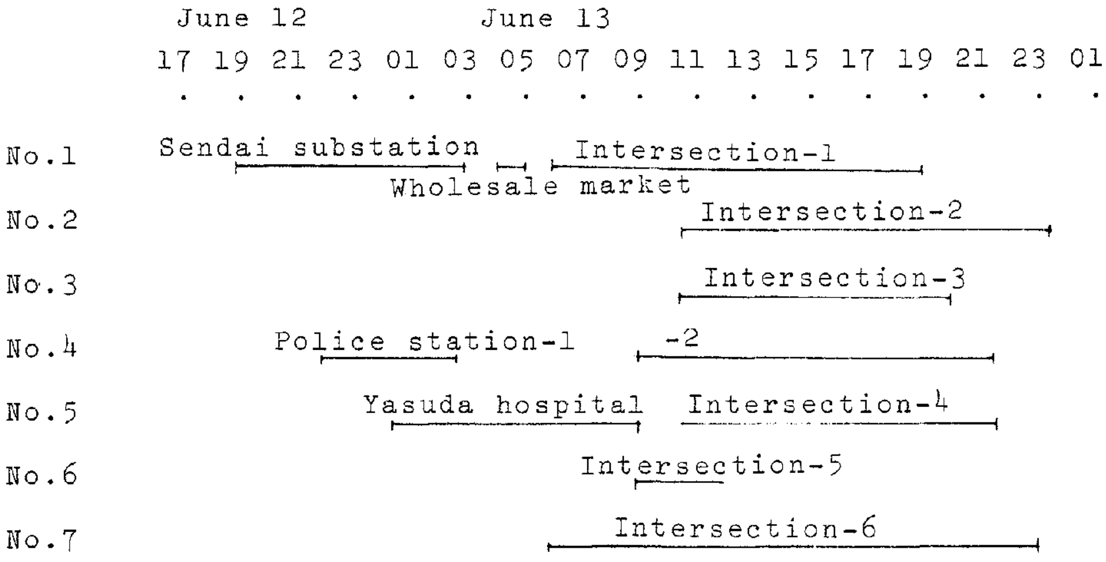
Fig.1 Interaction between subsystems

	El	Gs	W1	W2	Fd	Sw	Gb	Rd	Rt	Rw	Pr	Ap	T1	T2	Bc	M1	M2	Fr	Pl
El	A Et P	A Ef	A Et	A Et	A P	A Ef	A	B P		A Et	A	A	A Et	A Et	A Et	A	A Et P	A Bt	A Et P
Gs																			
W1						B		B											
W2					B		A	B											
Fd																			
Sw																			
Gb																			
Rd									B	B						B		B	(B)
Rt																			
Rw					B				(B)										(B)
Pr		B																	
Ap																			
T1		B	B							B					(B)				
T2				B															
Bc																			
M1																			
M2																			
Fr																			
Pl																			

El-Electric Power, Gs-Gas, W1-Water for domestic use,
W2-Water for industry, Fd-Food, Sw-Sewerage, Gb-Garbage,
Rd-Road, Rt-Bus, Rw-Railway, Pr-Port, Ap-Airport,
T1-Telephone, T2-Data transmission,
Bc-Broadcast, M1-Ambulance,M2-Medical service,
Fr-Fire station, Pl-Police station

A: Cause of functional disorder, B: Cause of partial functional disorder, (B): Needs of auxiary,
Et: Standby generator functioned, Ef: Standby generator failed to function, Bt: Battery, P: Mobile generator

Fig.2 Transposition of mobile generators



THE POSSIBILITY AND SIGNIFICANCE OF RESIDENT'S ORGANIZATION IN DISASTER RESTORATION

HISAO KATSURA

On June 12, 1978 the Miyagiken-oki earthquake caused structural damage to two types of urban residences; recently developed residential quarters and the mansions, a type of condominium house.

Today in Japan, management and preservation of an individual's property is the responsibility of the individual himself by law. Accordingly, restoration of damages to his property is his responsibility in all cases including natural disasters such as an earthquake. However, most structural damage is beyond the individual's ability of restoration. For example, the damage to residential quarters, created by landslides with ten or more houses on it, is widespread and massive such that restoration by the individual is almost impossible. Damage to structural members and building equipment of mansions (which is shared in common) is also beyond the individual's ability to restore. The causes of this damage may be due to the earthquake or improper construction. If the problem was in the building process, the responsibility should rest fundamentally with the building company which designed and constructed the building. It should also rest with the realtor, who was responsible for the planning and selling of the building to the residents, and on the local authority--Sendai City--who gave permission for construction. There is no doubt that the theory mentioned above is very sensible, but the fact is that this theory is not sufficiently performed in actuality. We find the building company seems to avoid the responsibility for foundation disasters but accepts responsibility for the damages of mansions. However, they only restore to pre-disaster condition rather than providing an increase of safety. Hence, permanent safety cannot be guaranteed.

The following is a report on the people who were involved with restoration of damages to their residences and the kind of problems they encountered.

1) Foundation damages

The investigation involved the Midorigaoka district where damage was the greatest. Here three big landslides occurred. This development was constructed twenty years ago, so the contractor responsible for this project could not be located. The administration office designated this area where additional landslides could occur as a danger area, and issued a warning to this effect. The administration office ordered the people to relocate, but most of the residents remained in an uncertain situation. To assure the safety of the buildings for these people, collective effort and cooperation of all the residents was needed. Requests agreed upon by all residents were needed to obtain equitable conditions for relocation or to provide safety improvements in the reconstruction of the foundations. However, organization and efforts of the residents did not always go well. Organizing movements at three of the damaged areas was discontinued. Two conditions that obstructed the movement were: (1) the strong consciousness of personal possession of land and building, which can be traced to the Japanese national character, and (2) the recognition of land damages and the danger it poses in the future. Foundation sinking caused by landslides is easily recognized. Accordingly, requests to the administration office and tradesmen by the residents for safety improvement was made by the organization. However, other requests for other easily recognized foundation damage such as ground cracks, inclination and cracks in retaining walls, did not occur.

Restoration for safety requires competent recognition of damage by the residents. It will unify the residents consciousness and organization and be a leverage factor in dealing with the administration office and tradesmen. In fact, one organization actually received compensation, though very small, from a contractor.

2) Damage of mansions

It is fortunate that this earthquake caused no significant damage to structural members which could have caused a collapse of building. However, partial damage of structural members caused the strength of building to decline, thus decreasing safety. Also, damage of common building equipment caused difficulty for the residents.

Eight largely damaged mansions in Sendai City were examined and although there was no agreement, restoration of the public space was done by the contractor. It was done for business reasons because the company did not want to lose credibility. It was fortunate for the residents that the company took this responsibility, but we cannot expect such a solution when the damage is large. If the scope of responsibility is not clear, there remains a problem as to whether the building safety was insured or not. These negotiations were accomplished by the resident organization. The resident organization, such as a management association or self-governing council, handles the negotiation with the company. The mansions which have such a resident organization receive prompt replies from the company. There are some cases where the management association itself restored the public space. Hence, the effect of proper organization is sufficiently recognized. Many mansions take this opportunity to organize management associations, because without such organization, safety of the building is left wholly to the company. Leaving restoration which deals with the strength of buildings (such as walls, columns and beams) to individuals is not preferable for the safety of the building.

How to share the responsibility between resident organization and the company in the event of a disaster should be addressed from the view of safety with proper input from the administration office.

3) Conclusion

This earthquake raised a serious question as to the method of Japanese urban design. It is not only the problem of damage restoration of newly developed residential quarters and mansions but also how to establish safety management in the urban residential areas and maintain a system of residential involvement in maintenance and management by recognizing the residential organization's role. To solve these problems the social side of the urban disaster prevention must be addressed.

TECHNICAL INFORMATION

CRITICAL USE FACILITIES IN THE URBAN SETTING

GEORGE A. AGRON

ABSTRACT

The current state of architectural and engineering technology can be applied to built environments at a level that will reduce the public threat of earthquake-induced injury and death. This technical knowledge affects where and how we construct new facilities, as well as how we improve or when we evacuate and destroy old ones.

But these innovations, many of them quite recent, must be employed in a planned, systematic and humanistic way in order for a populace to benefit fully from the improved security a seismically-sound physical environment can provide.

Disaster planning must integrate concerns for the built environment with those for healthcare, food and water, emergency shelter, fire damage, and a host of others. A key element in such planning involves both the preservation of structures and the provision of health care in a post-earthquake setting: the role of critical use facilities (including hospitals, fire, police and other public service centers) and the steps that must be taken to assure continued function of such facilities.

These are the structures which must not only remain standing and not contribute to the list of earthquake-generated hazards, but must be able to function at full, even accelerated capacity following a disaster. If such facilities are not appropriately distributed in each urban sector, damage to roads, bridges, etc. may preclude their availability to much of the population following a disaster.

The part that architects and engineers can and must play in this aspect of disaster planning is still emerging and will have continued significance as both technology and social planning evolve.

INTRODUCTION

The United States as a society has not particularly distinguished itself in planning in general. There is now a national network of freeways, representing the highest achievement in national physical planning. We are still some distance in time from development of a national health system. Even city planning is a relatively new phenomenon, about 50 years old, primarily directed toward assurance of economic development rather than for social planning. None of these statements is of itself negative. The nation has flourished and in many ways has set examples for the for the rest of the world, but there are real problems related to planning and implementation of programs which will permit our cities exposed to severe earthquakes to respond without severe traumatic experience.

My colleague Karl Steinbrugge and his associates painted a grim picture of potential earthquake losses in the San Francisco Bay Area in a report, A Study of Earthquake Losses in the San Francisco Bay Area, Data and Analysis, prepared for the Office of Emergency Preparedness, U.S. Department of Commerce, 1972 for the National Oceanic and Atmospheric Administration (NOAA). This report is of necessity a "worst case study", that is, assuming an earthquake equal to the 1906 event and assessing the physical character of the city as a basis for prediction of casualties and civic disruption. If the report were to be dated 1979 a few improvements would be noted. Some unsupported parapets have been removed or braced, new hospitals have increased potential for physical survival and operation continuity, freeway overpasses have been strengthened, and almost all schools in the city have been brought up to much higher earthquake resistance standards. Those not meeting these standards have been removed from service as school buildings. It is by no means certain that these improvements would have a significant effect on the expected casualty rate or on disruption of public services, transportation and communication. Nor are there any visible improvements in securing supplies stored in warehouses to provide food and other essential goods. This is the situation in San Francisco, a city which has suffered the most severe earthquake in contemporary history in the United States. It cannot be expected that other cities with significant seismic exposure are more advanced. I am sure that casualty and damage predictions for cities such as Boston, Schenectady, Charleston, S.C. and Vicksburg, Miss., all areas of high earthquake intensity, are not significantly different in scale.

Nonetheless, significant advances at a national and local level have occurred and may over time reduce the magnitude of potential casualties and damage. These advances may also increase performance of critical use facilities to deal with the problems generated by an earthquake disaster. First, there is now a much wider body of knowledge on seismic expectation and levels of risk, though not yet at the level of accurate prediction. At least there is none on which any region in the United States is yet willing to evacuate populations in anticipation of a major earthquake. Second, agencies with national responsibilities such as the Department of Defense and Veterans Administration have progressed dramatically in requiring their new facilities be designed not only to survive earthquakes, but to remain operational. Third, states such as California have enacted legislation greatly upgrading requirements of hospital design, largely out of the experience of the 1971 San Fernando Valley earthquake. Finally, in California and perhaps in other areas, the state Building Safety Board, an organization concerned with hospitals and other critical use facilities, is in the process of identifying essential hospital services as a basis for statewide planning to address the consequences of major seismic events.

CRITICAL USE FACILITIES

For purposes of this discussion, critical use facilities are defined as structures, permanent or temporary, which are intended to house or be a base for those activities required for response to the human consequences of major earthquakes in urban settings. Those activities include mobilization of resources relating to provision of communications and medical care; maintenance of public health and order through distribution of supplies as food and water; evacuation of adversely affected elements of the Population; and meeting other essential emergency needs generated by the earthquake's impact.

PLANNING FRAMEWORK

Public policy establishes the base for pre-disaster planning. It is founded on recognition of significant risk to life and property due to seismic hazards. Such recognition may lead to mandatory action to develop, and when necessary, implement an action plan to deal with the consequences of the seismic disaster. Government organizations are usually responsible for plan development and management of implementation, but effective planning and implementation requires voluntary cooperation from many agencies, individuals, institutions, industrial and commercial organizations, and professional societies. Planning resources must be available to generate and analyze planning data, estimate earthquake consequences, and develop and test an action plan for disaster response within a framework of public knowledge and acceptance. Even in areas of high seismic exposure, public knowledge and acceptance of disaster planning is not always easily accomplished. Even simple hazard reductions are difficult to accomplish, though some improvement in public recognition and action in that regard is evident.

DATA AND ANALYSIS

For planning purposes, three areas require study: the seismic character of the urban region, the urban characteristics themselves - demographic, natural and constructed - and the quantity, location, nature and capacity of critical use resources.

Seismic Character

Planning must be based on the best possible estimate of seismic probability, intensity and geographic range which could affect the urban community. We are dependent on scientists and professionals to provide such estimates, with recognition that definitive prediction is beyond present capacity. The knowledge and and skills presently available, however, do provide the basis for far greater reduction of hazard than we as a world community have yet undertaken. It is within present capability for scientists and professionals in seismology and geology to provide us with urban "design earthquake" data on which to base planning actions.

Urban Characteristics

The critical factors in urban analysis for planning purposes have to do with people - their numbers and location at different times, geography of the urban region, and characteristics of man-built elements of the urban environment. The structural quality of buildings, dams, roads, bridges, industrial plants and utility systems greatly affect their response to earthquakes with corresponding effect on potential loss of life, injury, exposure to environmental hazards, and physical isolation of the affected community.

Critical Use Resources

Every urban community includes a great number and range of critical use resources. These include, but are by no means limited to, disaster control centers; police, fire and military headquarters; utility generating and distribution centers; radio, television and telephone stations; hospitals and other health care facilities; warehouses; transportation; water resources, and trained staff for normal and emergency operation of these resources. Each of these individual resources has physical characteristics which will be differently affected by a major earthquake. What is critical, for purposes of analysis, is assessment of their capacity for survival, continued function, and emergency service. The human resources involved must be assessed in terms of availability, distribution and capability under emergency conditions.

PROJECTIONS

On the basis of these analyses, projections can be generated as to the consequences of the impact of the "design earthquake". The "Study of Earthquake Losses in the San Francisco Bay Area", mentioned previously, provides such projections.

That report, which may be paralleled by similar work in other areas, provides estimates of death and injury, of the nature and extent of physical destruction and land changes, and of effects on critical use facilities which could reasonably be expected to result from a major earthquake in the region of the study.

ACTION PLAN

Such projections can provide the basis for action planning to respond to major earthquakes with maximum possible effectiveness. If and when the event occurs, with appropriate assessment of casualties and destruction, and with mobilization of surviving resources, emergency response can be undertaken at disaster sites and at critical use facilities to ameliorate as much as possible the consequences of the disaster.

Within the framework of the foregoing, discussions will be focused on hospitals in seismic areas as typical of critical use facilities, and as the specific area of my professional concern. Further, this discussion will center on California experience because it is the primary focus of attention in planning reduced hazards in hospitals and for increased emergency capacity, both of which are critical to improvement of urban response to seismic events.

STATE OF CALIFORNIA EXPERIENCE

California has the highest seismic exposure of any state in our nation. It is the most populous state. Its main population centers are in San Diego, the Los Angeles basin and the San Francisco Bay Area. These areas are all traversed by major fault systems with different histories of activity, but in general, no area within these regions is immune from probability of major earthquakes.

Three California earthquakes have greatly affected public policy in regard to public buildings, schools, hospitals and other health facilities: The 1906 San Francisco quake, the 1933 Long Beach quake, in which schools and public buildings performed poorly, resulted in passage of the Field Act, legislation related to seismic safety of schools and the Riley Act related to public buildings. The San Fernando quake, in which hospitals were badly damaged, resulted in passage of the Hospital Safety Act (SB519).

The San Fernando quake stimulated public and government interest because of great damage to health facilities and lifelines. All lifelines were disrupted: water, sewage, gas, power and phones. The Van Norman (earthfill) dam almost collapsed. The primary area affected was mostly residential and with some exceptions, hospitals were the only multi-story reinforced concrete buildings in the area of strongest shaking. Schools performed well, experiencing only minor damage. This was attributed to Field Act requirements, which included strict seismic standards, structural plan review by the Office of the State Architect, and continuous inspection during construction.

Hospital damage was acute, for example.

1) An older hospital building at the Veteran's Administration at Sylmar collapsed, resulting in 34 deaths.

2) Holy Cross and Pacoima hospitals were badly damaged and were evacuated.

3) Olive View Hospital, a newly completed, 500-bed facility, complying with the latest codes, was severely damaged to the point where the main building nearly collapsed, and the psychiatric unit did collapse.

As mentioned above, the reaction to the poor performance of the hospitals was the passage of SB519, "The Hospital Safety Act", which became effective in March 1973. This law, patterned after the Field Act for schools requires:

1) Hospitals to be designed to remain functional following a disaster.

2) Geotechnic studies of sites.

3) Structural design by a structural engineer.

4) Structural plan review by the Office of the State Architect

5) Continuous construction inspection by certified inspectors.

The basic difference between SB519 and previous construction laws is the requirement that the building remain functional, as opposed to requiring only the structure to survive the quake. Thus, not only the structure, but also architectural, mechanical and electrical systems and components are subject to review.

Major code changes included:

1) Base shear laterial force coefficient was increased by a factor of 3.

2) Ductile design of concrete structures was required.

3) Lateral force coefficients for non structural elements were increased and checking by OSA is required.
   $C = 0.5$ for rigid mountings
   $C = 1.0$ for flexible mountings

4) Dynamic analysis is required if building is over 160 feet in height or is irregular in shape.

SB519 also established the Building Safety Board (BSB) a multidisciplinary group made up of seismologists, engineering geologists, structural engineers, architects, mechanical and electrical engineers, a hospital administrator and advisory members from state agencies. BSB acts in an advisory capacity to the state agencies regarding regulations and as an independent appeals board.

It should be noted that despite these activities, present seismic regulations apply only to new construction or to major programs for expansion and alteration of existing hospitals. A preponderance of California hospitals do not conform to current design criteria, and few have capacity for continued performance following a major quake.

It should be further noted that, as the NOAA report amply demonstrates, many hospitals lie within known active fault zones, and some lie almost directly on a fault. Considering that hospitals are located in relation to population centers, this is no surprise. Many public schools and universities and even a disaster command center are similarly located. At the present time there is no designated zone where school or hospital construction is prohibited on the basis of earthquake probability, although such construction is prohibited where landslide, flood or subsidence could be expected to occur.

The charts following this discussion outline the simplified process for disaster planning in areas of significant seismic risk.

These charts presume the establishment of an urban disaster planning framework based on a policy of effective response, and on legislation or other governmental action formalizing the basis for planning. It requires an organizational structure to develop and implement plans and adequate technical and economic resources for plan development and implementation. The basis of planning is the development of an expected casualty incidence and the definition of a functional capacity to provide essential medical care in response to the estimated casualty incidence. The disaster plan itself is a formal program of pre-disaster organization for casualty assessment, resources mobilization and medical response when the earthquake occurs.

The expected casualty incidence is estimated on the basis of anticipated earthquake characteristics, time of the event, and the physical characteristics of the urban setting. Intensity of the shock and time of the event directly affect the urban population in relation to the natural and man-built characteristics of the region. The natural characteristics with which we are concerned are those which are likely to produce casualties. These characteristics include the possibility of subsidence, tsunami, or landslides which the earthquake can generate. The manmade characteristics have to do with the physical capacity of the constructed environment, including buildings, roads, bridges, industrial plants, communications systems, utilities and other elements of the environment, which by virtue of their activity or construction, can contribute to loss of life, injury, and social trauma as a consequence of severe earthquake forces.

Response capacity is a measure of the characteristics of resources, especially critical use facilities: i.e., hospitals and other essential support resources.

Hospitals and other health care resources must be assessed as to their ability to survive the expected earthquake, function independently following the earthquake, and provide emergency care. In turn, functional capacity of hospitals is dependent on the survival capacity, post earthquake functional capacity and emergency capability of staff, supplies, transportation, utilities, and support. These together can be assessed to determine response capability of emergency medical care for the city as a whole, by urban sector and by institution.

Given the planning data on expected casualty incidence and response capacity, a disaster plan can be developed which mobilizes resources at disaster sites and at health care institutions. For successful implementation a disaster plan depends on a clear system for control of disaster operations and communications. The control center must be able to assess the actual incidence, geographic distribution and trauma of casualties while mobilizing facilities, staff, supplies, and transportation.

Within this general framework the following discussion will focus on hospitals and other health care institutions as an example of critical use facilities in earthquakes, and, accordingly, will discuss their capacity for survival, for independent functional operation and for provision of emergency medical care following a disaster.

