

Seismic Considerations— Hotels and Motels



EARTHQUAKE HAZARDS REDUCTION SERIES 36

Issued by FEMA in furtherance of the
Decade for Natural Disaster Reduction.





**Program
on
Improved
Seismic
Safety
Provisions**

SEISMIC CONSIDERATIONS: HOTELS AND MOTELS

Revised Edition

BSSC Program on Improved Seismic Safety Provisions

**SEISMIC CONSIDERATIONS:
HOTELS AND MOTELS**

Revised Edition

**Developed by the
Building Seismic Safety Council
for the
Federal Emergency Management Agency**

**BUILDING SEISMIC SAFETY COUNCIL
Washington, D.C.
1990**

FOREWORD

The Federal Emergency Management Agency (FEMA) is pleased to have sponsored the development and the updating of this publication, one of a series of five devoted to the seismic safety of specific building types with special occupancy and functional characteristics (i.e., schools, lodging facilities, health care facilities, office buildings, and apartment buildings). Owners, developers, designers, and regulatory officials concerned with such buildings are encouraged to become aware of their particular seismic vulnerabilities and of cost-effective means to alleviate such vulnerabilities through the selective use of the *NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings*. This revised edition of *Seismic Considerations: Hotels and Motels* reflects the content of the 1988 Edition of the *Provisions*.

Special thanks are due to Earle Kennett, Kennett/Nanita Associates, Gaithersburg, Maryland, who authored the initial edition of this publication, and to the BSSC staff and Board of Direction for their efforts in producing this revision.

Federal Emergency Management Agency

ACKNOWLEDGMENTS

This publication was made possible through very generous contributions of time and expertise on the part of many individuals. The Building Seismic Safety Council is particularly grateful to Earle Kennett of Kennett/Nanita Associates for their contributions in developing and promoting the first edition of this publication; to John F. Meehan, past Chief Structural Engineer for California's Office of the State Architect, for his technical review of the original publication and for his contribution of photographs; and to Christopher Arnold, Building Systems Development, Inc., San Mateo, California, and Ivan Viest, Consulting Engineer, Bethlehem, Pennsylvania, who developed material for other reports in the *Seismic Considerations* series that has been used in this revision.

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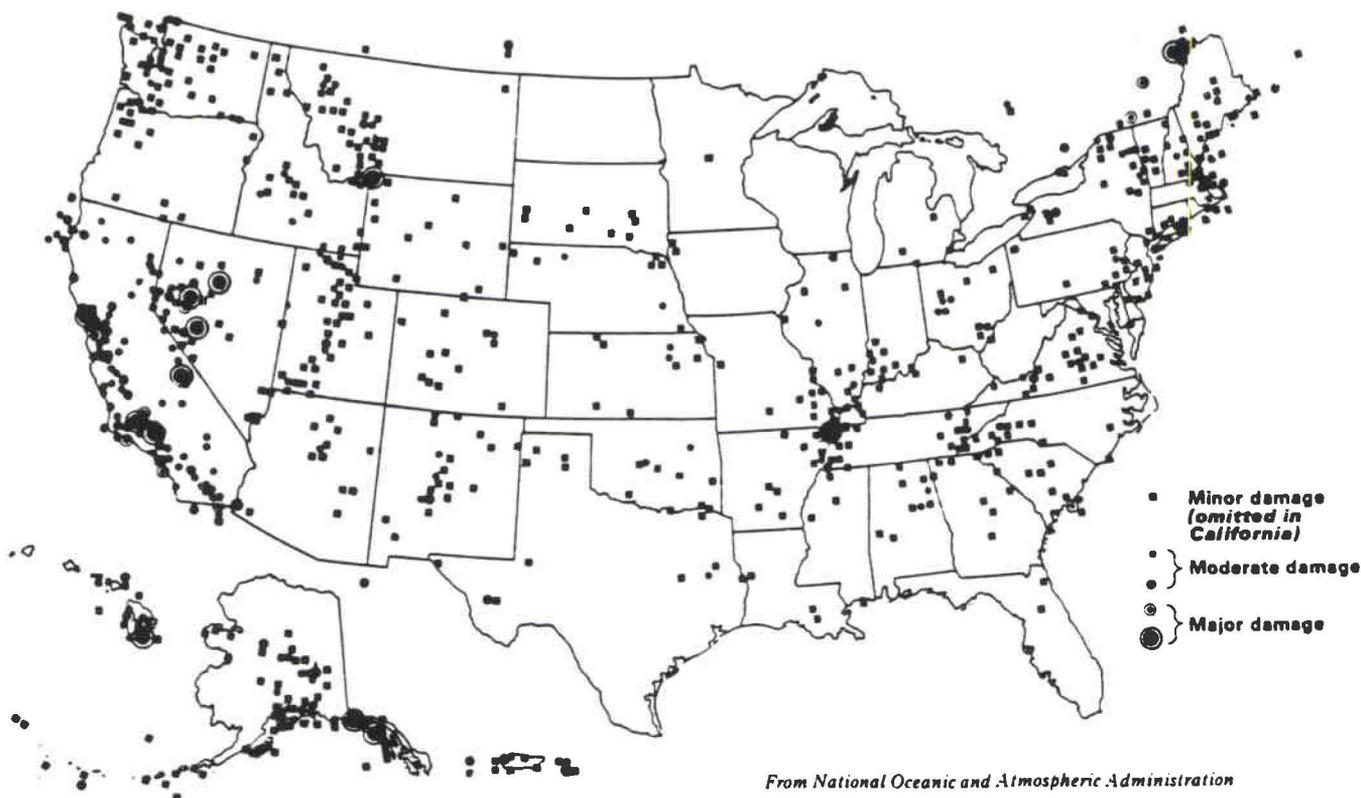
OVERVIEW

Need for Seismic Hazard Awareness

A severe earthquake is one of nature's most terrifying and devastating events and collapsing structures and falling debris do most of the killing. The Building Seismic Safety Council (BSSC) firmly believes that increased building earthquake resistance is in the best interest of all building owners and developers. The Council also is convinced that, once these individuals and organizations seriously consider the social, economic, and legal implications of the earthquake risk to their facilities and operations, they will actively support efforts to improve the seismic resistance of their buildings by requiring that their designers follow up-to-date seismic-resistant design guidelines in all earthquake-prone areas of the nation.

Damaging U.S. earthquakes.

Many building owners and developers, like many Americans in general, tend to associate earthquakes only with California. They are unaware that earthquakes are a national hazard. In fact, earthquakes have occurred and continue to occur in the majority of states and some of the most severe earthquakes recorded in this nation have occurred, not on the West Coast, but in the Midwest and East.



From National Oceanic and Atmospheric Administration

**Contents of
This Publication**

General information concerning the seismic hazard and seismic design for hotels and motels is contained in Part I of this publication and more technical details are presented in Part II. Appendixes provide information on related topics.

PART I

SEISMIC CONSIDERATIONS FOR HOTEL AND MOTEL DECISION-MAKERS

EARTHQUAKES AND LODGING FACILITIES

Earthquakes-- A National Hazard

A severe earthquake is one of nature's most terrifying and devastating events, and collapsing structures and falling debris do most of the killing. Media coverage of the 7.1 magnitude Loma Prieta earthquake in 1989 showed the nation just how horrifying an earthquake can be while also illustrating that modern buildings, designed and constructed under up-to-date seismic regulations, will perform well. Such regulations, however, have not been imposed in many areas of high to moderate seismic risk.

Many people assume that earthquakes are primarily confined to the West Coast when, in fact, more than 70 million Americans in 44 states are at some risk from earthquakes (see Figure 1 and Appendix B for an overview of U.S. seismicity). Indeed, three of the most severe U.S. earthquakes occurred, not on the West Coast, but in the East and Midwest--in Charleston, South Carolina, in 1886; at Cape Anne, Massachusetts, in 1755; and in New Madrid, Missouri, in 1811-12. The New Madrid event involved a series of three major shocks that affected a 2 million square mile area, which is equal to about two thirds of the total area of the continental United States excluding Alaska. The Charleston earthquake also had a "felt" area of 2 million square miles.

Between 1900 and 1986, about 3,500 lives were lost as a result of earthquakes in the United States and property damage has amounted to approximately \$5 billion (in 1979 dollars). Since 1987, however, earthquake-related property damage has more than exceeded that amount:

- The 1987 Whittier Narrows earthquake in Los Angeles caused three deaths and over \$350 million in property damage.
- The 1989 Loma Prieta earthquake in the San Francisco Bay area caused 62 deaths and over \$5 billion in property damage.

Further, consider the tremendous social and economic loss to the nation if just one earthquake comparable, for example, to the New Madrid event occurred today where a number of high-density urban areas such as Memphis and St. Louis stand in place of log cabins and Indian settlements. In St. Louis, for example, future earthquakes may cause far more damage than the earthquakes that occurred in the early nineteenth century when population density was low and there were no high-rise buildings. One needs to remember that there were only 2,000 people living in the St. Louis metropolitan area in 1811, as opposed to 2,400,000 today.

Further complicating the national seismic problem is the fact that science and technology have not yet generated a technique for accurately predicting when an earthquake will occur. Earthquakes are therefore a natural hazard even more difficult to deal with from a life safety standpoint than hurricanes or floods since one has no relatively immediate warning and cannot evacuate the area. However, geologic studies on a nationwide basis are rapidly advancing knowledge on the probability and nature of future earthquakes. These studies eventually should provide a more precise basis for establishing the relationship between seismic risk and appropriate seismic design.

The way in which buildings are designed and constructed ultimately determines the probability and extent of earthquake damage, and observation and experimentation have generated a considerable amount of information on effective seismic-resistant design and construction.

As a result of the study of buildings in and after earthquakes and experimental research in laboratories, where structures can be shaken to simulate the effects of earthquakes, a great deal is known about the relative safety of different types of construction. To accurately assess the seismic performance of a building requires considerable engineering expertise, but one need not be an expert to understand that a building constructed of bricks using poor quality mortar is much more likely to collapse than one that employs a well-engineered steel or reinforced concrete frame to provide integrity.

Nevertheless, since seismic safety is a complex issue that involves a relatively uncommon hazard and community values as well as life safety, this knowledge is not always applied even in areas of high risk. In California, for example, earthquakes have been a constant concern for many years and seismic building codes, although initially inadequate by today's standards, have been in effect for over 50 years. In other parts of the country, however, where the last major earthquake was well before anyone's memory, this is not so and even a moderate earthquake may do devastating damage.

**Lodging Facilities
Pose Special
Earthquake
Problems**

This situation is especially critical with respect to hotels and motels. Although lodging facility construction is similar to that of other buildings, the size, occupancy and purpose of these buildings dictate that seismic safety (like fire safety) be given special attention:

- Hotels and motels provide guests with a "home away from home" and, consequently, are occupied 24 hours a day by individuals who are generally unfamiliar with the building and its egress routes. In addition, they may be occupied by a large number of people who are not registered guests because of the diverse activities that occur in today's lodging facilities (e.g., conventions, parties, shopping).
- Hotels and motels often are complex buildings combining the functions of a lodging facility with those of an office building, restaurant, assembly hall, shopping area, and warehouse. After an earthquake, guests and visitors may be very confused, lights may be out, elevators will be inoperable, and hallways and room exits may be blocked by furnishings or other debris.