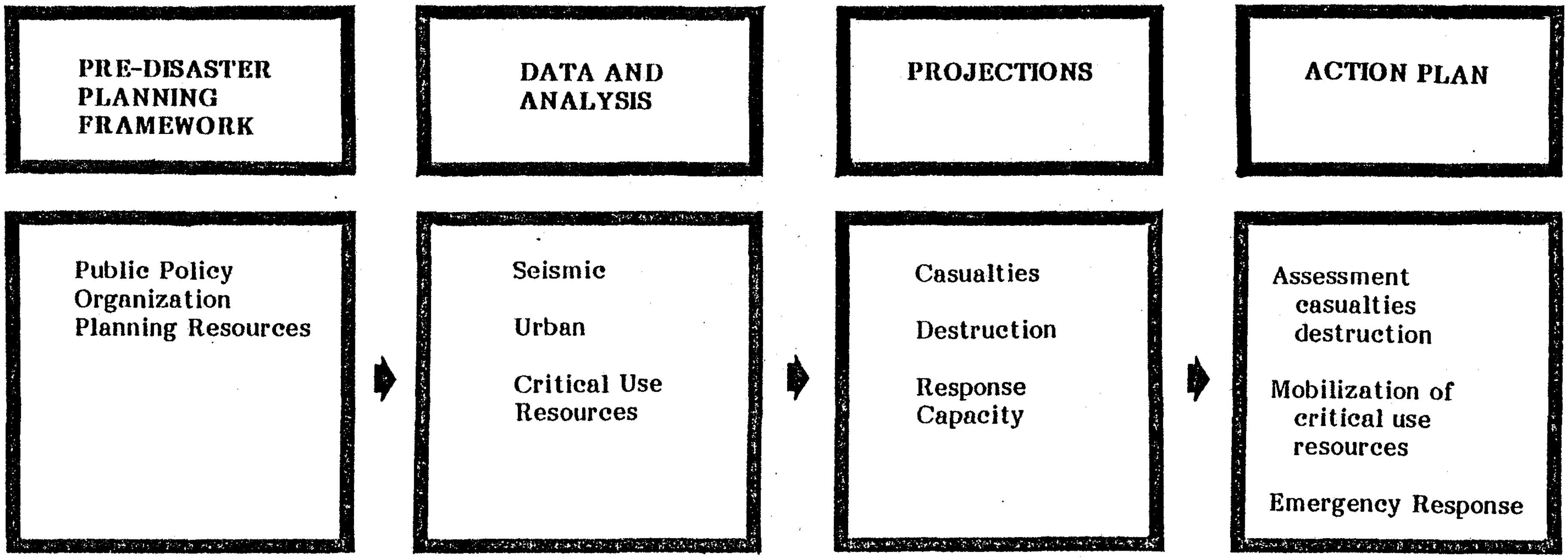
URBAN SEISMIC PRE-DISASTER PLANNING

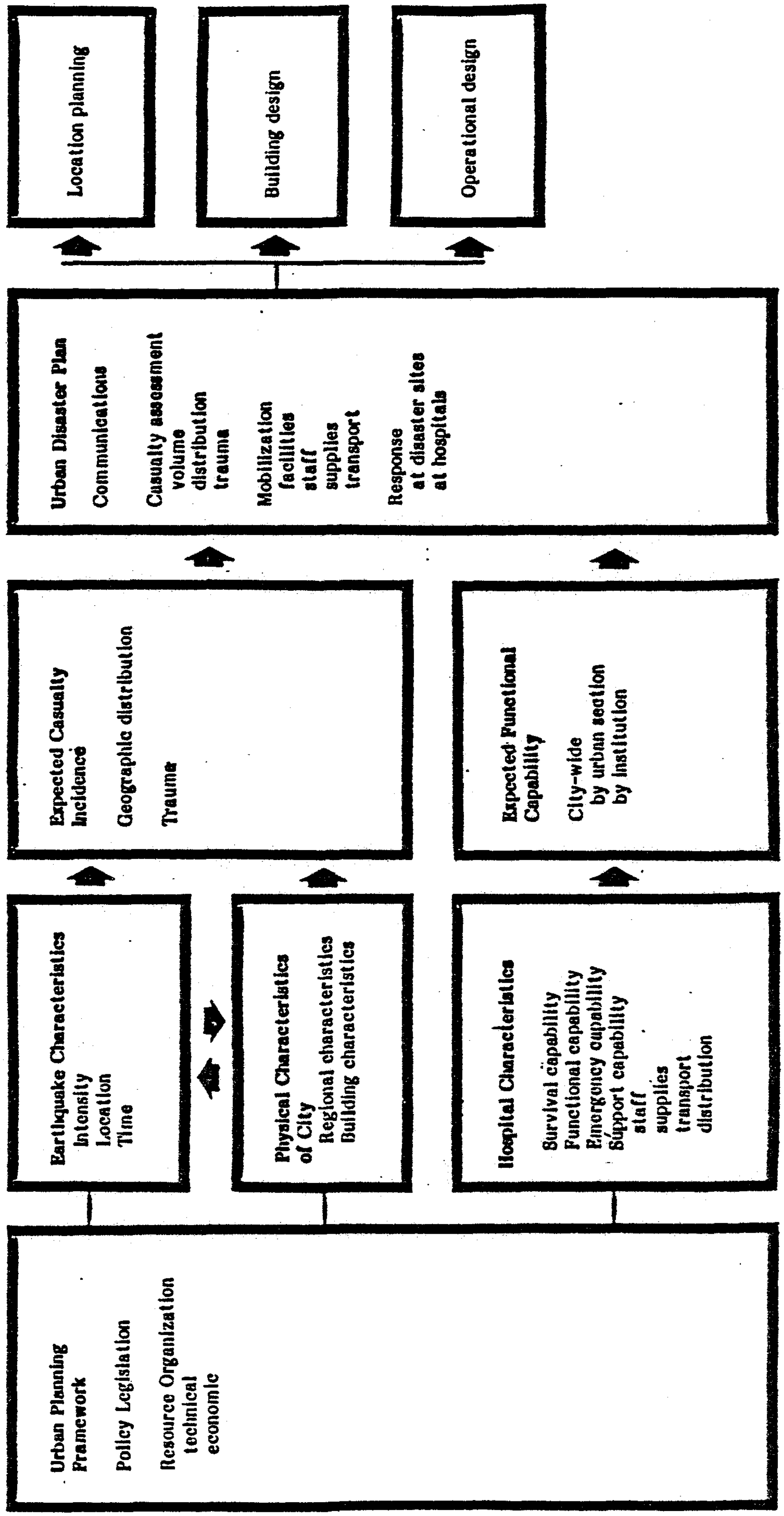
The following chart outlines in general terms a pre-disaster planning process to provide a framework for this discussion.

SURVIVAL CAPACITY

The ability of any building to survive an earthquake depends on its location and physical construction. However elegant its physical construction may be, that construction is meaningless if it is subject to subsidence, landslides, flooding or environmental hazards generated by an earthquake. In this regard, it is interesting to note that in the NOAA study of the San Francisco area, a number of hospitals are located within well identified fault zones and most others are sufficiently close to the two major faults of the region to cause concern. However that may be, most if not all hospitals in the area can be expected to survive as physical structures. Their capacity for functional survival is, however, another matter entirely.

Functional capacity has two main elements: physical integrity of the health facility as a whole including all non-structural systems, components, furnishings, equipment and supplies and emergency capacity of the space, staff, equipment and supplies available, including potential for functional reorganization to handle enormously increased volumes of work induced by the disaster.


PRE-DISASTER PLANNING FRAMEWORK
DATA AND ANALYSIS
PROJECTIONS
ACTION PLAN
Public Policy
Organization
Planning Resources
Seismic
Urban
Critical Use Resources
Casualties
Destruction
Response Capacity
Assessment casualties destruction
Mobilization of critical use resources
Emergency Response


Urban Planning Framework
Policy Legislation
Resource Organization
technical
economic
Earthquake Characteristics
Intensity
Location
Time
Physical Characteristics of City
Regional characteristics
Building characteristics
Hospital Characteristics
Survival capability
Functional capability
Emergency capability
Support capability
staff
supplies
transport
distribution
Expected Casualty
Incidence
Geographic distribution
Trauma
Expected Functional Capability
City-wide
by urban section
by institution
Urban Disaster Plan
Communications
Casualty assessment
volume
distribution
trauma
Mobilization
facilities
staff
supplies
transport
Response
at disaster sites
at hospitals
Location planning
Building design
Operational design

HOSPITAL DESIGN

In general, American design experience for hospitals in seismic areas has been governed by codes and regulations. These codes and regulations have been made more rigorous after each major earthquake in the United States. The Long Beach earthquake of 1933 and the 1971 San Fernando quake resulted in significant increases in requirements for lateral force resistance of buildings generally and hospitals specifically. Within that framework of regulation, hospital design until very recently was entirely conventional and each hospital was designed structurally and functionally at the then prevailing state of the art. Whatever the capacity to resist earthquake forces, no American hospitals constructed before 1970 and few since that date have been designed to permit functional change. The result of this design limitation has been early and costly obsolescence.

In 1967 the Veterans Administration, the owner of some 170 hospitals, with the largest single health care system in the United States undertook to address the issue of obsolescence on a systematic basis as a framework for design of its projected facilities. Our firm, in joint venture with Building Systems Development, was commissioned to study building system design and construction. The study was to produce a system for Veterans Administration hospitals which could be applied in any area of the United States, including areas of high seismic exposure.

Over a four year period our team developed what is now known as the Veterans Administration Hospital Building System. In brief, that system approaches hospital design as a modular discipline integrating architectural, structural, mechanical, electrical and transportation components in terms of planned integration. Basically, the hospital is considered as the organization of an assembly of modules having appropriate capacity to respond to functional requirements. Each module has three basic elements: a functional space housing activities, a service space above housing mechanical and electrical ducts, pipes, conduit and communications systems, and a service bay housing energy sources serving the modules. The concept of the module is based on interstitial organization. The floor of the service space is a ceiling platform having structural integrity and designed as a platform for construction and maintenance of mechanical, electrical and communication services. The service bay houses all air handling units and main electrical services supporting hospital functions.

Each module is thus a virtually independent building but capable of stacking in horizontal association to provide a wide range of functional accommodation. The size of modules is a function of economic duct and piping distribution and of fire safety standards. In general, modules can range in size from 7,500 s.f. to 22,500 s.f. but the selection of size is at the option of the designer. The intent is that modules be as repetitive as possible and as uniform as possible. Seismic resistance can be provided by shear walls, braced frames or rigid frames, again at the option of the designer. Materials of the structural frame can be steel or poured-in-place or pre-cast concrete at the designer's discretion. Modules are intended to be free of vertical penetrations by duct shafts, stairs, elevators and other major obstructions. These vertical components are to be housed in non-systems space adjacent to modular space and planned so as to provide no interference within functional areas or in the orderly and rational organization and distribution of building systems.

The resultant system provides a framework for design based on contemporary industrial practice. It involves no new products or construction methods with a single exception. That exception is the ceiling platform which is a poured gypsum platform, a new application of a method previously applied only to roof construction.

In 1973 our firm and its joint venture partner were commissioned to design the Loma Linda Veterans Administration Hospital in southern California to provide a replacement facility for the Veterans Administration hospital destroyed in the 1971 earthquake. The selected site lies one mile from the San Jacinto fault system and approximately seven miles from the San Andreas fault. We commissioned Woodward Clyde Associates and their consultant Dr. Harry Seed to establish a "design earthquake" which this hospital would have to resist. They conducted historic, photographic and geotechnical studies in that determination. Because of the possibility that the site was traversed by an inferred fault, a trench, diagonal across the site, 1,200 feet long and 20 feet deep, was dug and examined with the conclusion that the site itself showed no fault evidence and in consequence the site itself could be expected to act as a unit. It was also determined that the site was not subject to liquifaction or other adverse conditions affecting building construction.

Information provided by Woodward Clyde on potential earthquakes was translated by our structural engineers, Rutherford and Chekene, into recommended design criteria. In simplified form these criteria can be briefly listed as follows. To the extent possible, the building should be relatively low, symmetrical, highly regular and repetitive in structural organization and it should utilize concrete shear walls for lateral resistance to supplement the resistance provided by the structural steel frame. It was further recommended that, if possible, the building should be designed without the basement normally found in VA hospitals because the loading dock typically found on one side produced a highly eccentric perimiter wall pattern.

Although these are significant restraints, it was quickly established that this 500-bed hospital could be designed for fully acceptable functional performance within the given design guidelines. Because of the large amount of service interconnection necessary in hospitals, it was also recommended that the building be constructed to act as a single unit without separation joints.

While this building was in the design stage, the Veterans Administration developed two construction standards which it applied to this hospital. The first was the requirement for lateral bracing of all non-structural building components -- ducts, pipes, air handling equipment, partitions and building appurtenances, including support for ceiling-hung equipment such as x-ray supports, television sets, operating lights, and similar hospital equipment and furnishings. The second construction standard had to do with the provision of storage resources for water and fuel which will be discussed separately. The ceiling platform greatly simplified conformance with the construction standard for lateral bracing of non-structural systems. While the structure of the floor above provided one capacity for lateral bracing, the ceiling platform, by virtue of its rigidity and capacity to act as a structural diaphragm, provided a second level of anchorage for non-structural elements. The disciplined organization of services within the interstitial space permitted orderly and rational construction and simplified bracing systems while providing easy access to building systems and components requiring service, maintenance or repairs. The system also facilitates modifications during the life of the building. Thus, both functional and seismic resistance objectives were addressed simultaneously and efficiently.

The hospital is an assembly of 35 independent modules which, in final form, demonstrate conformance to our structural engineer's design guidelines. Parenthetically, the high degree of standardization, which pervades the design, simplified and accelerated construction since interferences between trades were all but eliminated. Construction was also accelerated because the ceiling platform provided the basis for simultaneous construction in both service space and functional space.

There are, or course, other ways in which to design hospitals for high building integrity in areas of significant seismic activity, but our examination of other hospitals constructed to comparable seismic requirements confirms the value of the modular and systematic approach to hospital design for survival and continued functional capacity following earthquake events. Fortunately, or unfortunately, the Loma Linda hospital has not been subjected to earthquakes since its construction. However, we have sufficient confidence in this approach that we are now applying this system in the design of other hospitals, one already completed and two under construction.

MAINTAINING FUNCTIONAL CAPACITY

As discussed above, the building at Loma Linda is constructed to resist the forces generated by the "design earthquake". However, during the course of design we approached the Veterans Administration to undertake a study of the protection of hospital furnishings, equipment and supplies, both to reduce life safety hazard and also to permit their continued functional service following an earthquake.

Assuming the survival of the physical plant and its continued operational capacity, and further assuming the disruption of normal electrical power, communications, water supply, waste disposal and fuel, the hospital must still be capable of independent operation. The Veterans Administration adopted a construction standard which requires that hospitals with any significant seismic exposure maintain an on-site storage reserve of four days supply of water and fuel to maintain operations and to provide means of temporary waste disposal to eliminate infection hazard if normal sewer systems are disrupted. Additionally, radio and microwave systems must be provided and kept functional. The four day period for emergency services to provide sufficient time for appropriate decision and action on continued maintenance of hospital service or to allow for evacuation if that proves a desirable alternate.

Further, the Veterans Administration authorized our firm to develop a document entitled "Study To Establish Seismic Protection Provisions for Furniture, Equipment and Supplies for Veterans Administrations Hospitals". This document was published in January 1976 and has received wide distribution. It identifies life safety hazards generated by equipment, furnishings and supplies made unstable during seismic activity and addresses means of reducing the hazard potential. Further, it identifies those items of equipment, furnishings and supplies, and those activities which are required to maintain effective hospital service in post disaster situations and addresses administrative solutions required to implement and monitor protection and emergency planning. Even the most cursory tour through a hospital can reveal potential serious problems which could be avoided by simple measures. As an example, it is possible to find hospital corridors lined with pictures hung on conventional hooks; any severe quake would shake the pictures to the floor, break the glass within their frames and make corridor travel a virtual impossibility at the moment when free, unimpaired movement is of critical importance. There are simple means of securing pictures to walls or partitions to assure they will not fall and become hazardous.

It was not unusual during our study to find medical gas cylinders restrained only by their connections to manifolds which would probably break and prevent medical gas service during an earthquake. Often we found large bottles of chemical reagents on high shelving totally unsecured against seismic displacement with enormous hazard to life and to continued functional capacity. It can be assumed that without protection planning, critical supplies such as pharmaceuticals would be scattered if not destroyed. Even more critical conditions were displayed when we examined patient bedrooms. Patients may be wholly dependent for survival on oxygen services: assuming the oxygen supply system is fixed to the wall unit at the patient headwall, there is nothing to restrain the movement of the bed with consequent tearing apart of lines serving the patient during an earthquake.

In cases such as this, there are difficult problems which cannot be fully solved to complete satisfaction under severe earthquake forces. If the bed is physically restrained from movement, the patient himself is still subject to very great lateral forces. The possiblity of providing bedrails or belt restraints can be considered. However, these may affect normal nursing care and produce a physiological environment which may be out of all proportion, at least from the patient perspective. Nonetheless, it is an issue to be considered, particularly in areas of high earthquake frequency.

While this document outlines basic essential hospital services based on Veterans Administration medical programs it is not comprehensive nor is it intended to be more than a guideline for consideration, planning and implementation by individual institutions.

It is to be noted that at this time the California State Building Safety Board is undertaking its own program to identify essential services as a basis for disaster planning for all California hospitals in seismic areas. Hospital organizations, institutions, and professionals, including two members of the team who developed the VA study, are involved in this exercise.

CONCLUSIONS

The foregoing discussion addresses at least in outline, methods of increasing the survival capacity of hospitals, of maintaining their services in functional condition and of planning for disaster services. Hopefully, these will form part of the inventory of information available to hospital owners, administrators and designers to improve their capacity for effective disaster response. The basic concepts presented here, I believe, apply also to other critical use facilities providing essential disaster services. Facilities housing disaster command centers, fire stations, police stations, public utility buildings and their equipment and appurtenances can be studied for similar purposes in a similar manner. Also, industries can contribute by applying similar programs and studies to their own physical plants and activities to reduce hazard and to increase operational potential.

Despite signficant improvements in the physical design of urban structures, and despite enormous advances in communications and in disaster planning in general, there is little question that major earthquakes can be expected to have consequences affecting life and property almost as if these advances had not occurred. The fundamental problem is reluctance of individuals, institutions and governments to assume the political, financial, technical, and human responsibilities proportionate to the issue of effective urban planning to minimize the effects of major earthquakes.

This conclusion should be no surprise. Major earthquakes are infrequent events. It is not physically impossible to reconstruct all our buildings, both public and private, to resist earthquakes at a level consistent with current knowledge and design capability; nor to assure the security of roads, utilities, and communications so that they would be unimpaired during these disasters. If these are problems at the macro level, there are equivalent problems at the micro level. Even in buildings constructed to resist earthquakes, little attention is paid to the removal or even the significant reduction of hazards within the buildings. Inspection of any warehouse in areas of known seismic hazard will reveal the problem. Few offices secure desks to floors and typewriters to desks; few show any thought of securing heavy file cabinets, bookcases or other furnishings to floors or walls. In short, there is no tendency of which I am aware to place a high premium on restraining those physical elements which can cause injury.

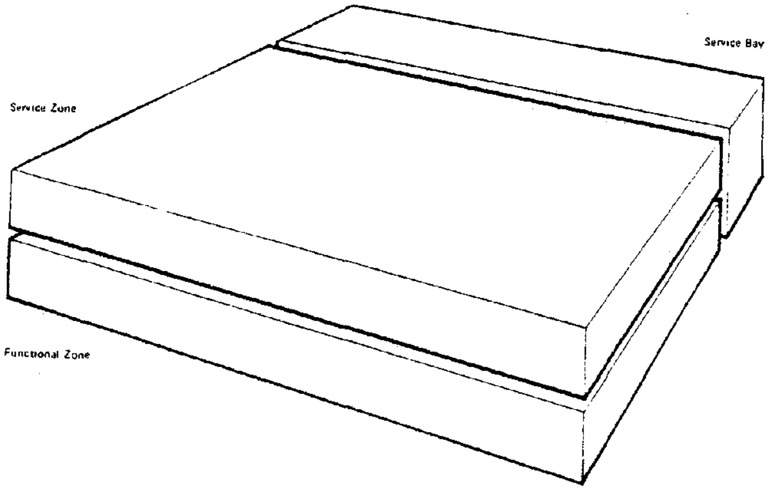
REFERENCES

Handbook H-08-8 "Earthquake Resistant Design Requirements for V.A. Hospital Facilities," published by the Veterans Administration, Washington, D.C.

CD-55 "Earthquake Resistant Design of Non-Structural Elements of Buildings", published by the Veterans Administration, Washington, D.C.

CD-54 "Post-Earthquake Emergency Utility Services and Access Facilities", published by the Veterans Administration, Washington, D.C.