SEISMIC HAZARD MITIGATION AND THE COST/BENEFITS OF SEISMIC DESIGN

Need for Local Seismic Hazard Assessment

Those responsible for lodging facilities need to research their local seismic situation to determine the precise seismic hazard. Once this is done, they will have a rational basis for deciding how much seismic risk they are willing to accept and the degree to which they wish to lessen the risk.

The use of up-to-date seismic design provisions--especially the *NEHRP Recommended Provisions*--in developing requirements for lodging facilities generally is considered to be one significant way of lessening the risk to life by bringing to bear the best available guidance for designing and constructing new buildings in a manner that will prevent their structural collapse during an earthquake. (Appendix A presents a review of the damage to hotels and the disruption of operations resulting from the 1985 Mexico City earthquake, the 1986 El Salvador earthquake, and the 1989 Loma Prieta earthquake.)

Life Safety Considerations

Lodging facility design must be concerned not only with life safety in terms of death or injury due to building collapse or property damage but also with the safe emergency egress of guests, staff, and visitors. Although promulgation of a seismic building code based on statistical probabilities can contribute significantly to building and occupant safety in an earthquake, it is not possible to describe on firm scientific ground the strongest earthquake that might occur at any specific location and, therefore, there always remains some degree of risk. This risk may be small, but it is greater than zero.

For an individual building designed in accordance with *NEHRP Recommended Provisions*, the intent is to ensure a level of safety such that in the "design earthquake" (i.e., one that has only a 10 percent probability of being exceeded in 50 years), structural damage will be limited. There may, however, be some nonstructural and contents damage but such damage will not be life-threatening. Any damage, structural or nonstructural, generally will be repairable. For a large earthquake of low probability of occurrence (e.g., one with a predicted occurrence interval of thousands of years), there may be structural damage and considerable nonstructural damage, but life-threatening collapse, while possible, is improbable. It must be emphasized, however, that it is not practical to obtain absolute safety from any natural or man-made hazard. A major earthquake may produce some damage (both structural and nonstructural) in even the most earthquake-resistant structures, but use of the *NEHRP Recommended Provisions* will provide a high level of life safety when applied by competent engineers knowledgeable about earthquake matters.

Economics of Seismic Design

Although the main purpose of seismic design is to save lives and prevent injuries, the decision to design against earthquakes and to establish seismic design standards often is based on economic considerations: By how much can we afford to reduce the risk of damage to our building? Because hotels and motels provide service, produce revenue, and are expensive to build and operate, the economics of seismic design are particularly critical. Beyond the consideration of life loss, economic analysis on a conventional real estate basis can provide some useful guidance concerning the effects of seismic design on lodging facility economics.

In general, the added cost of seismic design will be in increased design and analysis fees, additional materials (steel reinforcement, anchorages, seismic joints, etc.), and additional elements (bracing, columns, beams, etc.). The major factors influencing the increased costs of seismic design to comply with the *NEHRP Recommended Provisions* are:

- The complexity of the building form and structural framing system--It is much more economical to provide seismic resistance in a building with a simple form and framing.
- The overall cost of the structural system in relation to the total cost of the building--For a typical hotel, the structural system usually represents between 10 and 15 percent of the building cost.
- The stage of design at which increased seismic resistance is considered--The cost of seismic design can be greatly inflated if no attention is given to it until after the configuration of the building, the structural framing plan, and the materials of construction have been selected.

In the best case (a simple building with short spans where earthquake requirements are introduced at a very early stage of project planning), the increased cost for seismic design should be in the range of 1 to 4 percent of the structural system or between 1.5 and considerably less than 1 percent of the building cost. In the worst case (a complex, irregular building with long spans where earthquake requirements are considered only after the major design features are frozen), the increase can be considerably more--perhaps as large as 25 percent of the structural cost or up to almost 5 percent of the building cost. In addition, because of the importance of utilities and other nonstructural elements, an additional cost must be estimated for ensuring their protection, but this should not exceed 0.5 percent of construction cost.

The average increase in cost of lodging facilities conforming to the *NEHRP Recommended Provisions* should be less than 1.5 percent of the construction cost of the building, which, of course, is only a part of the total project costs. The actual construction cost of a hotel, for example, is only about 50 percent of the total project cost, which also includes technical expenses, administrative expenses, land cost, and site development. The cost of equipping a modern hotel further reduces the impact of a small increase in construction cost. If wages and salaries are taken into account, the capital cost of construction represents only a small percentage of yearly operating costs.

- In future dollars, the lost revenue to the hotel without seismic design will be \$3,881,696 (based on a loss of operational capability for 8 weeks assuming 65 percent occupancy at a per day guest rate of \$50 for a room and \$35 for food and beverages and not considering any lost revenue from restaurant/meeting/shopping services). The hotel with seismic design remains operational.
- The extra finance charges for the \$200,000 investment for seismic design will be \$460,000 in future dollars (25-year loan at 8 percent).

Thus, the total future extra costs of the hotel without seismic design would be \$9,621,396 (a minus \$533,200 in building worth, a minus \$5,867,000 in damage repairs, a minus \$3,881,696 in lost revenue, and a plus \$660,500 for the principal and finance charges for the seismic investment), and a 16 percent investment would be needed to receive a similar return on the original seismic design investment. In other words, the hotel owner would have to invest \$200,000 (the original cost of seismic design) at 16 percent per year for 25 years to be able to pay for hotel losses and repairs. In essence, then, seismic design for hotels and motels represents both increased life safety and a sound investment economically.

If earthquake damage is severe, the financial loss affects not only the lodging facility but also the staff and other businesses and professionals who provide goods and services to the lodging facility. Thus, the earthquake threat must be evaluated in economic terms as having a very broad effect on community business activities.

In addition, although they cannot yet be quantified, liability risks must be considered by those responsible for hotels and motels. Few data are available that reflect the magnitude of the risks that lodging facility decision-makers face in terms of liability for casualties incurred in their buildings during an earthquake, but this will almost certainly be decided by the courts after the next earthquake that causes life loss. As soon as the earthquake threat is identified and means of reducing its effect are documented, the hotel or motel that makes no reasonable provision for seismic design will be in a very tenuous legal situation when the earthquake occurs. Further, research on law suits involving performance problems in hotels over the past 15 years points to a disturbing trend (Figure 2; based on data from the Architecture and Engineering Performance Information Center). Of all lawsuits involving hotel property damage, bodily injury or management problems (cost overruns, delays, cost extras), almost one-third are bodily injury claims whereby the public user is suing the owner (the largest ratio of all commercial building types).

Liability for earthquake losses also may have a considerable impact on designers. After the 1985 earthquake in Mexico City, for example, a Mexico resident sought justice in the case of the loss of his family in an apartment building that collapsed as a result of the earthquake. His claims were based on an investigation of the design, materials, and construction of the building, and, as a result, the Mexican federal courts issued arrest warrants for the designers of the building. This case is reported to be the first to be brought against individuals as being responsible for deaths and injuries during an earthquake, but it is unrealistic to expect it to be the last.

PART II

**SEISMIC CONSIDERATIONS FOR
HOTEL AND MOTEL DESIGNERS**

HOTEL AND MOTEL EARTHQUAKE DESIGN PROBLEMS

Lodging Facility Inventory

According to the lodging industry's 1985 census, there were approximately 2.75 million hotel rooms in the United States. Based on demographic changes and trends, it is estimated that about 3 to 4 million new rooms and the remodeling of 1.5 to 2 million existing rooms will be needed to meet the demand through the end of this century.

For purposes of this publication, hotels and motels are considered to include:

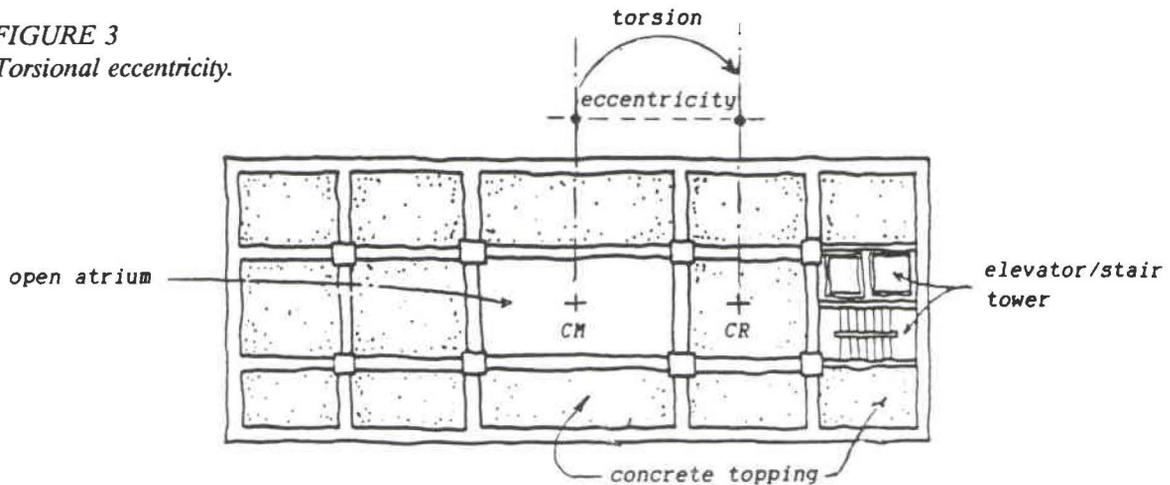
- **Downtown Hotels**--Typically large high-rise buildings located in major business districts that provide luxury accommodations and amenities. These hotels make up almost 11 percent of the hotel building stock while comprising almost 19 percent of the floor area. Specific seismic safety concerns include the effect adjoining buildings can have on the hotel, the hotel's effect on adjoining buildings and pedestrians, and the large number of occupants.
- **Convention Hotels**--A type of downtown hotel with very large potential occupancies and spaces with long spans (frequently enclosing areas of 200,000 square feet or more) that are especially susceptible to earthquake motion.
- **Airport Hotels**--Usually located at every major airport and providing the same upscale amenities as downtown hotels. Only 5 percent of hotels are of this type; however, they comprise 8 percent of the square footage. Specific seismic safety concerns include the effect of the hotel on the airport terminal with which it is integrated, the effect of the terminal and auxiliary structures (such as parking structures) on the hotel, and the tremendous number of transient persons in and around the hotel.
- **Suburban Hotels**--Varying in size and offering various levels of amenities. These hotels, although usually smaller in size and height and with lower occupancy densities than downtown and airport hotels, represent the largest amount (almost 31 percent) of the lodging facility floor area. Adjoining buildings tend not to be an earthquake concern, but these hotels tend to be relatively rigid because of their lower height and considerable property damage can result from earthquake motion.

Building Form Irregularities

Those who have studied the performance of buildings in earthquakes generally agree that the building's form greatly influences its performance under ground motion. This is because the shape and proportion of the building have a major effect on the distribution of earthquake forces--that is, on the relative size and nature of the forces as they work their way through the building.