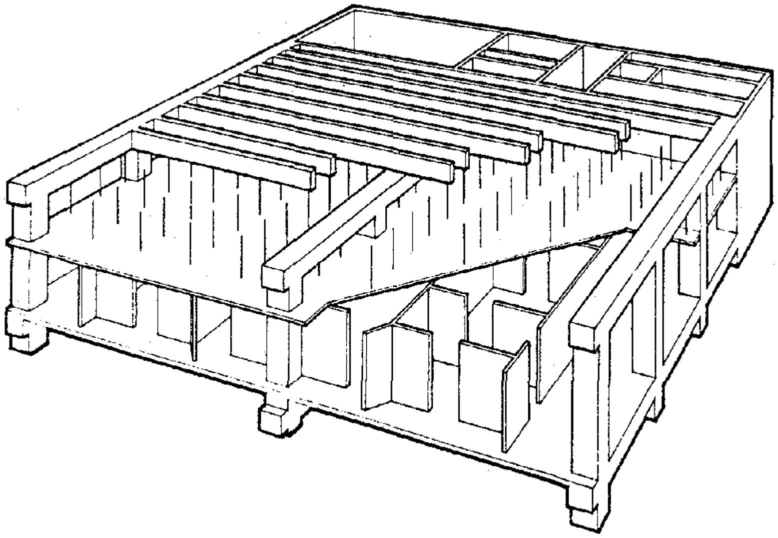
A Study to Establish Seismic Protection Provisions for Furniture, Equipment and Supplies for V.A. Hospitals, for the Veterans Administration by Stone, Marraccini and Patterson, San Francisco, 1975.



The Service Module

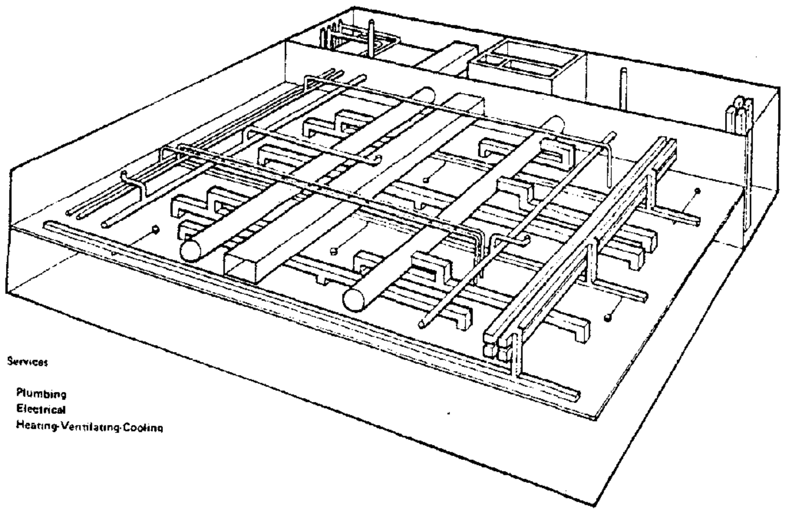
1. THE SERVICE MODULE

The basic planning module in a VA system is the service module which integrates functional and service spaces. They range from 10,000 to 15,000 square feet.



3. THE BUILDING SHELL

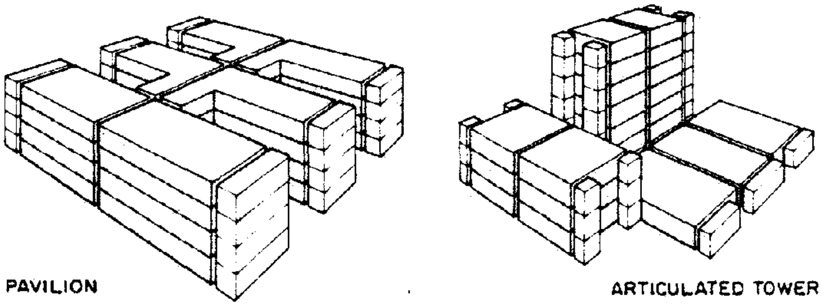
The building shell in a VA system hospital consists of ceiling, partitions and structure. Because the platform is a continuous diaphragm, all partitions are fastened to its underside, leaving the service zone unimpeded.



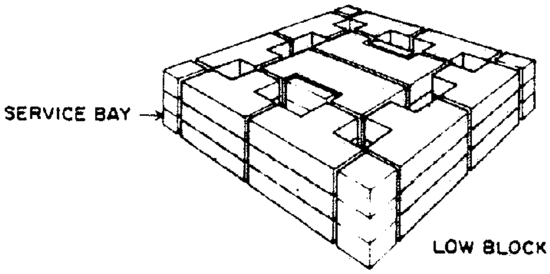
4. THE SERVICE ZONE

The service zone or interstitial space in a VA system hospital houses all the service systems (HVC, electrical, mechanical) and permits easy access for maintenance and alterations.

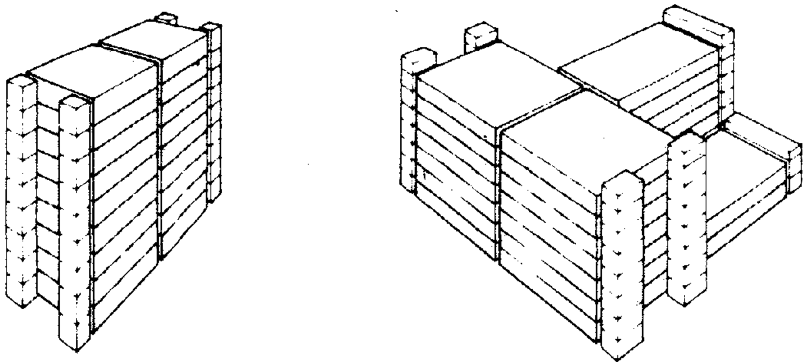
5. Service modules permit designers to see the structure as a series of building blocks that can be arranged in any of a number of configurations.


PAVILION

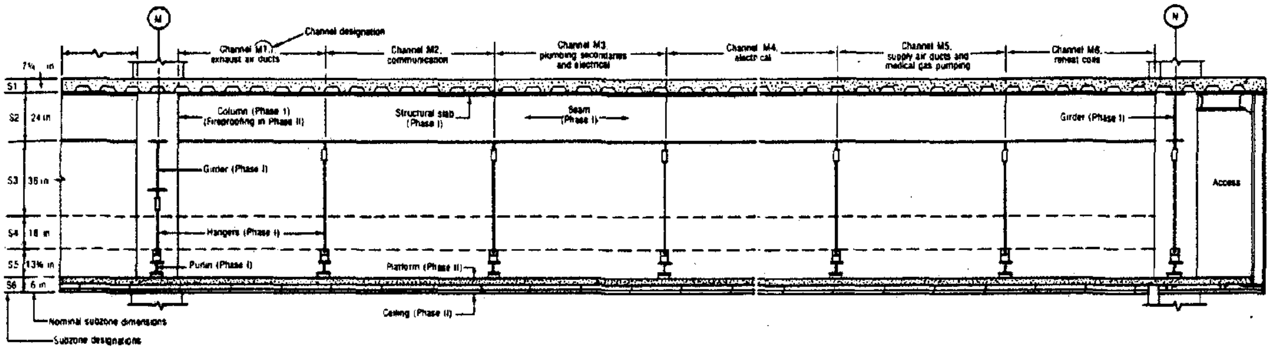
ARTICULATED TOWER



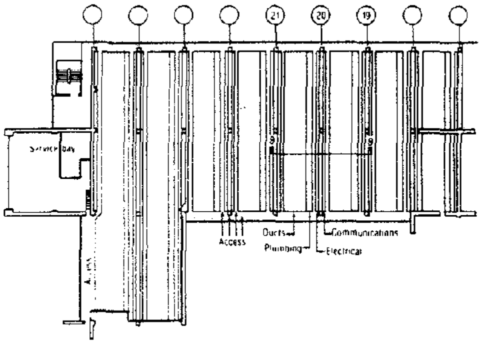
LOW BLOCK


HIGH BLOCK

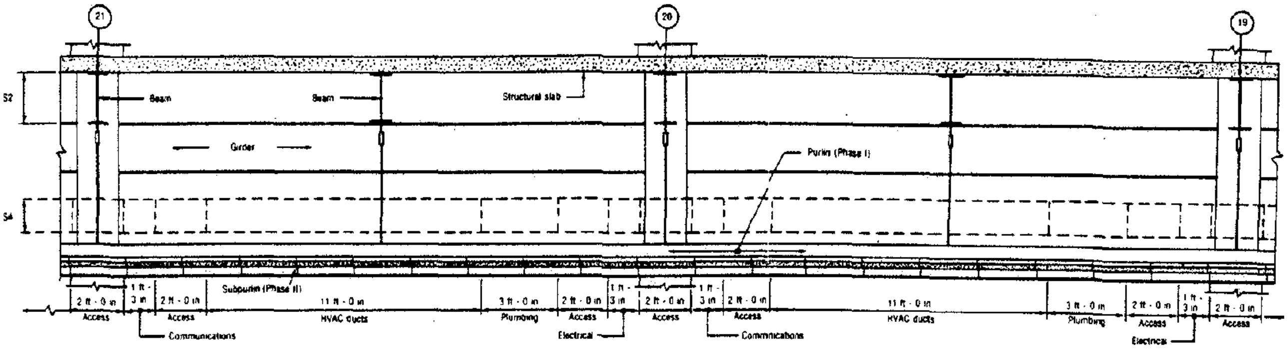
TOWER ON BASE

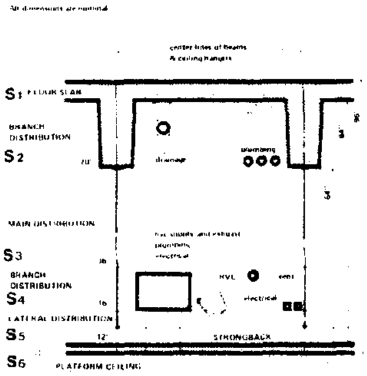


6. Section through the service zone (interstitial space). Phase indications refer to stages during Loma Linda construction.

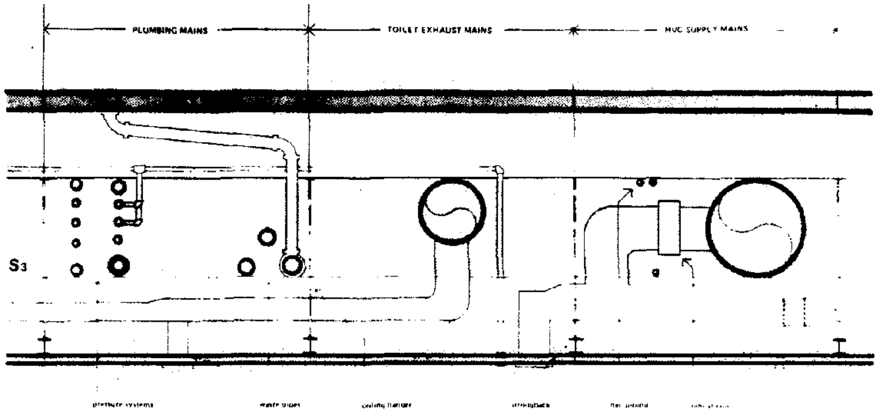


7. A plan (above) and section (below) showing channel arrangements and assignments in the S4 subzone in the interstitial space of VA building system hospital. This section is perpendicular to the section shown in figure 6.





PRIMARY SUBZONES:
section through beams

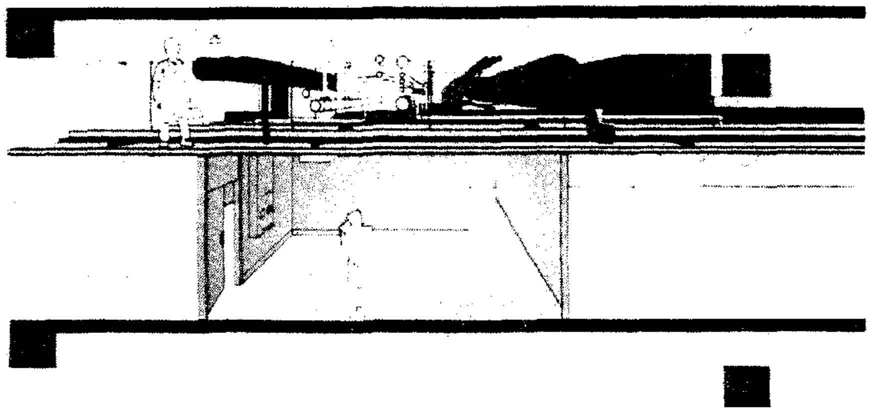


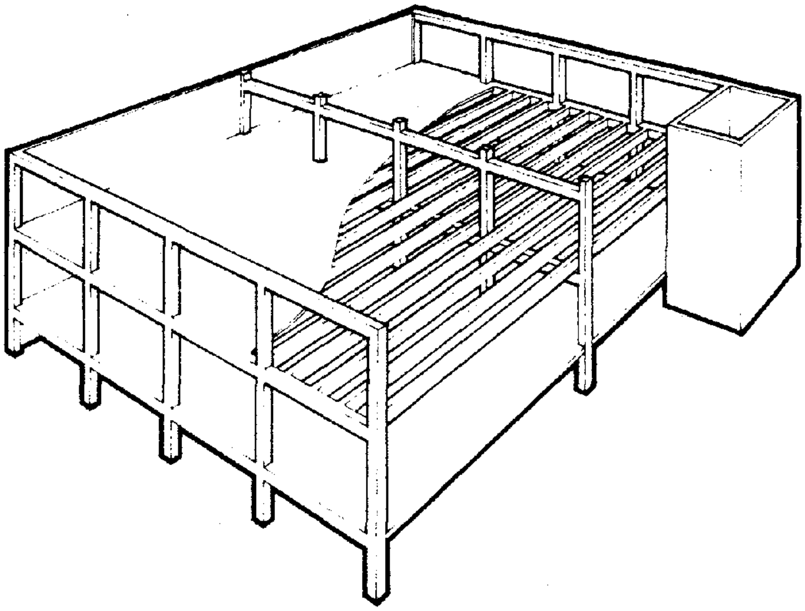
SECONDARY SUBZONES:
section parallel to beams

8. Subzones are horizontal layers of the service zone that define the direction of services. The main service distribution lines enter from the service bay immediately below the beams and run parallel to the main girder to the end of the service zone. The direction and depth of beams, girders and ceiling strongbacks visually locate the respective layers and provide physical references for initial location and later revisions.

Channels of the interstitial space are vertical divisions of the main distribution zone and are defined by the ceiling hanger spacing.

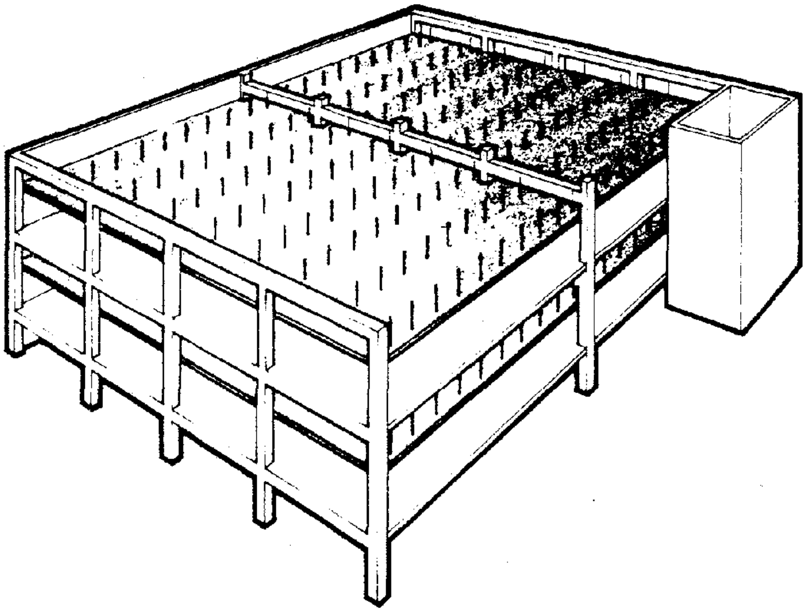
9. This perspective shows how the service zone provides easy access to services (pipes, ducts, wiring, etc.) for construction, maintenance, repair and change. This access in turn simplifies the design and construction process and improves performance and long-term adaptability of the building. Cost studies have indicated that the increased building height resulting from the fully accessible walk-on platofrm (as opposed to cat-walk or other method) is justified by these short and long-range benefits.





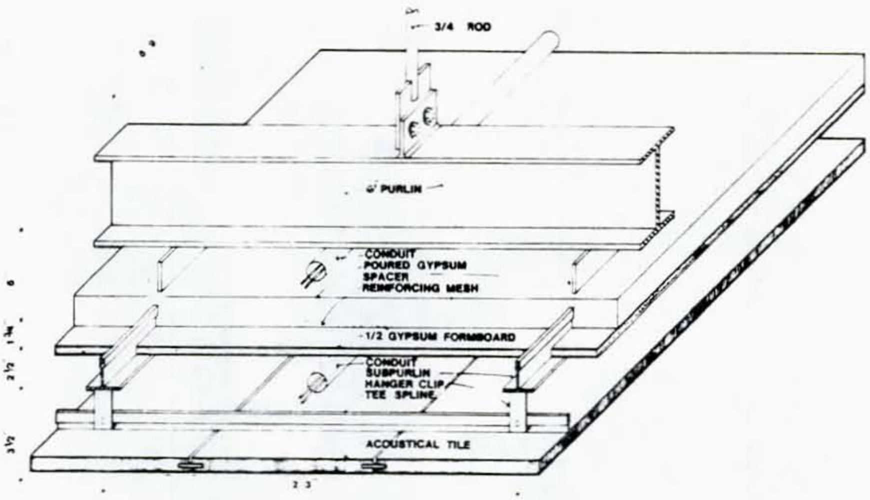
10. BASIC STRUCTURAL SYSTEM

The basic VA building system structure is a post, girder and beam assembly with shear walls or braced frames assuming all lateral loads.

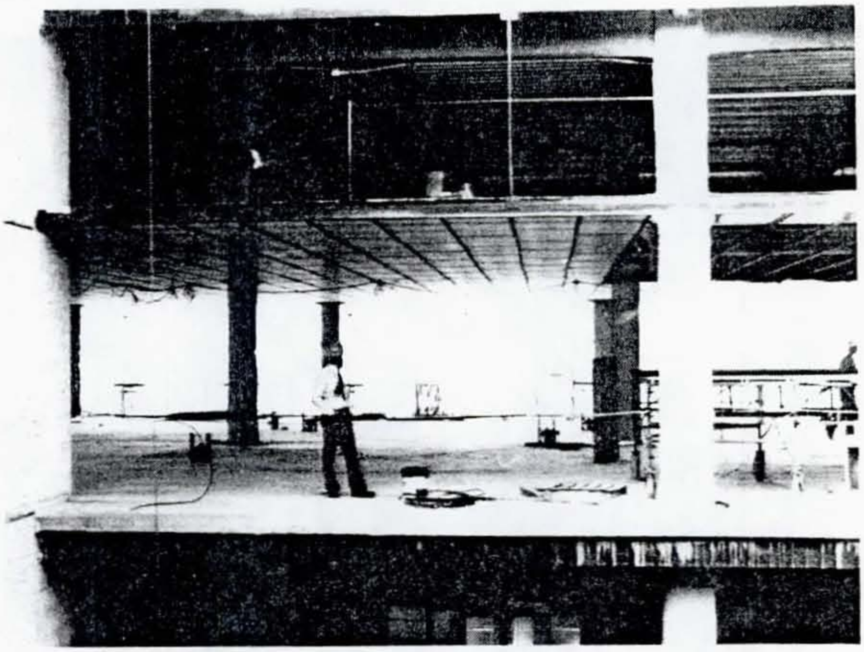


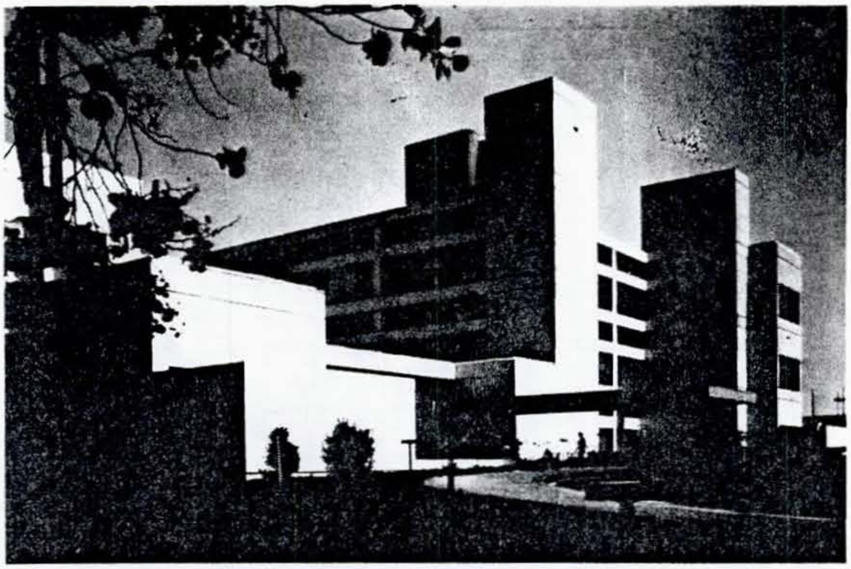
11. CEILING SUB-SYSTEM

12. This isometric drawing indicates the elements that comprise the VAH Loma Linda platform assembly. Material above the 1/2" gypsum formboard forms the interstitial walk surface. Material below the 1/2" gypsum formboard forms the architectural ceiling. Local conduit runs constitute the only building sub-system below the platform and above the acoustic tile. The acoustic tile is a blind spline system. Certain tiles can be removed from the architectural ceiling for change and modification to these conduit systems. All partitions and door framing in the functional zone abut the underside of 1/2" gypsum formboard.