A simple and symmetrical building form allows for the most even and balanced distribution of forces, but symmetry of form will not ensure low torsional effects. For instance, even in simple symmetrical rectangular buildings the location of stiff stair and elevator cores, solid and glazed walls, or other design elements that add mass to only one part of the building can result in different locations of the center of mass and the center of rigidity, and the torsion or twisting that results during an earthquake (Figure 3) has frequently caused substantial damage.

FIGURE 3
Torsional eccentricity.



A common building form that presents seismic design problems is that of the "re-entrant corner." The re-entrant corner is the common characteristic of overall building configurations that, in plan, assume the shape of an L, T, U, H, \dagger , or a combination of these shapes (Figure 4). These building shapes permit large plan areas to be accommodated in relatively compact form while still providing a high percentage of perimeter rooms with access to air and light. Because of these characteristics, they are commonly used in lodging facility design with the courtyard form being especially prevalent for high-rise hotels on small urban sites. These configurations are so common and familiar that the fact that they represent one of the most difficult problem areas in seismic design may seem surprising, but examples of earthquake damage to re-entrant corner type buildings are common. First noted before the turn of the century, this earthquake problem was generally acknowledged by the experts of the day in the 1920s.

FIGURE 6
Hotel Continental
 after 1985 Mexico
 City earthquake
 (EQE, Inc., San
 Francisco).



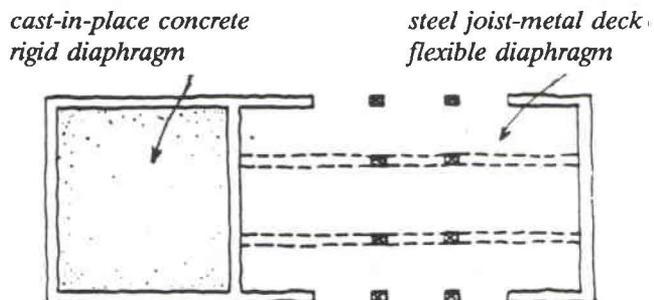
Typical problems with the building form characteristics of lodging facility design are as follows:

- The juxtaposition of solid and glazed walls.
- The location of and materials used for atria, interior courtyards, and lobbies.
- The placement of off-center circulation cores for more efficient guest traffic.
- The size and shape of wings used to house and distribute guest rooms.

**Structural
 Discontinuities**

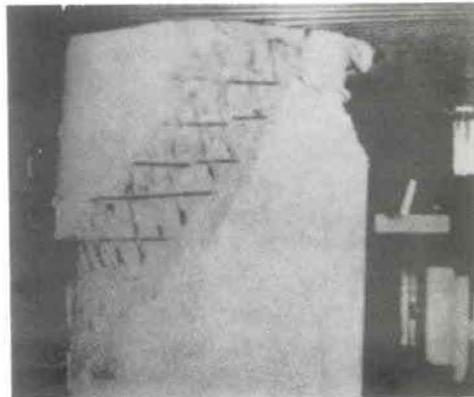
It is not generally recognized that large discontinuities (or abrupt changes) in the strength (Figure 7) or stiffness of a building can cause adverse seismic response effects. This is particularly the case where there are abrupt changes in the vertical arrangement of the structure that result in discontinuities (changes) of strength or stiffness from floor to floor.

FIGURE 7
 Discontinuity in
 strength.



Where earthquake forces are not an issue, the "soft" story presents no problem, but in earthquakes around the world, buildings with this condition have suffered severely. The Macuto Sheraton Hotel in Caracas experienced severe structural damage during the 1967 Venezuela earthquake (Figure 10). The building was constructed with stiff bearing walls above a mezzanine floor while column and beam framing provided the structural support below the mezzanine. The building had an abrupt change of stiffness from frames to structural walls above the mezzanine, and the more flexible and less strong frame portion under the walls led to a concentration of loads in the lower floor causing major column failure.

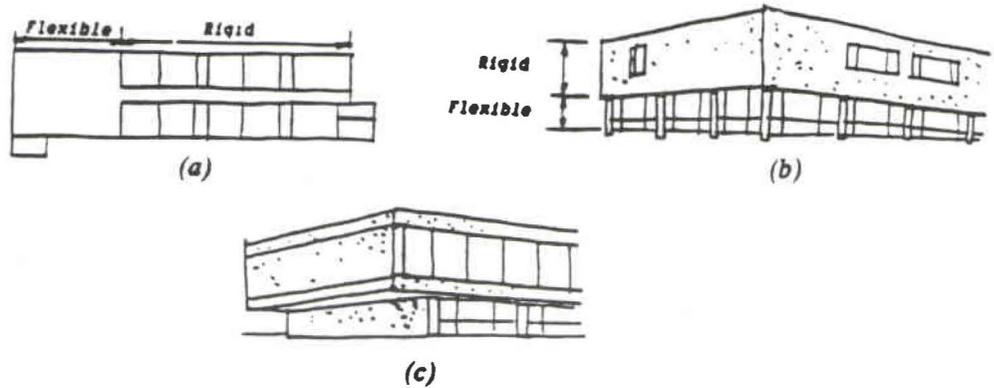
*FIGURE 10
Hotel Macuto
Sheraton in
Caracas after
1967 earthquake.*



Discontinuity also must be considered in plan. The placement of an area with flexible long span beams next to an area with rigid shorter spans or shear walls can result in each system reacting differently to the ground motion, causing damage between the different systems by transferring more of the load to the stiffer system or through pounding between the systems.

- The placement of stiff floors (guest room areas) above a more flexible first floor (commercial areas, lobbies) (Figure 12b).
- Discontinuities in column or wall placement from one floor to another (Figure 12c).

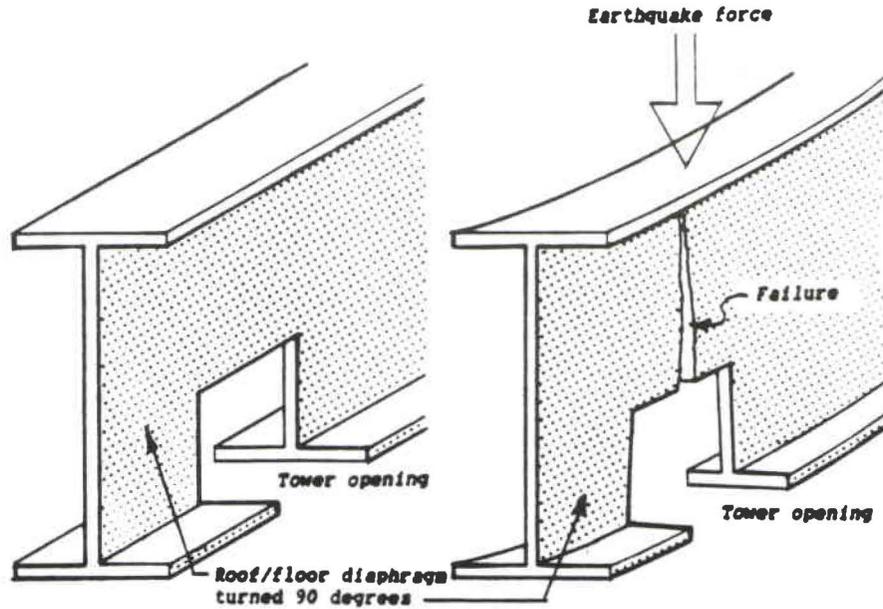
FIGURE 12
Strength discontinuity:
(a) plan, (b) elevation, and (c) wall-column placement.



Roof and Floor Diaphragms

The earthquake loads at any level of a building will be distributed to the vertical structural elements through the roof and floor diaphragms. The roof/floor deck or slab (the horizontal diaphragm) responds to loads like a deep beam. The deck or slab is the web of the beam carrying the shear and the perimeter spandrel or wall is the flange of the beam resisting bending (Figure 13).

FIGURE 13
Openings in diaphragms.



Particular issues related to diaphragms in hotel and motel design are as follows:

- The use of excessively large openings in the floor and roof diaphragms to provide for centralized circulation cores in the lobby and in the roof diaphragm to provide for atria or skylights.
- The mixing of more flexible diaphragms (steel decking for longer spans) with more rigid diaphragms (concrete slab for shorter span guest areas) causing discontinuities in the diaphragm stiffness/rigidity.

Displacement and Drift

Drift is the lateral displacement of one floor relative to the floor below. Buildings subjected to earthquakes need drift control to restrict damage to interior partitions, elevator and stair enclosures, glass, and envelope cladding systems and, more importantly, to minimize differential movement demands on the seismic resisting structural elements.

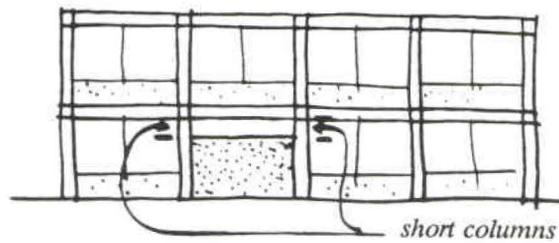
Drift control, or the recognition of the amount of potential drift, greatly influences the amount of damage control that is designed into the building. Since damage control generally is not a building code concern for typical buildings and since the state of the art is almost entirely empirical, the drift limits found in codes generally have been established without regard to considerations such as present worth of future repairs versus additional structural costs to limit drift.

Stress or strength limitations imposed by normal design level forces occasionally may provide adequate drift control. However, the design of relatively flexible moment resisting frames and of tall, narrow shear wall buildings for seismic risk areas should be governed, at least in part, by drift considerations. In areas where the potential for high seismic loads is great, drift considerations are of major concern for buildings of medium height and higher and should be given attention in the design of multistory lodging facilities.

In hotel and motel design, however, the potential amount of property damage to nonstructural elements, equipment, and personal property that may result from use of these drift levels may not be acceptable. Downtime for cleanup and repair, operational dysfunction (water, heating, airconditioning, lighting), and liability for personal property damage and loss may warrant the imposition of more stringent drift limits for these types of buildings.

Total building drift is the absolute displacement of any point in the building relative to the base. Adjoining buildings or adjoining wings of the same building must be considered since individual structures do not have identical modes of earthquake response and, therefore, have the tendency to pound against one another. Building separations or joints must be provided between adjoining structures to permit the different parts to respond independently to the earthquake ground motion.