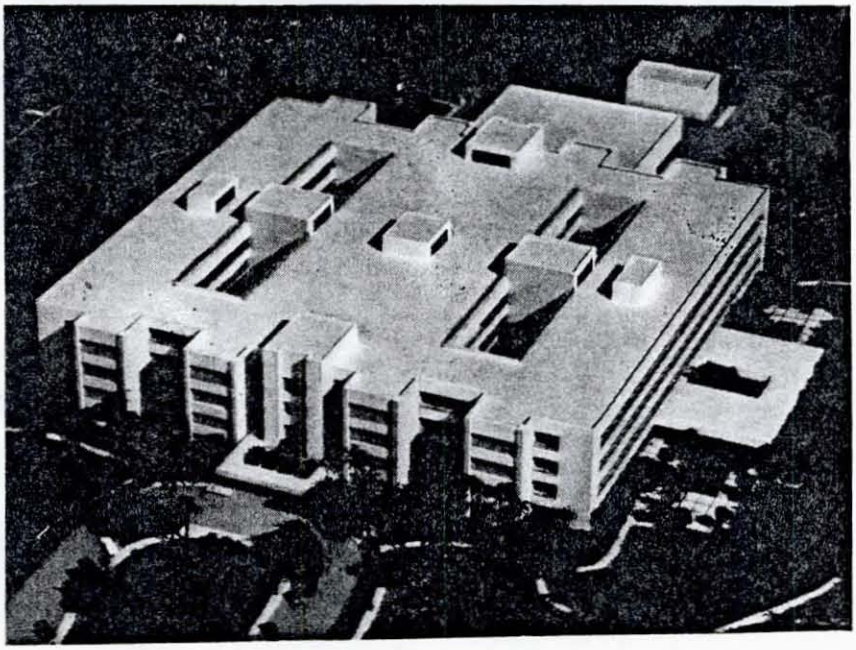


13. Progress photo indicates concurrent construction activity in the interstitial and functional levels. Because work can proceed simultaneously at these two levels, construction time is saved and costs are trimmed.



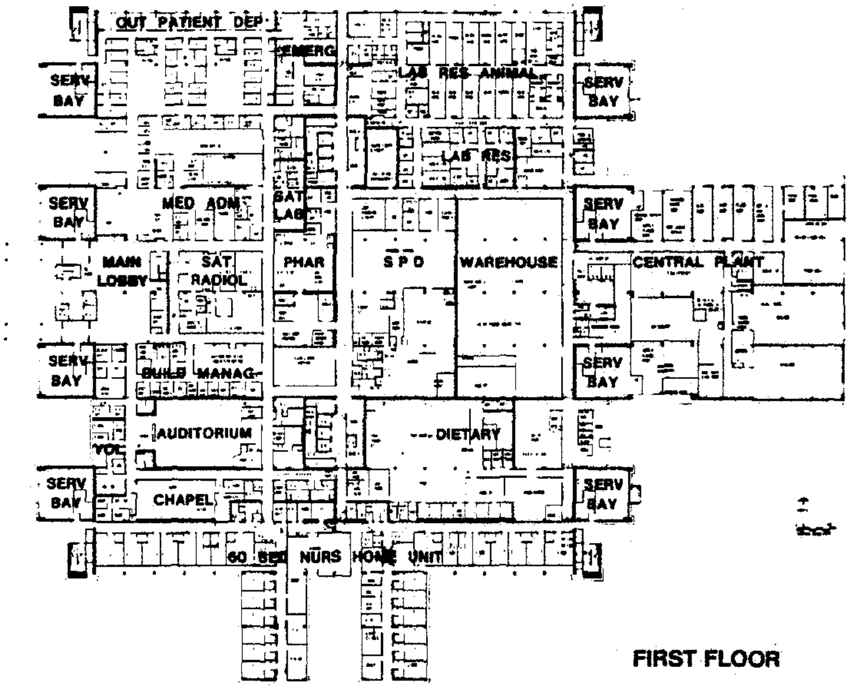


14. Saddleback Community Hospital
Stone, Marraccini and Patterson, Architects

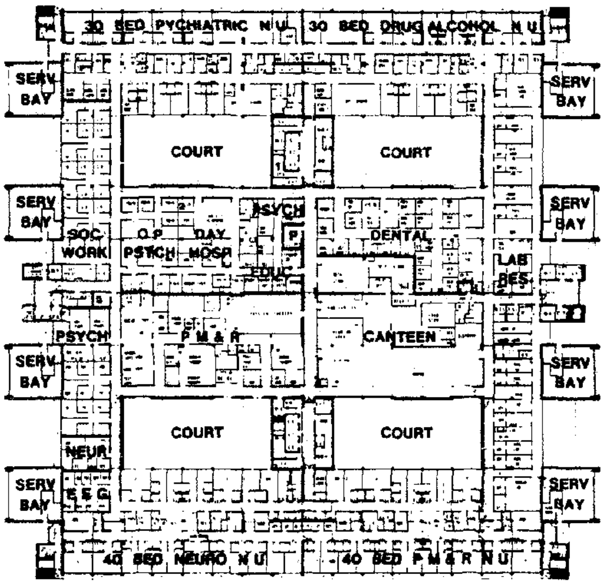


15. Veterans Administration Hospital, Loma Linda, California. Model, looking east. The four identical towers on the west face, and their counterparts on the east face, house service bays, four per tower. Each service bay houses mechanical and electrical equipment providing capacity to the service module with which it is associated.

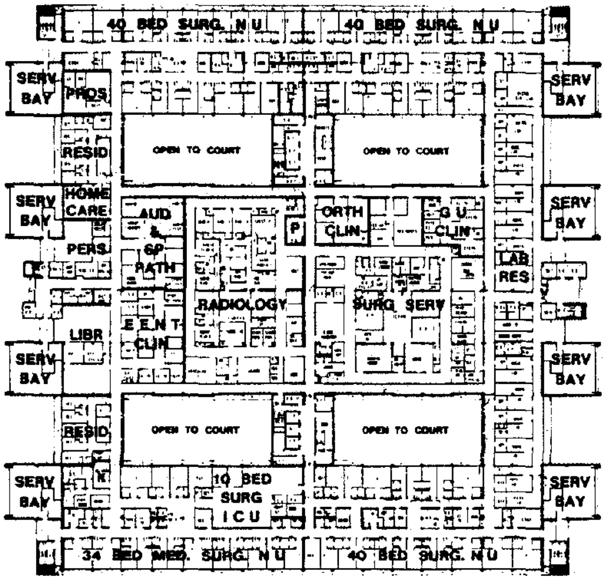
16-19. Floor plans for Veterans Administration Hospital at Loma Linda, California.



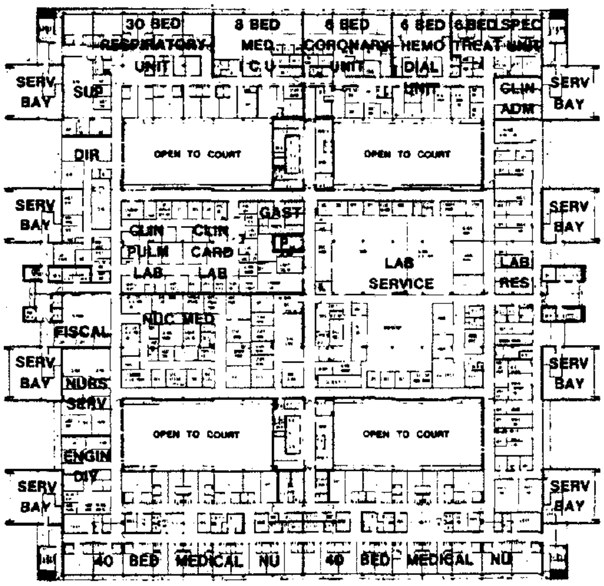
FIRST FLOOR



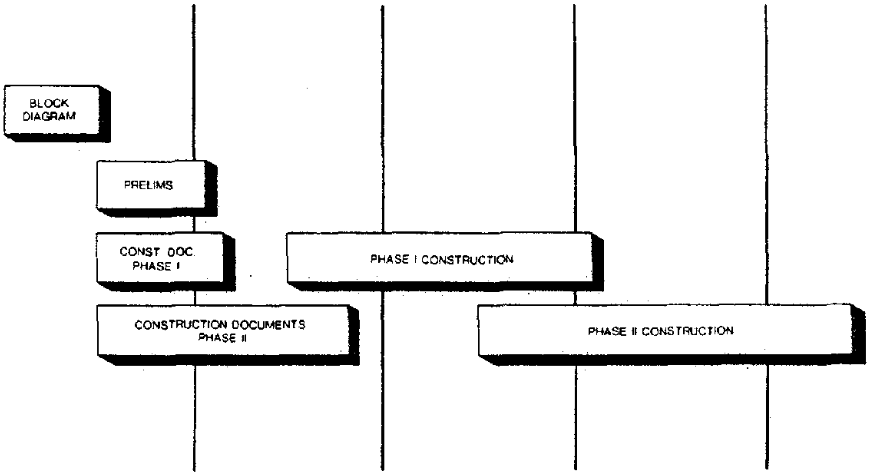
SECOND FLOOR



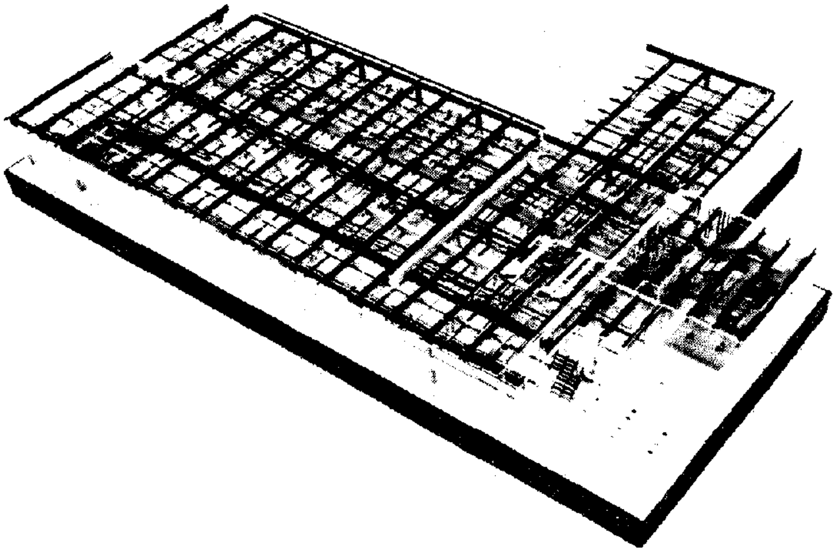
THIRD FLOOR



FOURTH FLOOR

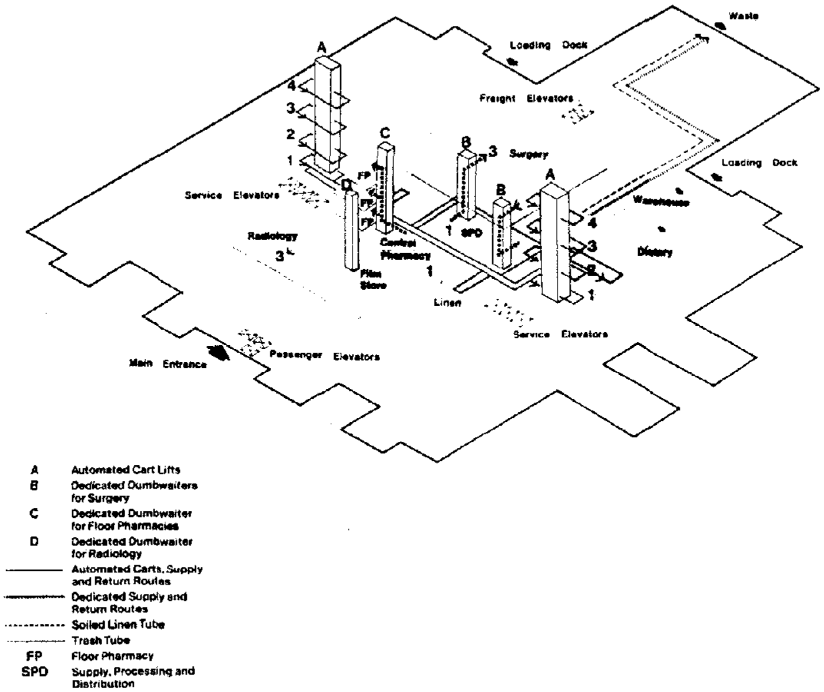


22. Overlapping design and construction phases contributed to time saving on VAH Loma Linda and integration of building systems on the service zone, achieved during the documentation phase, permitted fabrication and installation of services during the construction phase with a minimum of conflict.



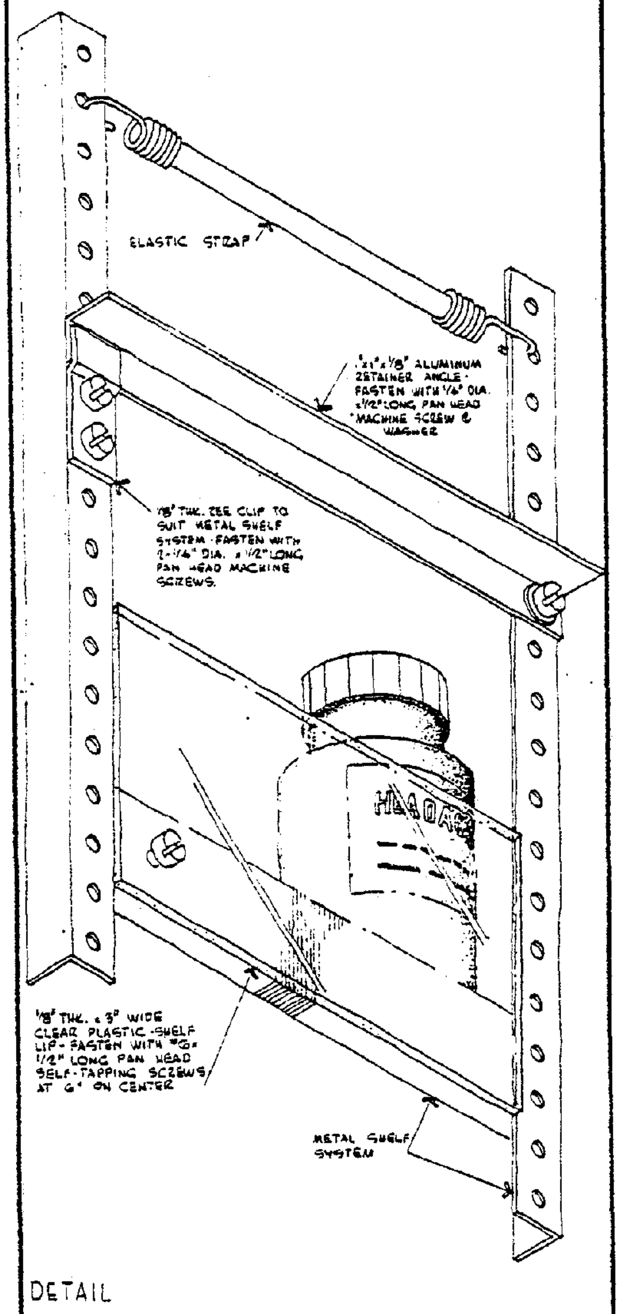
23. This model shows the detailed organization of the interstitial space above the ceiling in a VA building system module. The model enables contractors to better understand the interstitial subzones prior to bidding on VAH Loma Linda.

20. This diagram of transport elements in VAH Loma Linda demonstrates the variety of systems employed. The major transport mode is the automated cart system.



21. Site development planning for the VA hospital at Loma Linda responds to the warm, dry setting, to the scale and location of the building, and to traffic and parking needs. The site is intended for use as well as aspect, and should provide a setting of interest and variety to enhance both the hospital and the community.

SHELF MOUNTED ITEMS



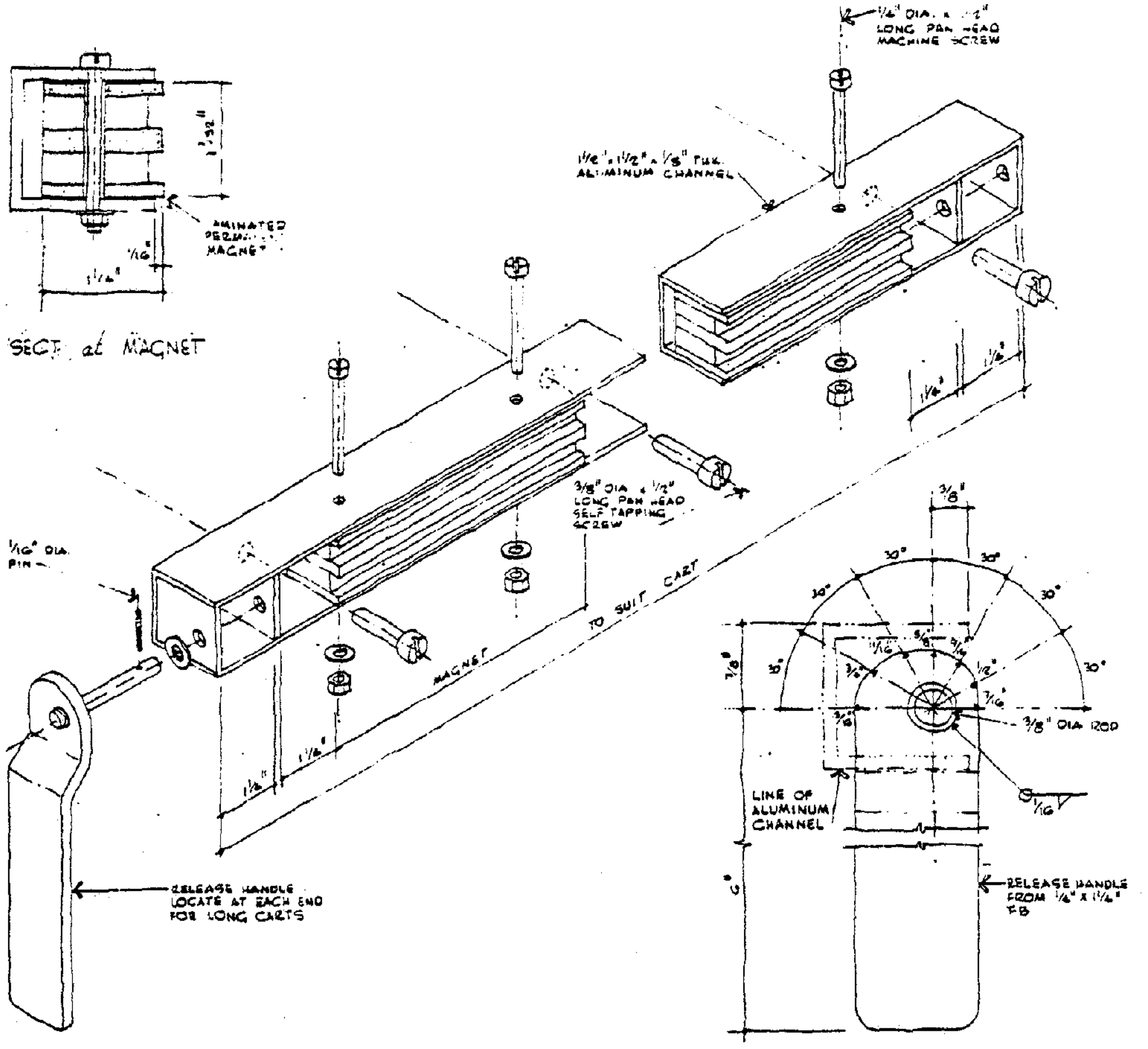
A. *Basic attachment of shelf retainer elements.*

NOTE: the detail drawing to the left is a composite drawing showing all of the elements within the various usage examples appearing on the following pages.

B. *The elastic straps shown on the following pages are obtainable in diameters of 5/16", 3/8", 7/16", 1/2" and 9/16" and in lengths of from 12" to 72".*

The components of the elastic straps may also be purchased in bulk quantities and fabricated to suit local requirements as needed.