FIGURE 16
*Nonstructural infill
creates short
columns that attract
earthquake forces.*

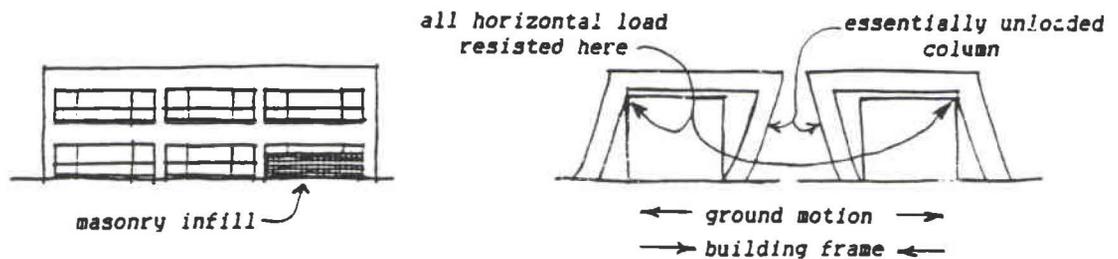


During the 1985 Mexico City earthquake, the construction joints of the columns at the floor levels of the Hotel El Presidente were sheared as the infill walls resisted any horizontal deflection of the columns (Figure 17). The Krystal Hotel also suffered major cracking of infill panels during the same earthquake (Figure 18). The panels apparently were not designed to take the loads transferred to them by the columns restrained by the panels.

FIGURE 17
*Hotel El Presidente
after 1985 Mexico
City earthquake
(Masonry Institute of
America).*



FIGURE 20
Effect of
infill walls.



Connections

Structural member connections are among the most critical elements of earthquake-resistant design. Probably the most important single attribute of an earthquake-resistant building is that it is tied together to act as a unit, but no set of seismic provisions issued before the *NEHRP Recommended Provisions* (and its predecessor, the Applied Technology Council's ATC 3-06) stated this requirement. It is generally accepted by structural engineers that to develop adequate connections between structural elements is more difficult than to provide strength in the members themselves. This has been demonstrated clearly in past earthquakes where considerable damage originated at connections rather than in the structural members.

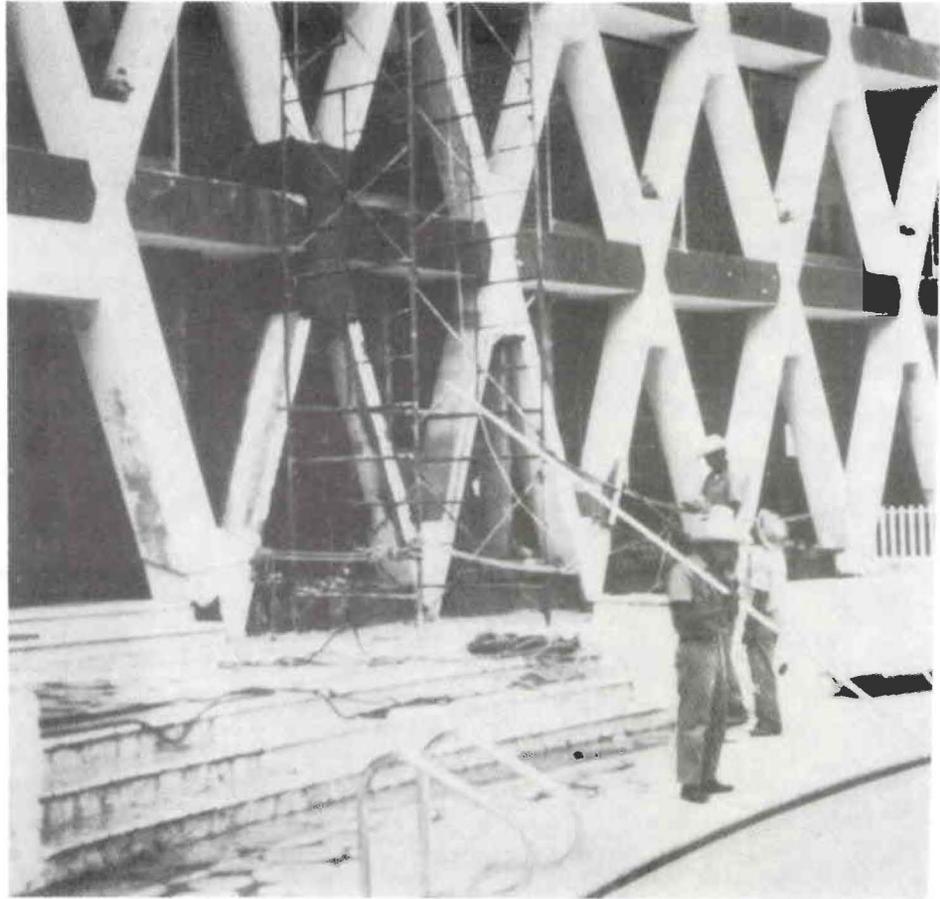
Furthermore, properly designed structural elements are usually ductile--i.e., their failure is preceded by large permanent deformations that dissipate a considerable amount of energy. On the other hand, connections often are relatively brittle. Therefore, a good structural design requires connections to be stronger than the members they connect so as to force failure to take place in the ductile members rather than in the relatively brittle connections.

A structural element cannot transmit forces in excess of the capacity of the connections used to join the elements together. Thus, structural members and the elements that connect them should be of approximately equal strength to be fully effective. If there is a weak link, the earthquake will find it. This was the case in the partial collapse of the center of the Hotel del Prado during the 1985 Mexico City earthquake (Figure 21).

The issue of connections is particularly important for structures that rely on a small number of supporting members, such as a roof supported by four columns. If one column or its connection fails, the roof falls. If the same roof is supported by eight columns, the loss of one column may not be serious. Engineers refer to the attribute of having more than the minimum number of structural members as "redundancy." It provides an important additional safety factor.

The large open spaces common in hotels often completely lack redundancy which means that every component must remain operative to ensure the integrity of the structural system under lateral loads. Thus, appropriate connections should be used and consideration should be given to the use of higher performance connections (ductile, in particular).

FIGURE 22
Hotel Camino
Real after
1976 Guatemala
City earthquake.