MOBILE CART ANCHORAGE - MAGNETIC

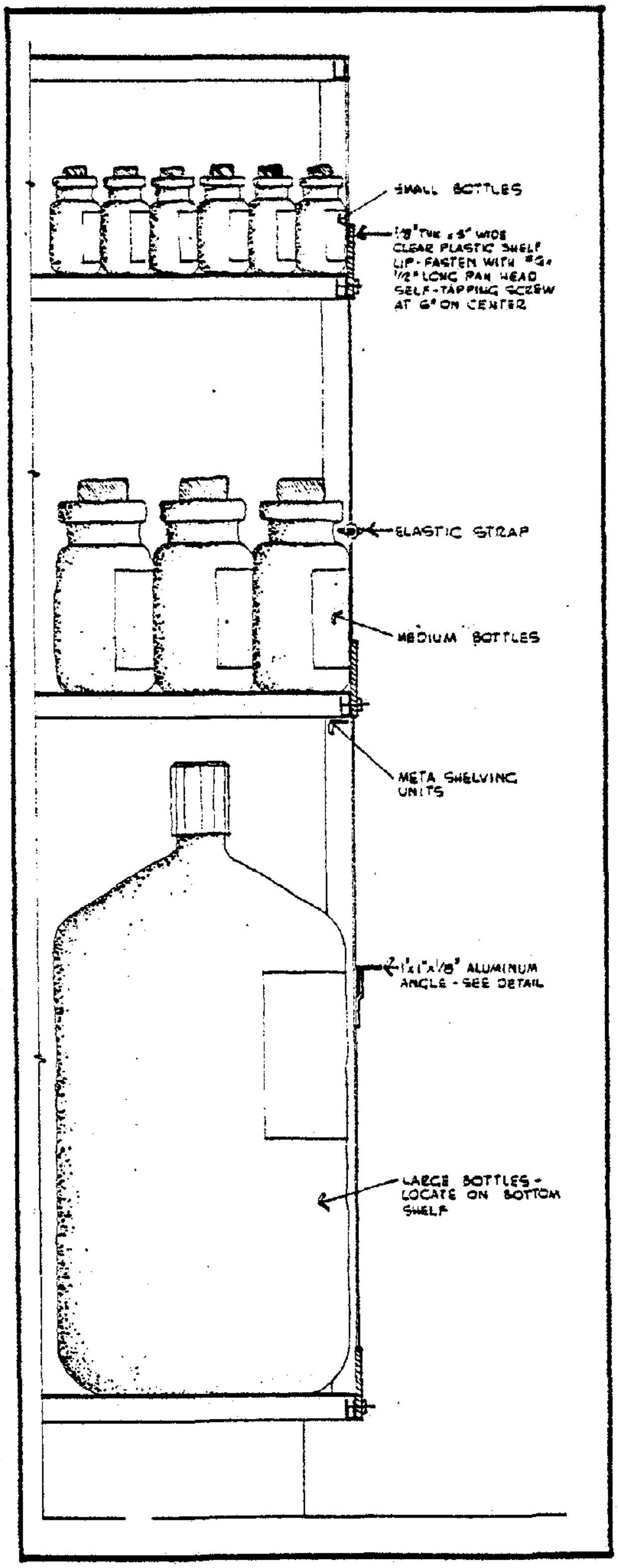


SECT. at MAGNET

ISOMETRIC of MAGNETIC LOCK ASSEMBLY

RELEASE HANDLE CAM DETAIL

SHELF MOUNTED ITEMS



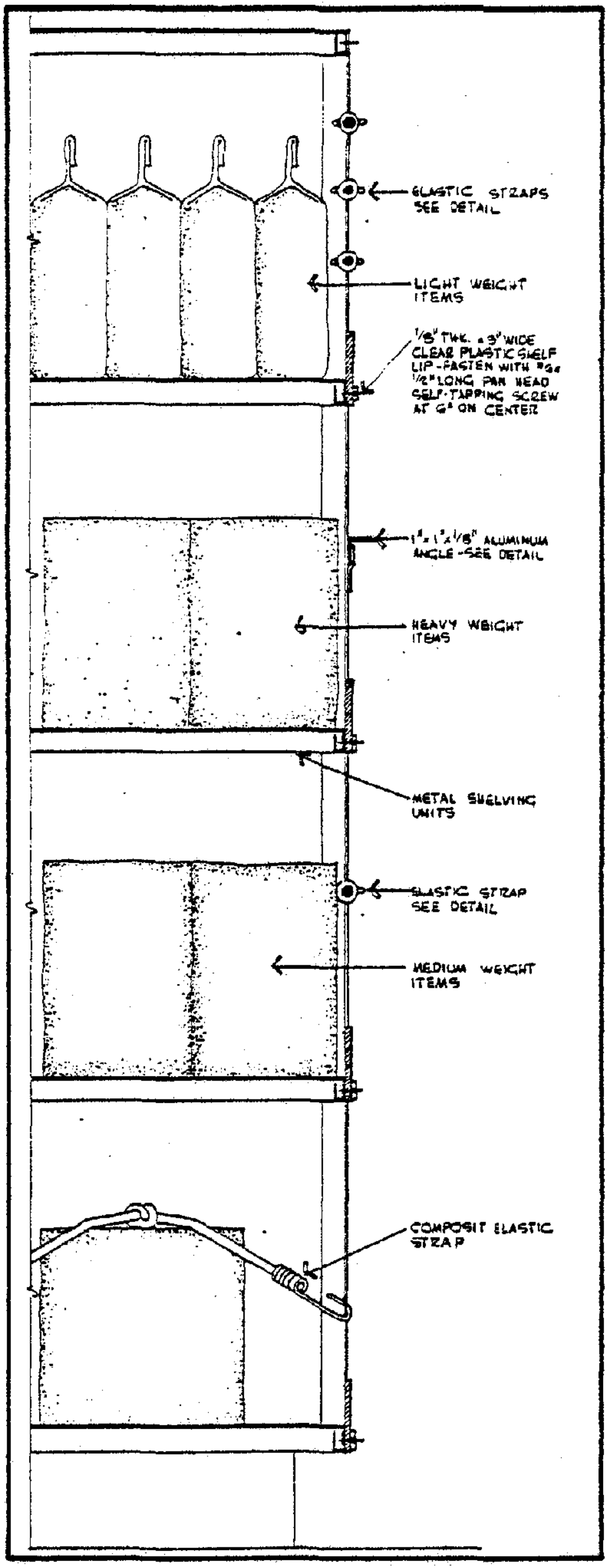
C. *Example of some typical usages:*

1. *Small bottles*

2. *Medium bottles*

3. *Large bottles*

SHELF MOUNTED ITEMS



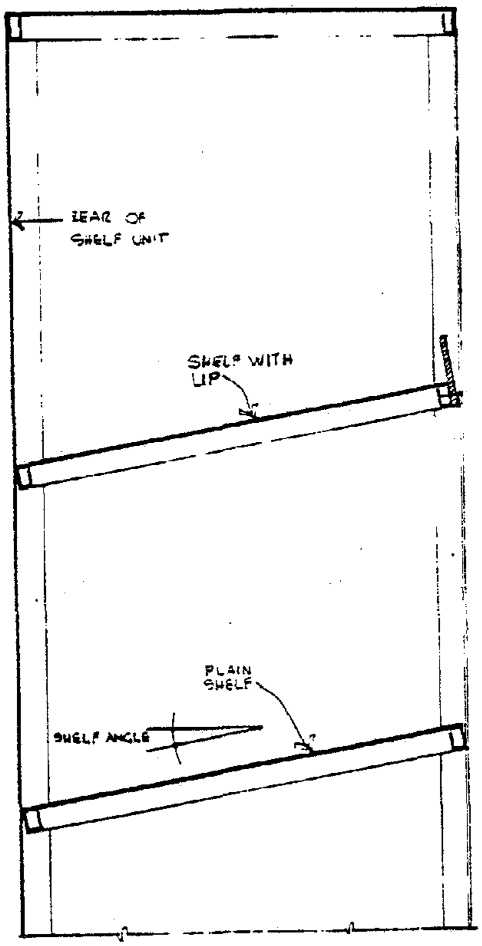
4. *Lightweight items*

5. *Heavyweight items*

6. *Medium weight items*

7. *Special anchorage detail*

SHELF MOUNTED ITEMS



D. Sloping shelf option:

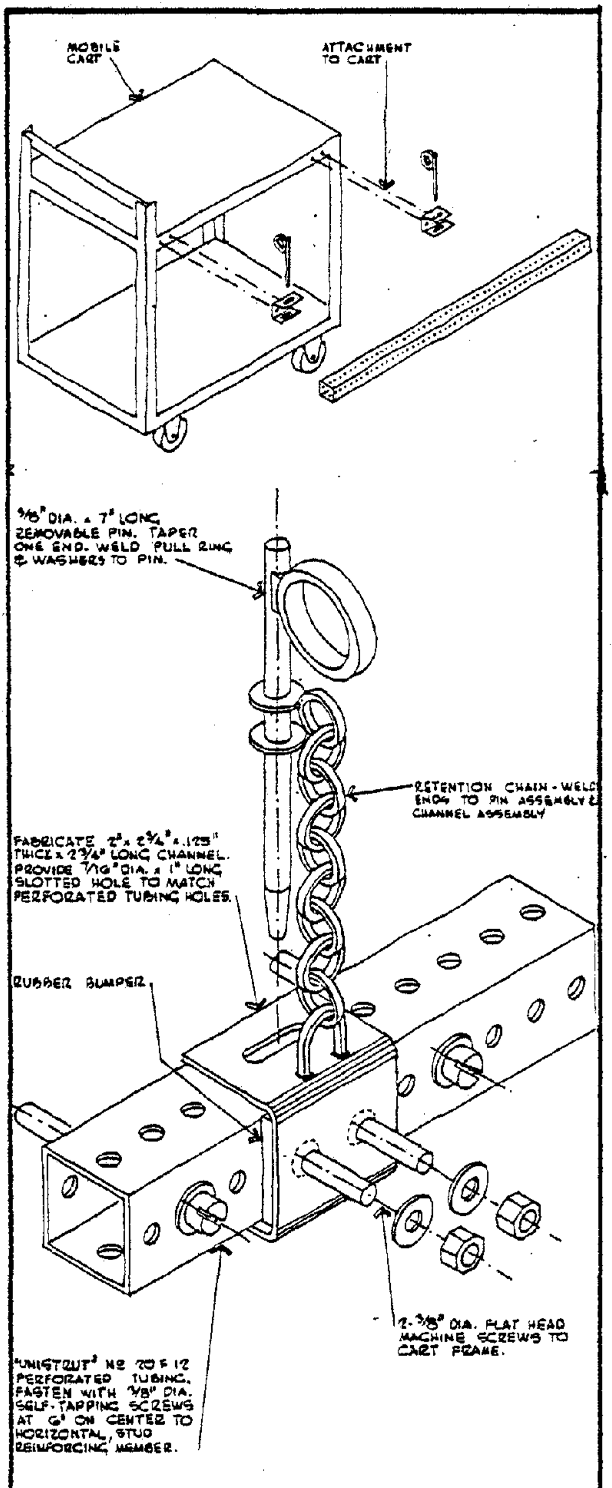
This may be done by itself or in combination with any of the preceding usage examples, at no additional cost.

MOBILE CART ANCHORAGE - MECHANICAL

B. Option 2, channel and pin type:

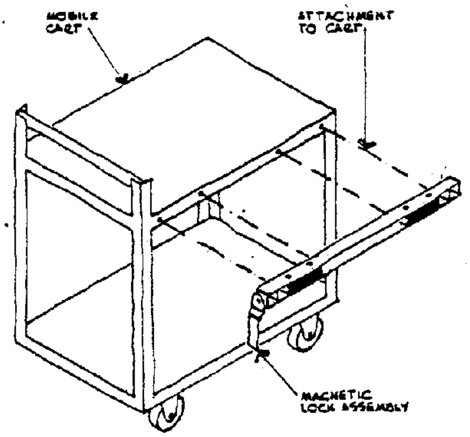
1. Isometric view of assembly.

2. Isometric view of pin connection detail.

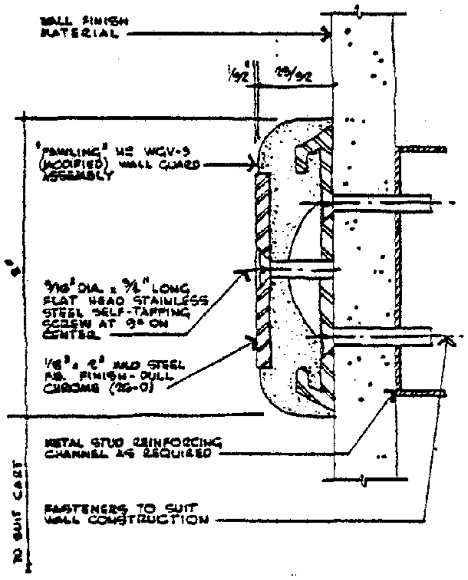


ANCHORAGE DETAIL

MOBILE CART ANCHORAGE – MAGNETIC



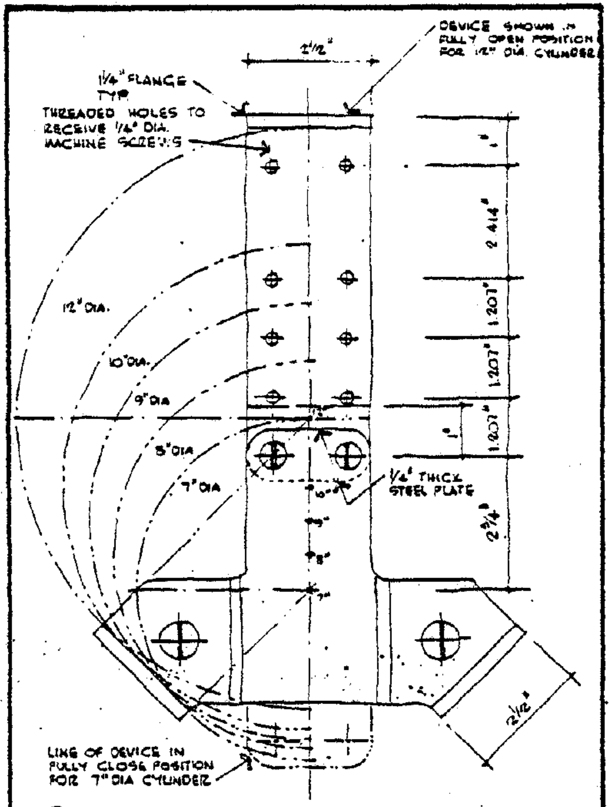
A. *Typical attachment of magnetic lock assembly to mobile cart.*



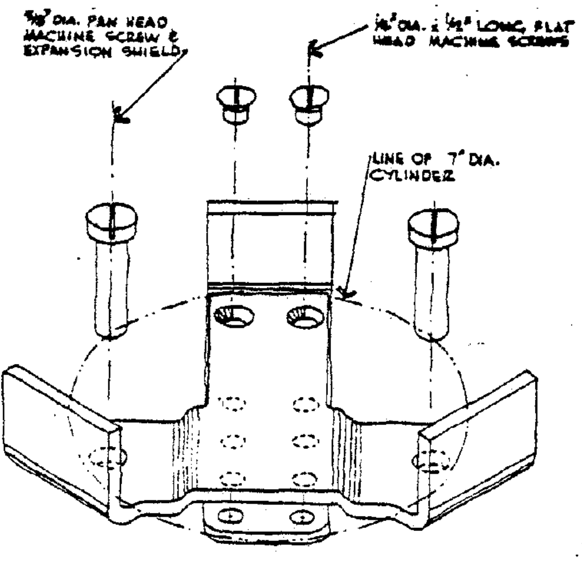
B. *Typical wall guard detail suitable for magnetic lock assembly.*

C. *Typical fabrication details of the magentic lock assembly. (see following page).*

GAS CYLINDER ANCHORAGE



PLAN



ISOMETRIC VIEW

B. *Gas cylinder adjustable floor clip detail.*

C. *Schedule of costs.*

Size	*Material*	*Labor*
T or 300	*$10.00*	*$7.00*
H or 200	*$ 9.50*	*$7.00*
M or 100	*$ 8.75*	*$7.00*
E	*$ 2.25*	*$4.50*
D	*$ 2.25*	*$4.50*
B	*$ 2.25*	*$4.50*
80	*$ 9.25*	*$7.00*
30	*$ 2.75*	*$4.50*
12	*$ 2.25*	*$4.50*
6	*$ 2.25*	*$4.50*
Acet. #5	*$11.25*	*$7.00*
Acet. #4	*$ 9.25*	*$7.00*
Acet. #3	*$ 8.75*	*$7.00*

GUIDELINES TO EVALUATE SEISMIC PERFORMANCE OF REINFORCED CONCRETE BUILDINGS TO PREDICT SEVERE EARTHQUAKE DAMAGE

MASAYA MURAKAMI

INTRODUCTION

It has been predicted by a subcommittee of experts organized by the Central Disaster Prevention Council and the National Land Agency of Japan that an extremely severe earthquake with a Richter Magnitude of 8 will occur on the Tokai-Coast in this century: tremendous devastations in the Tokai area, is expected, especially in the Shizuoka-Prefecture. The Tokai area has experienced a severe earthquake every 100 years. More than 120 years have passed since the last major earthquake in 1854.

The possible level of resultant devastation in terms of economics social disruption and loss of life has become a matter of significant concern to the local government. Various kinds of counter measures have been considered including public responsibilities before and after disasters, and a plan to perform damage assessment, strengthen vital reinforced concrete buildings and adjust local requirements for the design of new buildings.

A project sponsored by the local government has been carried out by the SPRC (Seismic Performance Reinforced Concrete Buildings) Research Group. The purposes of the project are as follows;

The purposes of the project are as follows; 1) develop a computer program of the seismic-capacity evaluation method [1], [2] and save time. 2) provide a seismic protection criterion consistent with the evaluation method against the predicted severe earthquake condition. 3) suggest the adjustments of the local requirements for the design of new buildings subject to such conditions.

This paper reviews a part of the project with emphasis on 1) the basic concept of the seismic-capacity evaluation method and 2) the seismic protection criterion consistent with the evaluation method in the predicted severe earthquake conditon.

EVALUATION METHOD

GENERAL

A practical method to evaluate the seismic-capacity of existing medium- and low-rise reinforced concrete buildings was proposed in April 1977 by a subcommittee orgainzed by the Ministry of Construction of Japan. The method proposes a unified seismic index to evaluate the seismic-capacities of reinforced concrete buildings having various types of framing systems. These systems include ductile moment-resisting frame, shear wall and wall-frame structures. The seismic performance of the damaged and undamaged buildings structural system due to several earthquakes was examined to verify the reliability of this method and a seismic protection criterion was based upon the results. However, the predicted earthquake is much more severe than the experienced earthquakes. Due to this fact, a new seismic protection criterion conforming to the predicted earthquake condition is essential.

SEISMIC INDEX OF STRUCTURES

The unified seismic index of structures (I_S) is employed to evaluate its seismic-capacity. This index is calculated by equation (1) at each story of the structure and in each direction.

$$I_S = E_O * G * S_D * T \qquad (1)$$

where

E_O: basic structural index calculated by ultimate lateral strength and ductility of structures.

G : local geological index to modify E_O-value.

S_D: structural configuration index to modify E_O-value due to grade of geometric irregularities, torsions and discontinuities of stiffness and mass.

T : age index to modify E_0-value due to grade of deteriorations of strength and ductility.

The overall method consists of three sequential stages which are classified by the grade of simplification and reliance. If the first evaluation procedure, which is the simplest, but least reliable, cannot clearly evaluate a building as safe, the building should be evaluated by the second method. This repetitive procedure is generally designed to provide a rapid and practical method for evaluating the structural adequacy of a large number of buildings subjected to strong earthquake motions.

BASIC STRUCTURAL INDEX (E_0)

Since the G-, S_D- and T-indices are the modification factors less than or equal to 1.0, the E_0-index is a basic structural index producing a great influence on the seismic index. The outline for estimating the E_0-index is described here.

The E_0-index is composed of the strength index (C), the ductility index (F) and the story index (β). The evaluation starts by categorizing the failure type of each column and wall. The types of failures used in the three evaluation methods are shown in Tables 1 and 2. Then, all columns and walls at each story are classified into three groups, namely, Group-1, -2 and -3, according to their F-indices shown in Tables 1 and 2. The minimum F-index in a group is assigned as the value of the entire group and the F-index of Group-1 should be the lowest of the three. The number of the group should not be more than three and the adoption of the smaller number is a safety-side assumption which evaluates the E_0-index lower.

The C-index of each group is calculated by Equation (2).

$$C_j = \Sigma Q_j / \sum_{i}^{n} W_k \qquad (2)$$

where

Q_j: story shear of Group-j at ultimate stage

W_k : weight at kth story

n : total number of stories

i : story level under consideration; i=1 designates first story

The E_O-index is calculated eith by Eq. (3) or Eq. (4) for predicting the possible damaged condition of buildings.

$$E_O = \beta * \sqrt{E_1{}^2 + E_2{}^2 + E_3{}^2} \qquad (3)$$

$$E_O = \beta * (C_1 + \alpha_2 * C_2 + \alpha_3 * C_3) * F_1 \qquad (4)$$

where

E_j: $C_j * F_j$

β_i: $(n + 1)/(n + i)$. coefficient at ith story determined to modify dynamic behavior of a n-storied building to that of a one-storied building. For particular case in third evaluation method, β_i becomes $2 * (2 * n + 1)/3 * (n + i)$.

α_2, α_3: values given in Table 3.

Equation (3) is selected when a building is not expected to fail completely until the group having the largest F-index fails. Equation (4) is prescribed when the total damage of a building is caused by the failure of the group having the smallest F-index (Group-1).

A group of the single story buildings composed of shear walls and ductile frames can be used as an example. The shear walls are categorized into Group-1 and the ductile frames into Group-2. Since the Group-3 does not exist, the F_3-index and C_3-index are neglected in Equations (3) and (4). The relationship between the story shear and the story drift of the buildings is assumed as illustrated in Fig. 1. A quarter of the circle in Fig. 2 shows the condition of Equation (3). The seismic capacities of the buildings on the line are evaluated equally. In the case where the complete failure of the buildings takes place at the ultimate stage of the frames, the total damage of the shear walls does not cause the complete failure to the buildings. The broken line in Fig. 2 shows the condition of Equation (4), where the complete failure of the buildings breaks out at the ultimate stage of the shear walls, although the frames do not reach to the final damage.

COMMENTARY

The nonlinear response analysis was carried out to verify the above-mentioned ideas incorporated into Equations (3) and (4) [5]. The single-degree-of-freedom structural models used in the dynamic analysis consisted of a parallel combination of two hysteretic loops, namely, the so-called "Origin-Oriented Model" and "Degrading Trilinear Model" [6]. The former representing the shear walls and the latter representing the frames, which fail primarly in shear and flexure, respectively. El Centro 1940 (N-S), Taft 1952 (E-W) and Hachinohe 1968 (N-S) were selected for the dynamic analysis, and the maximum acceleration of each earthquake motion was modified to 30% of the acceleration of the gravity. Since various strength values were prescribed for the walls and frames, and the ultimate displacement of the shear walls and the yielding displacement of the frames were assumed constant, the initial natural periods varied in the range of 0.1 to 0.6 second.

The results of the response analysis were expressed in the E_1-E_2 domain as shown in Figures 3 through 5. As recognized by the figures, the use of Equations (3) and (4) in evaluating the seismic performance of the wall-frame reinforced concrete buildings seems reasonable for practical purposes, while more detailed investigation is necessary to refine the evaluation method.

SEISMIC PROTECTION PROCEDURE

SEISMIC PROTECTION INDEX

A tentative seismic protection index (E_T) is proposed to evaluate the seismic performance of buildings by comparing its value with the seismic index (I_s) shown in Eq. (1), which is calculated by Eq. (5).

$$E_T = E_S * C_G * C_I \qquad (5)$$

where

E_S: basic seismic protection idex

C_G: topographic index shown in Table 4.

C_I: importance index, $C_I \geqq 1.25$

BASIC SEISMIC PROTECTION INDEX (E_S)

The E_S-index in calculated by Eq. (6) considering the failure type, the predominant period and the total number of stories.

$$E_S = D_{TG} * \alpha_{TG} \tag{6}$$

where

D_{TG}: dynamic magnification index determined by selecting the smaller value shown in Table 5 or 6 according to failure type, predominant period and total number of stories

α_{TG}: seismic coefficient of ground motion depending on epicentral distance as shown in Table 7

For example, the basic seismic protection index (E_T) in Zone E (α_{TG} = 0.23) is shown in Table 8 for practical use. The five Zones depending on the epicentral distance had been tentatively determined as shown in Fir. 6 by the local government of Shizuoka-Prefecture.

SEISMIC PROTECTION CRITERION

GENERAL

It would be undesirable to cope with a predicted earthquake along in every region of the high seismic country like Japan, even if the magnitude and epicenter of the earthquake had been precisely determined.

There are smaller but more frequent earthquakes which can cause damage to buildings near the epicenter. An example of this would be the 1978 Izu-Ohshima-Kinkai eqrthquake hit the Izu Peninsula in Shizuoka-Prefecture. Furthermore, there exist larger but more distant earthquakes. Therefore, it is quite common practice that a seismic protection criterion is established to provide buildings in this area with the seismic performance considering the regional seismic activity as well as the predicted earthquake. The corresponding level of the seismic protection criterion to the former consideration is a lower limit, because it is independent of the epicentral distance due to the predicted earthquake.

In the evaluation method, Equations (1) through (4) suggest that the seismic index in a special case is as follows when assuming the G- S_D and T-indices and B to be unit,

$$I_s = E_O = C * F \tag{7}$$

This indicates that a building is a new single story one with a regular plan and section at a normal site which is composed of one of three groups. Two framing systems are selected to determine the level of the criterion, one being a shear wall structure and the other being a ductile frame structure. The hysteretic models corresponding to each structural system are the above-mentioned ones, namely "Origin-Oriented Model" and "Degrading Trilinear Model".

If the acceleration of a given ground motion and the strength of a prescribed model only are assumed variables in the seismic response analysis of a single-degree-of-freedom system, the acceleration, strength and ductility factor are connected with each other so that one of them is obtained by determining the others, because the strength is normalized by a force equal to the model mass multiplied by the acceleration, and the ductility factor has no dimension. Since the F-index of a frame building is defined by a ductility factor as shown in Table 2, and the ductility factor and C-index can be calculated in the evaluation method, the seismic index (I_s) in Equation (7) corresponds to the level of acceleration.

The precise definition of earthquake ground motions is very difficult if not possible. However, in this paper, ground motions are chracterized by the wave forms (predominant frequency contents) and the peak accelerations considering a site condition and the epicentral distance of the predicted earthquake. The characteristics of ground motions, even a given site, are highly variable. Therefore it should be encouraged to evaluate the structural adequacy of buildings subjected to strong motions by non-deterministic methods which recognize uncertainties of ground motions and which predict response in probabilistic terms.

For this reason, the required strength ratios for above-mentioned models subject to five types of artificial accelerograms [7] were adopted to establish the seismic protection criterion. The five types of accelerograms called Types A, B. B_{02}, C and D are composed of twenty accelerograms and have the predominant period of 0.4 sec.

Following the paper [8], Type A is designed to represent the upper bound for the ground motions expected in the vicinity of the causative fault during an earthquake having a Richter Magnitude of 8 or greater. Type B is intended to represent the ground motions close to the fault in a Magnitude 7 earthquake, such as the 1940 El Centro, California earthquake and the 1952 Taft, California earthquake. Type

C is intended to represent the ground motions in the epicentral region of Magnitude 5.5 to 6.0 shocks, such as occurred during the 1957 San Francisco earthquake and the 1935 Helena, Montana earthquake. Type D is intended to represent the ground motions present in the immediate vicinity of the fault of a 4.5 to 5.5 Magnitude earthquake having a small focal depth, such as the Parkfield, California earthquake.

Type B_{02} accelerograms are generated to examine the influence of a relatively narrow band exitation on structural response. The frequency contents of the exitation are larger in the neighborhood of the predominant period thant those of the other types of earthquake. The characteristics of five types of accelerograms seem to represent those of the past strong motions observed in Japan when comparing them to each other on structural response, if appropriate adjustments are done. These adjustments are to shift the level of the predominant frequencies in the ground motions and also change the intensity of the ground motions.

It is assumed here that a free-field motion is the same as the corresponding foundation motion. For structures supported on soft soil, the foundation motion is generally different from the free-field motion and may include a rocking component as well as a lateral component. A substantial part of the vibrational energy of the flexibly supported structures may be dissipated into the supporting medium by radiation of waves and by hysteretic action in the soil, both having the effect of increasing the overall damping of the structural systems and reducing the deformation of the structures. The latter effects are more important, because it increases with increasing intensity of ground shaking. Furthermore the local failure of soil under the foundation may reduce the intensity of the foundation motions in the overall structural system. These effects of soil-structure interaction are important in the situation considered in this paper where the intensity of ground shaking is higher, but they are not directly considered and are implicitly evaluated in the overall procedure to establish the seismic protection criterion.

WAVE FORM AND INTENSITY OF GROUND MOTION

The ground motions used here are defined in terms of the characteristics of the five types of artificial accelerograms as mentioned above and in terms of their mean peak accelerations. A site condition is characterized by its predominant period. Two adjustments are made to apply these types of accelerograms to a different site condition by following the suggestions of the paper [7]: One modification involves shifting the level of the predominant frequencies in the accelerograms and the other with modifying the level of the mean peak accelerations. The former adjustment is accomplished by changing the time scale of the accelerograms and the latter by making the mean peak accelerations vary in proportion ot the square root of the ratio of the original time interval in relation to the new time interval. These adjustments mean that the intensity of the power spectral density in a bedrock is constant, but the tranfer function is modified only in terms of the predominant period depending on a subsoil condition. Furthermore the assumption on the mean peak acceleration conforms to the empirical formula of the paper [9].

MEAN PEAK ACCELERATION

As previously stated, the level of the mean peak accelerations at a site depends upon the predominant period and epicentral distance. However, these basic levels are defined in terms of acceleration at the site with the pre-dominant period of 0.4 seconds; that is, TG = 0.4 seconds.

The lower and upper limits of the mean peak accelerations are assumed to be 0.23 and 0.45G, respectively. The latter value being suggested in the paper [6], where G is the acceleration of the gravity.

The levels of the mean peak accelerations range from 0.23 to 0.45G are associated to the epicentral distance in the following procedure consisting of three phases; (1) the mean peak acceleration of the site with TG = 0.4 seconds by the values $\sqrt{2}$ which is equal to the square root of the ratio 0.4 to 0.2 seconds, (2) the mean peak acceleration at a bedrock is obtained by dividing the resulting acceleration by the dynamic magnification factor of 2.5 which corresponds to the high intensity of ground shaking and agrees with the results of the paper [9], [10], (3) the epicentral distance is evaluated by using the relationship between the acceleration at the bedrock and the epicentral distance shown in Fig. 7 [11]. Since the relationship is established by arranging the past earthquake records observed at a rock or at a stiff soil, the acceleration at a stiff soil may be reduced according to the soil condition.

For example, the acceleration of 0.45G for TG = 0.4 seconds is modified to 0.63.G for TG = 0.2 in the first phase and to 0.25G at the bedrock in the second phase. The epicentral distance is established at the value of 25 km by using Fig. 7 in the final phase. On the other hand, when evaluating the acceleration of 0.63G for TG = 0.2 seconds by adopting the empirical formula of the paper [9], the epicentral distance is estimated to be the range of 60 to 80 km. Therefore the relationship between the mean peak acceleration and the epicentral distance is boldly assumed as shown in Table 9. The level of the acceleration on the epicentral zone is not clarified by the current state-of-knowledge, but is assumed to be the same as the acceleration of 0.45G for TG = 0.4 seconds. There is a basis that when defining the intensity of earthquake ground motions in terms of velocity, the intensity of the four types of accelerograms adopted here is very high for the following reason. Their mean peak velocities and displacements are shown in Table 10. The velocity of Type A is equal to 69 kine and is modified to 28 kine by the same adjustment in the second phase. The velocity of 28 kine is equal to that at the epicentre by using the results of the paper [11] shown in Fig. 8.

REQUIRED STRENGTH RATIOS

Required strength ratios of two structural models for four types of accelerograms at the sites with the predominant period of 0.4 seconds are shown in Figs. 9 and 10 [7]. They are defined as the normarized strength required to restrict a ductility factor within a fixed value at a fixed probability of exceedance and depend on the natural period of structures. One characteristic feature of all sets of curves in these figures is that the four curves representing earthquake Types A, B, and C are quite similar to each other, with the Type D earthquake being different. The fact that the required strength ratios of Type D earthquake, in the case of the degrading trilinear model are larger than those of the other types, is interpreted by the reason that the deviations of response ductility factors for Type D earthquake are larger than those of the other types. Considering these factors, the curves in Figs. 9 and 10 and the characteristics of the predicted earthquake, the required strength ratios of Type B earthquakes for the degrading trilinear model and those of Type A earthquakes for the origin-oriented model are selected to establish the seismic protection criterion.

BASIC SEISMIC PROTECTION INDEX (E_S)

The E_S-index of the flexural failure type is evaluated in the case of $\mu_{95} = 2$, $T_2 = \sqrt{2}T_1$ and $P_y = 3P_c$ shown in Fig. 9, where μ_{95}, T_2, T_1, P_y, and P_c are ductility factors with a 5% probability of exceedance, the period corresponding to yielding secant stiffness, the initial natural period, the cracking strength and the ultimate strength respectively. The F-index shown in Eq. (7) is determined from the ductility factor of 2.0 as shown in Table 2, the value being 2.1. Eqs. (6) and (7) are transformed as follows.

$$E_o/\alpha_{TG} = \beta * F \tag{8}$$

$$E_S/ {}_{TG} = D_{TG} \tag{9}$$

where β is the required strength ratio. Thus the magnification factor (D_{TG}) is determined by multiplying the required strength ratio (β) by the F-index of 2.1, shown in Fig. 11. The curve for TG = 0.4 seconds is the same as that shown in Fig. 9 and the other curves are modified by the values of TG. The envelope curves are the same regardless of the values of TG, because the required strength ratio (β) varies in inverse proportion to the square root of the natural period (T_1). The seismic coefficient (α_{TG}) of ground motion also varies in inverse proportion to the predominant period (TG), and further the values of T_1 and TG are normalized on structural response by the above-mentioned adjustment; that is, changing the time scale of accelerograms.

In the same procedure the E_S-index is evaluated in the case of μ_{95} = 10.0 which follows the suggestion of the paper [6]. Since the F-index is equal to 1.0 as shown in Table 2, the required strength ratio and the dynamic magnification factor are all the same, showing Fig. 12.

The natural period (T_1) is determined by the total number of stories (N) following the suggestion of the evaluation method.

These results are shown in Equations (10) through (13).

A) Flexural Failure Type

$$E_S = 4.3 \sqrt{1/\ (10*T)} * \alpha_{TG} \tag{10}$$

$$\begin{array}{lll} T = 0.2 & \text{for } N = 1 & \\ T = 0.2 \ \sqrt[4]{3 * (N-1)} & \text{for } N \geq 2 & \\ T = TG/2 & \text{for } T \leq TG/2 & (11) \end{array}$$

B) Shear Failure Type

$$E_S = 4.1 \sqrt{1/\ (10*T)} * \alpha_{TG} \tag{12}$$

$$\begin{array}{lll} T = 0.14 & \text{for } N = 1 & \\ T = 0.14 \sqrt[4]{3 * (N-1)} & \text{for } N \geq 2 & \\ T = TG/2 & \text{for } T \leq TG/2 & (13) \end{array}$$

The E_S-index has a different value depending on the failure type, but the difference is very small. Therefore, the E_S-index can be easily unified so that it is consistent with the seismic index in the evaluation method, although further improvements are necessary to refine both seismic indices.

SEISMIC PROTECTION INDEX

Seismic protection index (E_T) depends on the indices E_S, C_G, and C_I as shown in Equation (5). The index C_G is assumed considering the topography, which is determined using the required strength ratio for Type B_{02} earthquake. The C_I-index should be determined in order to mitigate damages of vital buildings, especially, structures having essential facilities necessary for post-earthquake recovery, because the seismic protection criterion is based upon whether buildings are completely damaged or not. A modification adopted in the final stage should be recognized, where the seismic coefficient is 0.45 in Zone A shown in Table 9 is reduced to 0.36 as shown in Table 7. The modification is adopted considering hysteretic action in the soil as mentioned above and permitting buildings to suffer more serious damages near the epicentral zone of the predicted earthquake. Furthermore it should be considered that such earthquakes as Type B_{02} with a relatively narrow band exitation require a higher strength to reduce the damages than the other types of earthquakes used do.

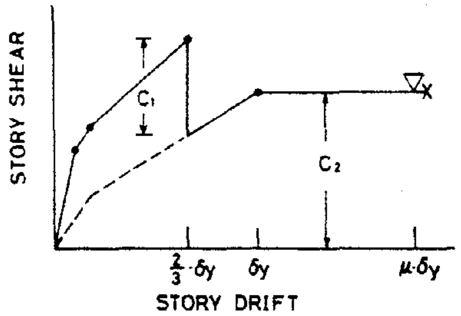


Fig.1 Assumed Story Shear vs. Story Drift after Reference [1],[2]

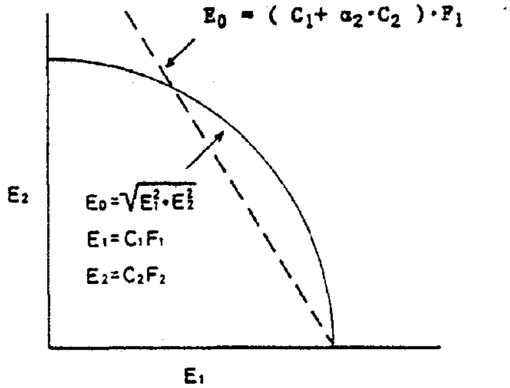


Fig.2 Seismic Capacity of Frame-Wall Buildings after Reference [1],[2]

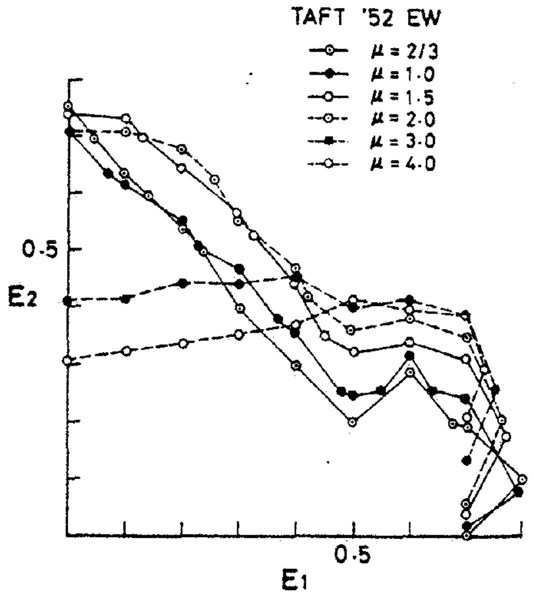


Fig.3 Earthquake Response vs. E_0-index after Reference [2]

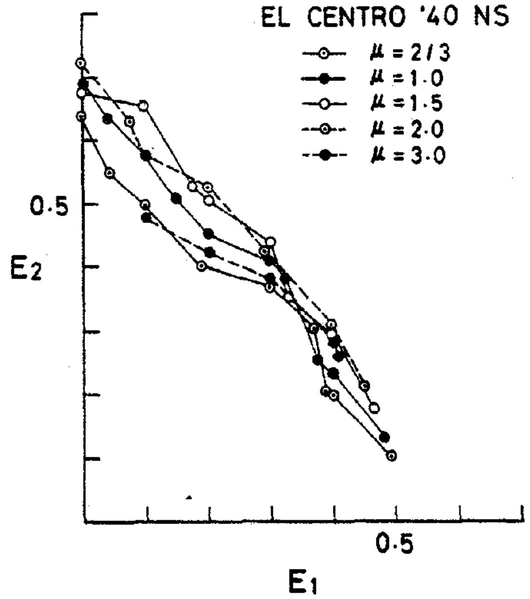


Fig.4 Earthquake Response vs. E_0-index after Reference [2]

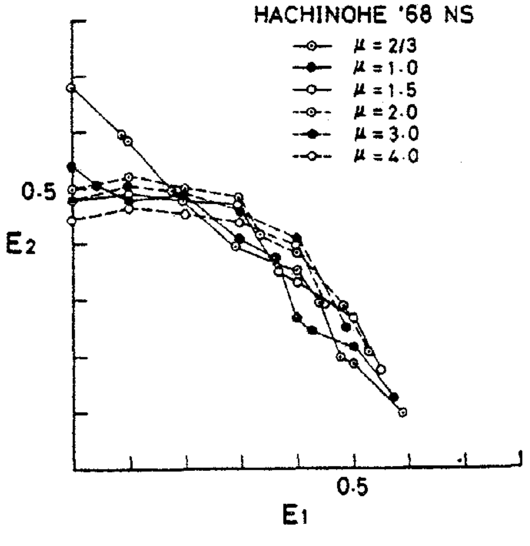


Fig.5 Earthquake Response vs. E_0-index after Reference [2]

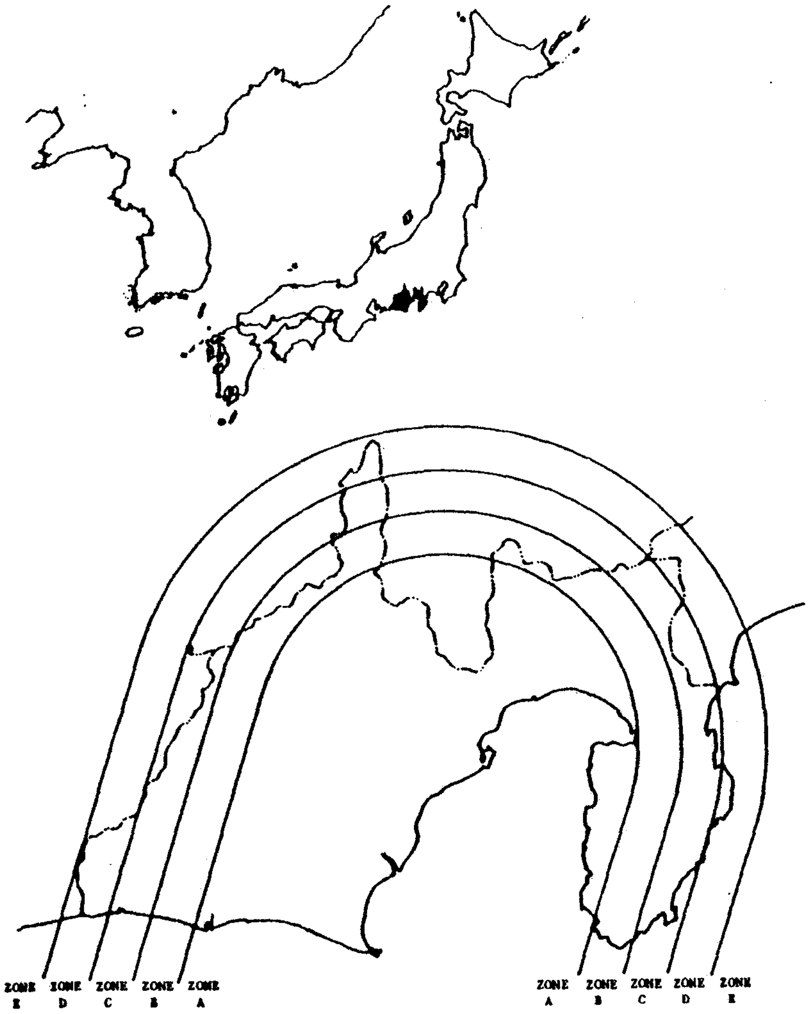


Fig.6 Tentative Zoning due to Seismic Risk

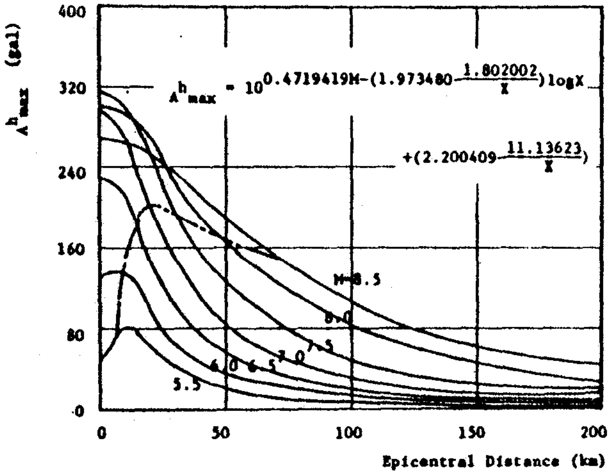


Fig.7 Acceleration vs. Epicentral Distance

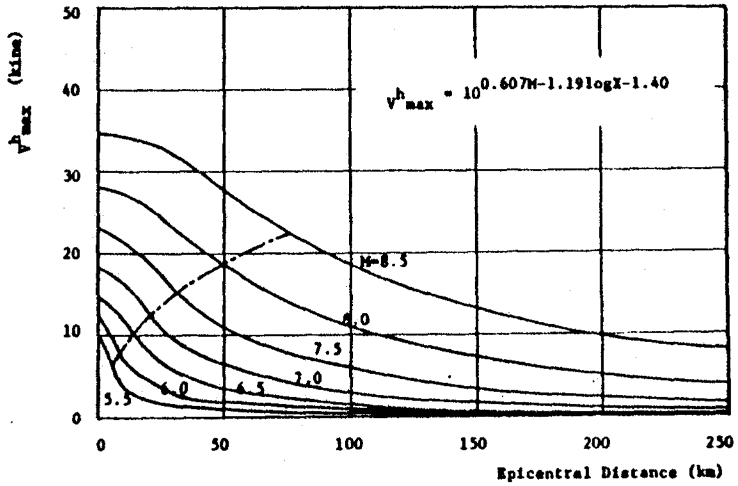


Fig.8 Velocity vs. Epicentral Distance

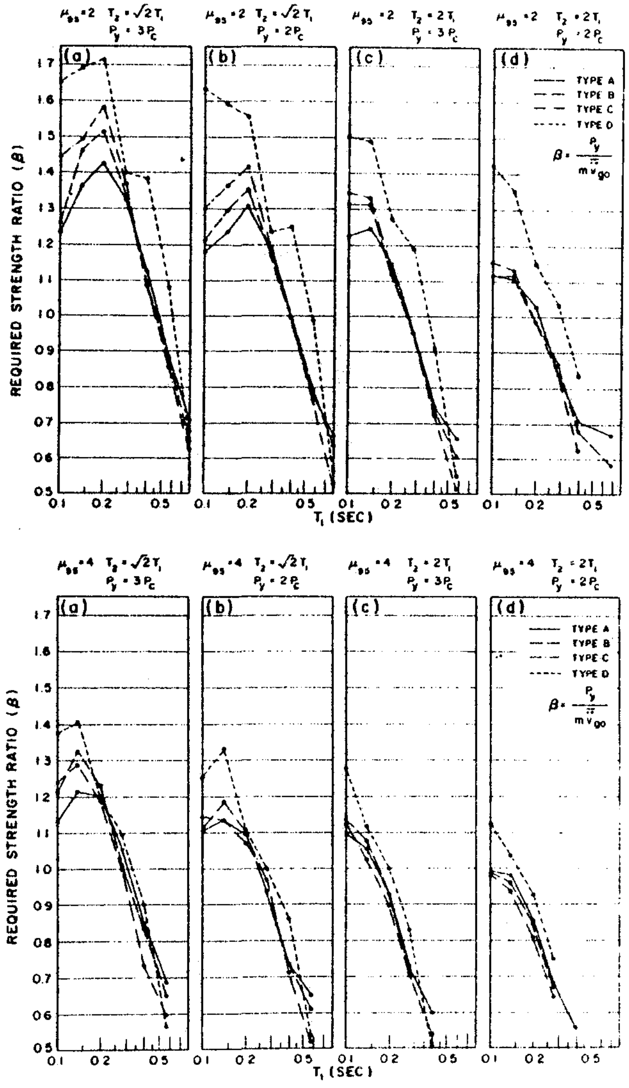


Fig.9 Required Strength Ratio for Flexural Failure Type

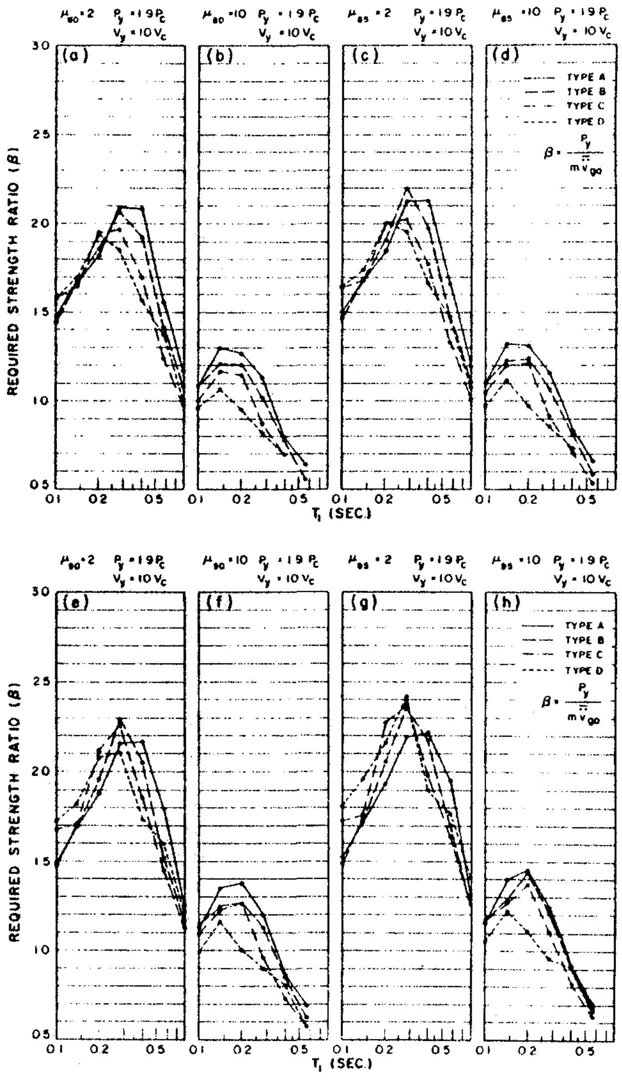


Fig.10 Required Strength Ratio for Shear Failure Type

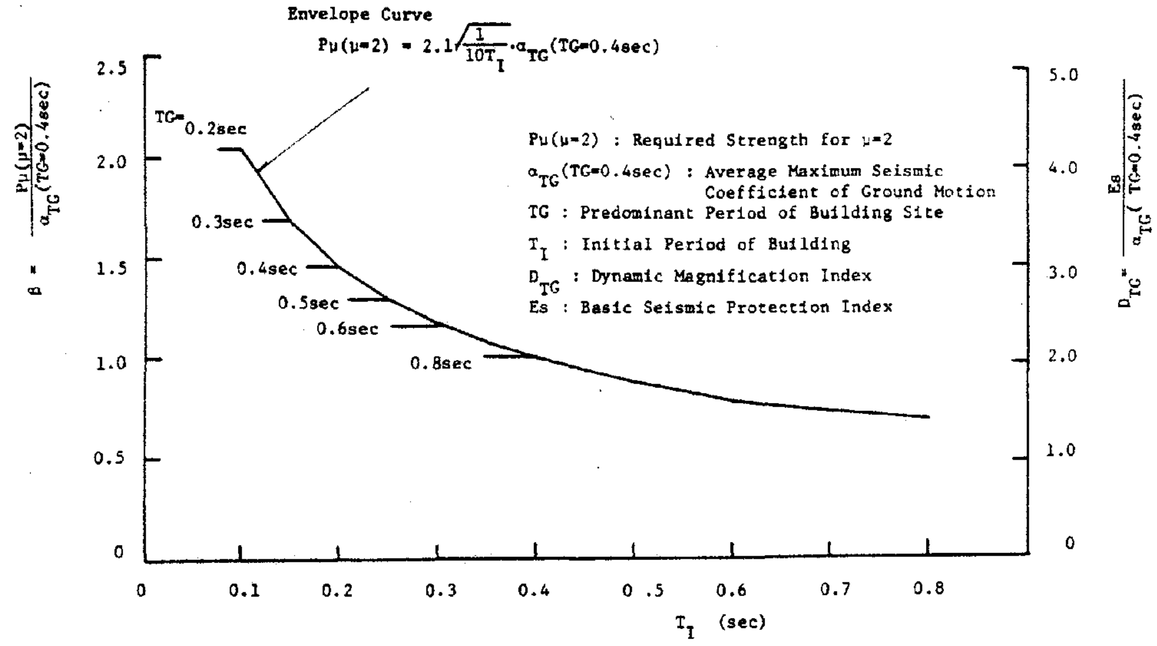


Fig.11 Required Strength Ratio and Magnification Factor for Flexural Failure Type

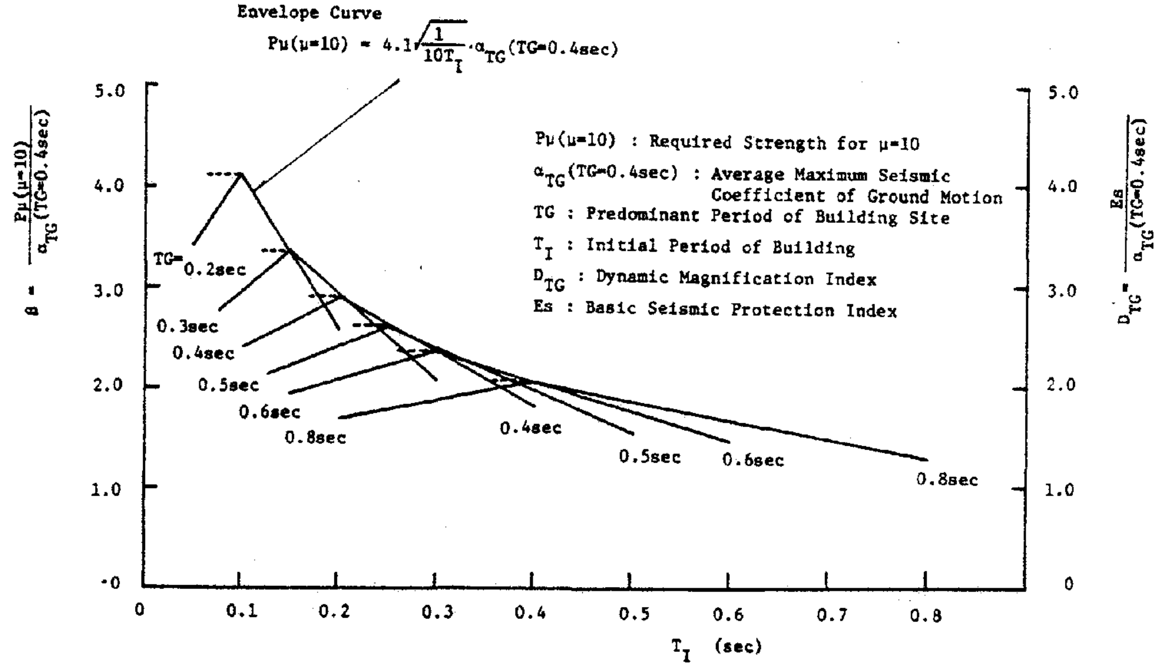


Fig.12 Required Strength Ratio and Magnification Factor for Shear Failure Type

Table 1 Type of Failure and F-index for First Evaluation Method after Reference [1],[2]

Type	F-index
Column	1.0
Wall	1.0
Extremely Short Column	0.8

All columns and walls are assumed brittle members

Table 2 Type of Failure and F-index for Second and Third Evaluation Methods after Reference [1],[2]

Type	F-index	
Ductile Column-1 (Bending column)	$1.27-3.2^{1)}$	Second & Third
Ductile Wall-1 (Bending wall)	1.0-2.0	
Brittle Column-1 (Shear column)	1.0	
Brittle Wall (Shear wall)	1.0	
Extremely Brittle Column	0.8	
Ductile Column-2 (Column in beam bending type of frame)	3.0	Third
Brittle Column-2 (Column in beam shear type of frame)	1.5	
Ductile Wall-2 (Wall fails in overturning)	3.0	

1) $F = \frac{\sqrt{2\mu-1}}{0.75(1+0.05\mu)}$

μ = Ultimate ductility factor

Table 3 The Values of α_2 and α_3 in Eq.(4) after Reference [1],[2]

First Group Second and Third Groups	Extremely Brittle column	Brittle Column, or Brittle Wall
Ductile Column	0.5	0.7
Ductile Wall	0.7	1.0
Brittle Column or Brittle Wall	0.7	-

Table 4 Topographic Index

Regular Condition	Edge of Cliff	Unconformable Strata	Hill
1.0	1.25	1.25	1.25

Table 5 Dynamic Magnification Factor and Predominant Period of Building Site

Predominant Period TG	Both Failure Type
0.3 sec	3.6
0.4 sec	3.1
0.5 sec	2.8
0.6 sec	2.5
0.7 sec	2.4
0.8 sec	2.2

Table 6 Dynamic Magnification Factor and Number of Story

Number of Story N	Flexual Failure Type	Shear Failure Type
1	3.1	3.5
2	2.7	3.0
3	2.5	2.8
4	2.4	2.6
5	2.3	2.5
6	2.2	2.5

Table 7 Epicentral Distance and
Seismic Coefficient of Ground Motion

Zone	Epicentral Distance	α_{TG}
A	25 ∿ 40 km	0.36
B	40 ∿ 50	0.33
C	50 ∿ 60	0.30
D	60 ∿ 70	0.27
E	≥ 70	0.23

Table 8 Basic Seismic Protection Index Es in Zone E (α_{TG}= 0.23)

( ) Flexal Failure Type

Predominant Period TG / Number of Story N	0.3sec	0.4sec	0.5sec	0.6sec	0.7sec	0.8sec
1	0.80 (0.70)	0.70 (0.70)	0.65 (0.65)	0.60 (0.60)	0.55 (0.55)	0.50 (0.50)
2	0.70 (0.60)	0.70 (0.60)	0.65 (0.60)	0.60 (0.60)	0.55 (0.55)	0.50 (0.50)
3	0.65 (0.60)	0.65 (0.60)	0.65 (0.60)	0.60 (0.60)	0.55 (0.55)	0.50 (0.50)
4	0.60 (0.55)	0.60 (0.55)	0.60 (0.55)	0.60 (0.55)	0.55 (0.55)	0.50 (0.50)
5	0.60 (0.55)	0.60 (0.55)	0.60 (0.55)	0.60 (0.55)	0.55 (0.55)	0.50 (0.50)
6	0.60 (0.50)	0.60 (0.50)	0.60 (0.50)	0.60 (0.50)	0.55 (0.50)	0.50 (0.50)

Table 9 Epicentral Distance and Mean Peak Acceleration

Epicentral Distance	Mean Peak Acceleration	α_{TG}
25 ∿ 40 km	0.45g	0.45
40 ∿ 50 km	0.33g	0.33
50 ∿ 60 km	0.30g	0.30
60 ∿ 70 km	0.27g	0.27

Table 10 Mean Peak Velocity and Displacement of A Type ∿ D Type Earthquake when α_{TG} = 0.45

Earthquake Type	Mean Peak Velocity	Mean Peak Displacement
D Type	36 kine	5.2 cm
C Type	40 kine	9.0 cm
B Type	66 kine	48.0 cm
A Type	69 kine	46.0 cm

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EFFICIENCY OF TREES FOR FIRE DISASTER PREVENTION IN URBAN PLANNING

NOBUFUMI IWAKAWA

1) Introduction

The efficiency of trees is indispensable for disaster prevention in urban planning. When considering the effect of trees in the urban area, their safety values might be initially examined. Among these safety values, the application for fire disaster prevention will be discussed in this paper.

2) Examination of the Burning-Stop Line of the Great Fire

Examination of the conflagration caused by the 1923 Kanto Earthquake (one of the most severe earthquakes in Japan) revealed that a burning-stop line was directly related to a green district. The statistics showed that about 37% of the total length of the line was influenced, pointing to the efficiency of a green district for fire disaster prevention.

3) Green Districts

Fire preventive efficiency of green districts was realized in 1923 when great fires occurred following the Kanto Earthquake. In the 1924 report titled "Parks and Open Spaces for Evacuation Areas", Messrs. Kawada and Yanagisawa stated:

> "When a park or an open space of an area of 30,000 TSUBO (about 99,000 m^2 is surrounded by broad-leaved trees and its shape is almost square, the people taking refuge in this kind of place can be safe from fire attacks at all

> sides. In addition, if a water pool is located at the center of the open space, the safety performance of the area would be increased. However, if a park or an open space is rather small and its space is less than 2,000 TSUBO (about 6,600 m^2) safety from fire for human lives cannot be insured even if it has broad-leaved trees."

We may consider that a rough estimation of the area more than 5 hectares provides safety from fire while one of less than 1 hectare is hazardous. In addition to this estimation, the effect of trees should be taken into account. Consider, for example, both the garden of Iwasaki Family (Kiyosumi Park at present) in Fukagawa, Tokyo, and the former Clothing Ordinance Area (at that time) in Honjo, Tokyo during the Kanto Earthquake fire. Massive fire victims were recorded due to the fire in Honjo where there was no protective trees for fire. By contrast the people who took refuge in the residence of Iwasaki Family were safe, because of its woody garden. The above example shows the value and importance of a green district for fire disaster prevention.

4) Fire Preventive Power of Trees

Fire preventive power of trees has been recognized for many years. In Japan Viburnum Awabuki in the Izu Area has been used as a type of fire preventive tree while in the Kanto Region, species of Shiia Sieboldii and Quercus myrsinaefolia have been used for the purpose of fire prevention. Chamaecyparis pisifera and Podocarpus macrophylla have also been used for the same purpose in Tohoku and Hokuriku Regions. From these experiences, it can be concluded that the fire preventive power of trees consists of 1) the resistive power against fire (resisting flames, heated air, radiant heat, and fire-flakes), and, 2) the screening power against fire (trees which work as a screen to reduce the effect of the fire).

The investigation of this fire preventive power has focused primarily on the individual leaf of the trees. The results show that the leaf with the best fire retardancy is one that is thick and has a hydrated ratio. It is defined that "a leaf is regarded to have fire preventive power when an average of more than 50% of the leaf is heated for 5 minutes at the temperature of 100°C, and still contains more than 75% of its absolute hydrated ratio.

When comparing leaves, branches and trunks of trees with timbers, the former is far more incombustible than the latter. Leaves of trees usually grow in every direction, piling on each other; moreover they rustle in the wind, therefore, the degree of heat acceptance of each leaf is not constant. Since trees are hydrated, they release the water when they are exposed to heat. Consequently, the heat is dissapated, delaying the decomposing of the trees.

In order to investigate the fire preventive power of trees with such complex functions as mentioned above, it is not satisfactory to conduct the experiments on only the individual leaf. The Building Research Institute, Ministry of Construction, has been working on a "Total Technical Development Project" since 1977 examining mature trees.

5) Fire Resistive Power

1) Ignition Property of Trees

When trees are subjected to radient heat of about 9,000 kcal/m^2h, the flashover a part of the fire-faced side is started in each tree after the time shows in the following chart:

(Surveyed by N. Iwakawa, in 1978)

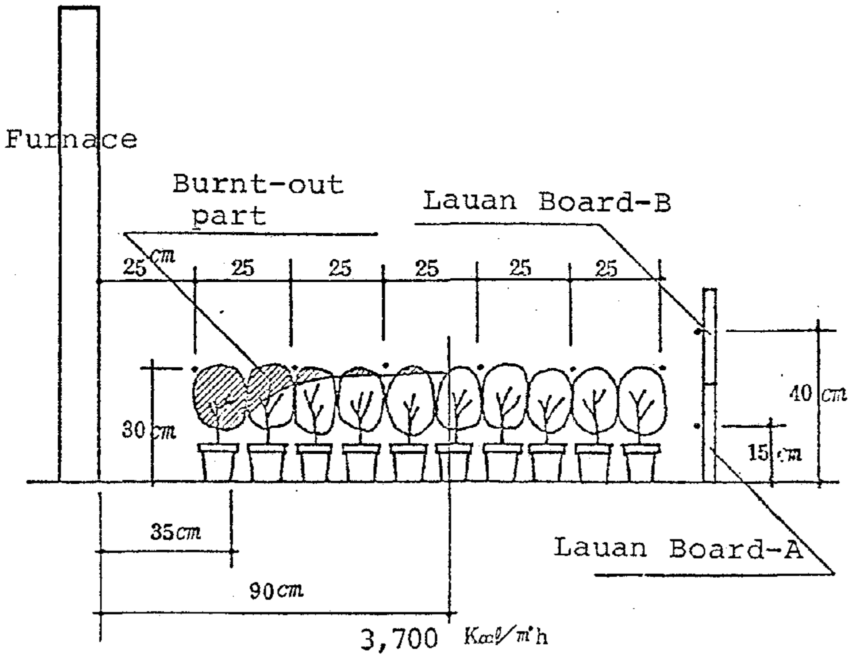
Kinds of Trees	Time required for flashover a part
	(Minute(s))
Viburnum Awabuki, Euonymus japonica, and Ternstroemia japonica	5 - 9
Camellia Sasanqus, and Pittosporum Tobira	3 - 4
Quercus myrsinaefolia, Buxus microphylla, Rhododendron indicum, Cinnamomum Camphora, Juniperus chinensis, Ginkgo biloba, Acer Buergerianum, Zelkova serrata, Styrax japonica, and Quercus serrata	1 - 3

When examining the flashover situation, most of the trees are burnt by the flame only at the surface of the leaves exposed to the heat; the burning then stops after the surface is burnt. Following the first stage, the secondary layer of leaves is burnt by the flame when the heat reaches the degree of flashover where the same phenomenon is repeated. This trend of ignition is especially remarkable in deciduous trees. However, trees such as Quercus myrsinae-folia and Juniperus chinensis, whose fire resistive power is small, would burn intensively until almost whole parts of the tree are burnt out without any process of half-burning.

The differences of ignition performance for different species of trees has been discussed. For the same species, extension of burning is late when the densities of leaves and branches are high. Examination of the burning process on sectional part of trees show that if the density of leaves is low, burning is rapidly spread almost to the root, and if the density is high, half-burning is repeated, beginning with surface burning and then the following second layer of leaves. With regard to the limited value of ignition, 3,700 kcal/m^{2}h, is confirmed as shown in Fig. 1.

Fig. 1 Ignition Scope

(Investigated by Japanese Institute of Landscape Architects)



As shown in the Fig. 1, after exposing the trees to radiant heat for 60 minutes, when a flame is ignited, the first group of trees burns intensively at the fire ignited point (7,000 kcal/m^2h). and finally burns down to the roots. When the surface layer of trees behind the first gorup of trees is burnt out, the fire does not extend to the other layers. When a flame is set to trees exposed more than 3,700 kcal/m^2h, only the surface layer is burnt out and in most cases the fire stops on the process of half-burnt. When trees are exposed to less than 3,700 kcal/m^2h, flashover does not occur even if a flame is set to the tree, because the leaves are hydrated. This value is very high compared with the permissible radiant heat of timbers, 2,500 kcal/m^2h.

2) <u>Change of Weight in Leaves by Heat</u>

When leaves are exposed to radiant heat, their weight rapidly decreases. The degree of decrease is slowed down after 6 minutes, the weight reaching a stable condition. This trend is somewhat different depending on the species of trees with the curve for thick leaves usually gently decreasing. (See Figs. 2 & 3.)

Figs. 2 and 3 Change of Weight in Leaves by Heat

(Investigated by N. Iwakawa, in 1978)

Fig. 2

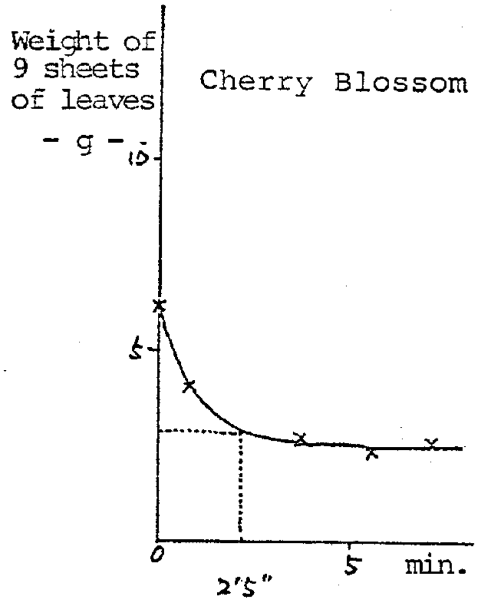
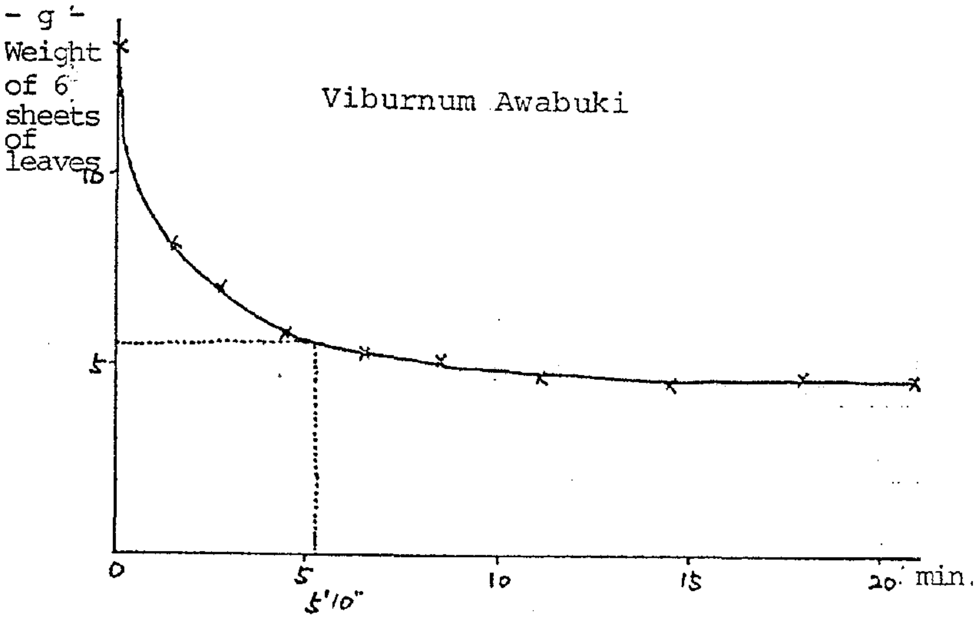


Fig. 3



As a general trend, flashover occurs when 90% of the weight in balanced condition is less.

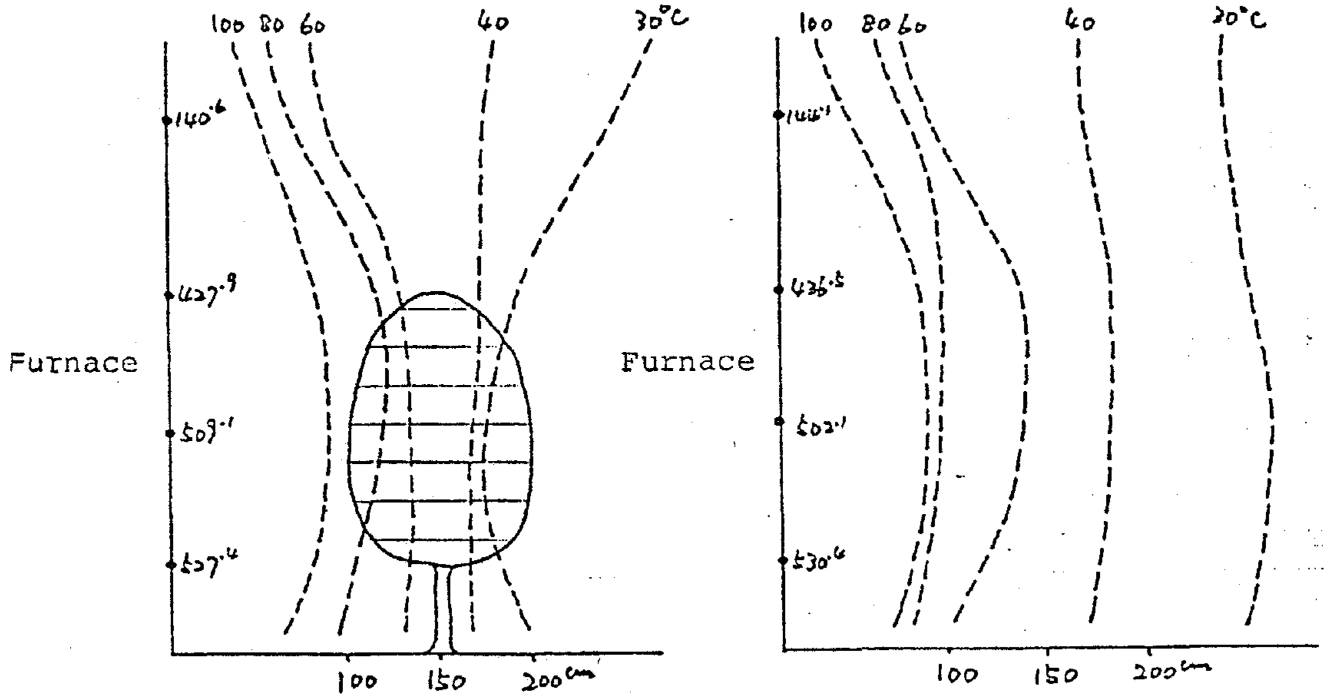
SCREENING POWER AGAINST FIRE

Distribution of Temperatures Around Trees

Because of the screening power of trees against heat, temperature behind the trees is remarkably reduced. It was reported that heat transition with 1 - 3 sheets of leaves heated by the radient heat of 5,000 - 8,000 kcal/m^2h, only a small percentage of the heat was transmitted. Fig. 4 shows the example on <u>Buxus microphylla</u> where the great screening effect can be recognized in the middle of the trees.

Fig. 4 Temperature Around Trees

(Investigated by N. Iwakawa, in 1978)



In Case the Trees are Existing

In Case No Trees are Existing

6) Subject in the Future

The hazardous point in ignition for wooden houses is 4,000 $kcal/m^2h$, and the hazardous point for a human being is 2,050 $kcal/m^2h$. By comparison trees are not ignited even at the point of 10,000 $kcal/m^2h$. Natural ignition in trees was observed at the occasion of the Full-Scale Fire Test on January 1979 with a house constructed by the traditional technique. The result showed a value of a little higher than 13,000 $kcal/m^2h$.

(The test species of the tree was Juniperus chinensis.)

The fire preventive power of trees is extremely high but in extreme cases such as a forest fire, trees are finally burnt out when the fire is exceptionally strong. Therefore, it is necessary to establish a balanced urban design method based on the proper examination of the relationship between the trees and fire intensity. Fire preventive power and efficiency varies with the species, age, scale, and the arrangement of trees. Further study in this field is a significant subject for Urban Design and Seismic Safety.

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SUMMARY–
RECOMMENDATIONS
CONCLUSIONS

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SUMMARY – RECOMMENDATIONS

INTRODUCTION

The U.S./ Japan Joint Seminar on Urban Design and Seismic Safety is a landmark seminar for at least two reasons:

1) Within our scope of knowledge it was the first structured attempt to interweave urban design concepts and their ramifications on earthquake hazard mitigation.

2) It was the first attempt for a U.S./Japan joint activity in this most critical area.

Accordingly, many of the papers presented at this seminar were wide ranging, covering everything from landscaping aspects of fire safety through human behavior and historic preservation. It also became readily apparent that the very concept of urban design has considerable differences in the U.S. and Japan. These differences were most apparent in the direction of research emphasis as well as (from a U.S. point of view) an abnormal concern on the part of the entire Japanese populace regarding fire. This concern for fire and its effect on the urban scene result in a considerable difference in level of priorities in the areas of basic life safety, water supply and fire barriers as compared to urban scale, open space, density and many of the items that American designers now consider necessary amenities to an urban center. These differences can be more readily understood when viewed against the different perspectives of history, economic and social backgrounds.

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Although there was some disagreement as to the priorities of issues involved, it was agreed that the conference was the first step toward defining the goals and improving communication between the two countries. It was further agreed that the basic concept of studying seismic safety and urban design was a necessary improvement in our fundamental research if we are to effectively prevent our cities from the potential disaster of earthquakes.

Towards this end it was felt that the need to identify issues should be a major concern and one of the prime purposes of this seminar.

MUTUAL CONCERNS

The concerns of the participants can be broken down into four general categories. These categories are based not only upon the materials presented at the conference but also the discussions that were generated by these presentations. The four major areas are: 1) Technical/Political Considerations, 2) Planning & Urban Design, 3) Post Disaster Recovery and 4) Education.

I. Technical/Political Considerations deal with both the technical information of seismic safety and urban design as well as the political aspects of dealing with the improvement of life safety in our cities. The following subtopics fall into this category.

   A) When dealing with the various aspects of Life Safety and its improvement, it is important to establish a precise definition of the term "Life Safety". Along this line, the need to establish the extent of responsibility of all those involved is required. That is, the organization of the Public, Professionals and Administration (Decision Makers).

   B) Vulnerability analysis of our cities can effect planning decisions that relate to future development. All existing buildings, Facilities (Critical Use and Hazardous), Lifelines and Transportation systems should be examined to test their durability in the event of a disaster. Historical preservation sites should also be addressed in relation to restoration vs. replacement.

   C) Related to Vulnerability analysis is Risk Analysis, that is defining Acceptable Risk in terms of life loss and property damage. This Risk Analysis can be based upon the location of various areas in relation to fault zones and other hazards. The mapping of these zones by their level of risk could prove useful for future planning.

D) The establishment of comprehensive standards that would aid in the development of safer cities is needed. Conflicts among existing codes as well as problems with implementation of new codes illustrate this need. These comprehensive standards should also take into account social/economic needs of the cities which seem to be neglected in our present codes.

E) Psychological Behavioral Analysis would be useful in studying the social disruption caused by a disaster. These studies could be done by the scenerio technique to evaluate the reactions (eg. Need to escape from the disaster) during and after the disaster strikes.

F) Fire Following an Earthquake is a major concern in Japan today as it once was in the U.S. (e.g. the San Francisco earthquake and fire). Techniques in Prevention, Firefighting and Evacuation during an actual fire should be developed and analyzed for use in various situations.

G) The fear associated with Building Collapse may be the cause of over-reaction that is responsible for buildings which may be structurally over designed. Criteria for structural requirements for earthquake resistance should be re-examined.

H) Documentation of the Characteristics of Hazards (Natural Disasters), Categorized by disaster types, should be continued and in some cases expanded. In this area, information dealing with recovery times, types/extent of damage, numbers of deaths/injuries, etc., would be helpful in future disaster planning.

I) Critical Use Facilities or those considered essential public facilities should be studied with emphasis placed upon aspects such as sitting in relation to faults and post earthquake operations. These studies should include but not be limited to such facilities as: Large scale assembly areas, emergency medical care, food services, civil defense, firefighting, police, emergency/interim shelter.

J) Precise Prediction of Earthquakes is not yet possible although knowing the probable frequency and magnitude of a predicted earthquake is more valuable than no information at all. The development and analysis of risk maps can be studied with emphasis placed upon improving the accuracy of predictions. Other relationships such as Epicenter location to areas of damage, fault to buildings and building types and their durability in relation to each other should also be studied.

K) The final issue within this secion deals with the appropriateness of available resources for seismic safety. That is, the question as to whether a disproportionate amount of funding and time has been spent on seismic safety alone, without an equal amount of attention paid to urban design concerns with regard to other natural hazards.

II. PLANNING AND URBAN DESIGN is the section dealing with the various aspects of planning for safer cities. Within this section the following subtopics were addressed as issues.

A) The Difference in Design Scales becomes a problem when comparing traditional Urban Design (City wide) and Architecture (individual) design. There needs to be a bridge between the two on the medium scale or neighborhood level. That is, using smaller, more manageable divisions of three dimentional space for future planning. Under this system the community members play a more active role in the planning and are more willing to participate for a common good.

B) Approaches to New Urban Design Planning can be developed to create safer cities. Land Use Management that includes Urban Analysis, seismic safety elements, population growth patterns and locational design criters should be evaluated for future use. Study of spatial Relationship such as urban areas to industrial areas as well as time/frequency/degree of use of various city locations could also provide useful information. The previously mentioned comprehensive planning with emphasis placed upon considerations defined by area location would also be useful.

C) An Inventory of Existing Buildings and Facilities would be another helpful tool in effective city planning. A study of this nature would take into account the composite effect of old buildings as well as non-conforming or unsafe structures. Public facilities and hazardous facilities (nuclear facilities, chemical plants/storage, refineries, etc.) should also be studied for their potential adverse impact upon the city during a disaster.

D) The Development of a Nationalized Hazards Reduction Policy is the final issue of this section. Through policy input at various levels (community, city, state and federal) this policy can be comprehensive and readily accepted. The implementation of this policy will be the key to the development of new areas and redevelopment of old areas to minimize risk.

III. POST DISASTER RECOVERY deals with the return to normal urban activity after the earthquake has struck. This section takes into account disaster relief (period immediately following the disaster) as well as long range recovery planning.

A) Lifelines or those systems which are related to basic life support require further study as to ways to improve service to the public, especially during disaster relief.

B) Damage evaluation is helpful not only in the repair and resumption of service after a disaster but also in planning future systems, implementing the knowledge gained about the types and extent of the damages. In this same area, methods for providing interim service should also be explored.

C) Emergency plans for use in the event of a disaster must be developed and revised according to changing load requirements caused by newly developed areas or changes in population density of an area. Along this same line things such as interim shelter/assembly areas and communication/information transfer studies should be completed for future use.

D) Evacuation systems for use during an emergency must be addressed. Attention should be paid to street size/ location in relation to population density and open space. Routes of evacuation and their alternates should also be studied as should be their design and location in relation to urban areas.

IV. EDUCATION of those who are affected by Urban Design and Seismic Safety is the final step in the exchange of useful information. The following topics, although differing in level of exchange all fall into this category.

A) Procedures for Exchange of Information will prove helpful in getting the information to those who need it most. Joint research case studies/demonstration projects and additional joint seminars are examples of direct information transfer. The establishment of worldwide information centers based on a network of data bank information systems would allow direct access to a greater amount of people. This sharing of information would also reduce the redundancy of research in areas where information already exists and establish the areas where further research is needed.

B) Education and Training of Professionals should begin early as a part of academic training. The various professional schools should include seismic safety and Urban Design Training as part of their curriculum. There is a need for better training for individuals as Urban Designers and researchers. The various professional organizations (i.e., A.I.A., J.I.P, etc.) could aid in this cause by educating their memberships in an ongoing process as to developments and changes within Urban Design and Seismic Safety.

C) Public Awareness and Community Participation are essential in any public program. The community support can best be gained by showing a need through example projects, seminars sponsored either by the professionals, or Government education programs. Input into Government policies at community level meetings should help gain support for the instituted policies.

D) Case Studies and Comparative Analysis will reveal the differences in research emphasis between the different countries (e.g., U.S./Japan - Social/Cultural, Land Masses and historical differences). These differences should prove useful in determining the type of information each country would like to have. This information can be obtained through the documentation of actual disasters as well as the scenario technique for U.S./Japanese cities to study the reactions of the people and estimations of possible damage.

Clearly, within the four sections (Technical/Political Considerations, Planning and Urban Design, Post Disaster Recovery and Education) many questions remain unanswered. Discussion of these topics did however establish new research directions as well as reinforce existing research needs.

CONCLUSIONS

It was brought out by the conference that the responsibility for public safety lies upon all of us. However, a much larger portion of the responsibility rests upon the actual decision makers involved in Urban Design as it relates to Public Safety. Because of the very specialized nature of this emergency field, the practicioner must have better training as a researcher in Urban Design.

The Urban Designer should be able to play a more active role in the planning of our cities so that they will be safer places to live. To do this, there must be better collaboration between the various specialists within the field of study in order to work towards the common goal of better public safety.

Through this conference it was realized that a meeting such as this, on an international level was long overdue. It brought nations together for common concerns and established links between seismic safety and Urban Design.

One of the main goals of the conference was to establish starting points for future research needs, and topics for future conferences. In this way it was possible to facilitate the exchange of information between the two countries. Based upon the presentations and subsequent discussions at this, the initial conference, the following recommendations are made:

1) Additional conferences to be held as a means of continuing the exchange of information between countries. The topics of these conferences would be based upon the topics of mutual concern established at previous conferences.

2) Expand the number of participating countries (possibly the entire Pacific Basin) to allow the exchange of information by a greater number of people.

3) Establish worldwide information centers and data banks to which all interested nations would have access. In this way also helping to facilitate the transfer and sharing of information.

4) Establish Joint research in various cities (e.g. U.S.-San Francisco/Japan-Tokyo) including demonstration projects and case studies which would assist in the collecting of information for future use.

In these ways we could be making a more positive effort toward making our cities safer places to live for ourselves as well as future generations. This goal of improving public safety is our responsibility.

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