In a moment resisting frame system, redundancy can be achieved by making all joints of the vertical load-carrying frame moment resisting. Of course, proper ductility must be provided in the members of the structural system. These multiple points of resistance can prevent a catastrophic collapse due to failure of a member or joint. However, if this system is designed with the moment resisting connections limited to exterior columns (a common practice) clad only in lightweight architectural curtain walls, the building may experience large deformations during an earthquake and, consequently, a great deal of interior damage.

The "aesthetic" design of a shear wall system can also cause interesting problems. The use of center shear walls (e.g., around a circulation core) with glass curtain walls for the rest of a hotel's guest areas can result in the shear wall bending and, thus, becoming more of a beam than a shear wall. Where no redundant or reserve system is provided behind this type of framing, performance has not been good.

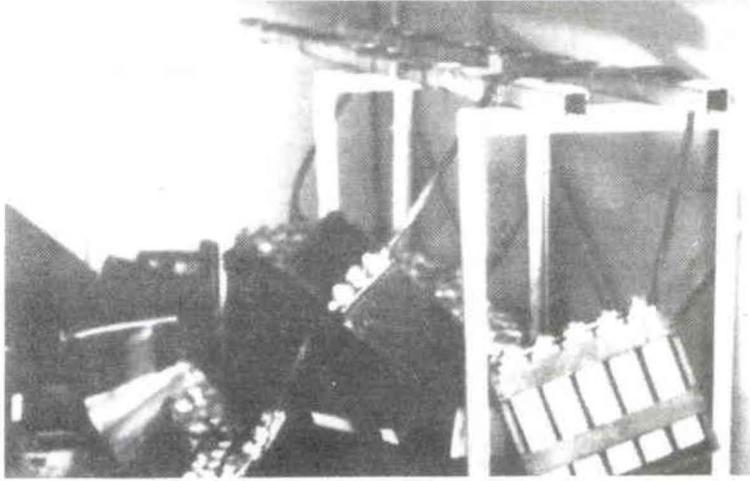
During the 1976 Guatemala earthquake, for example, the Camino Real Hotel survived the earthquake intact; however, its interior was almost completely demolished due to the large displacements the building experienced. Serious property loss also occurred at the Holiday Inn as a result of the 1971 San Fernando earthquake. The Holiday Inn required only \$2,000 in minor structural repairs but there was \$143,000 in nonstructural damage, and this from an earthquake that was considered to cause only limited damage. During the 1985 Mexico City earthquake, merchandise and equipment were thrown about throughout the shops on the ground floor of the Holiday Inn resulting in major replacement costs and disruption of services (Figure 23).

FIGURE 23
Holiday Inn in Ixtapa after 1985 earthquake (EQE, Inc., San Francisco, California).



The nonstructural components with both life safety and major property damage consequences include exterior nonbearing walls, exterior veneers, infill walls, interior partition systems, windows, ceiling systems, elevators, mechanical equipment, and electrical and lighting equipment. All these components are subject to damage, either directly due to shaking or because of movement of the structure (which may be an intentional part of the seismic design). Hotel and motel occupants will be particularly vulnerable to nonstructural damage that effects egress. Light fixtures or glass, ceiling tile and wall finishes that fall on hallways and stairs can make movement difficult, particularly if combined with power failure and loss of lights.

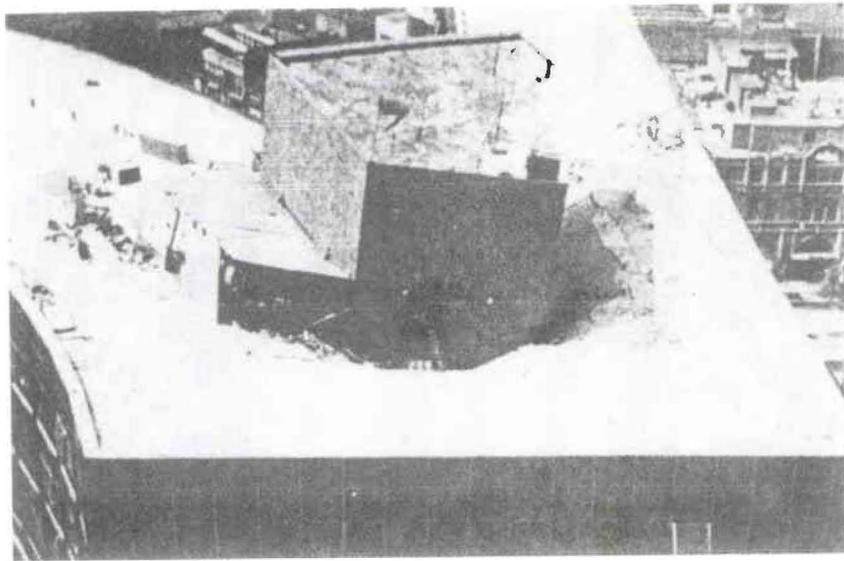
*FIGURE 25
Collapse of
emergency electrical
equipment.*



*FIGURE 26
Collapse of
ceiling/lighting
system.*



FIGURE 28
Hotel Intercontinental
after 1972 earthquake
in Managua.



Elevator damage is a recurring problem during earthquakes (Figures 29), and the large number of elevators in lodging facilities make this an especially costly potential problem. Counterweights can break, bending their guide rails so they swing free causing cable and brake shoes to fall, shearing electric cables and, in some cases, smashing through elevator cabs. Additional damage can occur in the elevator machine room penthouse. The controls and motors can be thrown off their bases cutting supports and the electrical cables. Almost 700 elevators were damaged as a result of the 1971 San Fernando earthquake, and preliminary data indicate that more than 80 elevators suffered damage during the 1989 Loma Prieta earthquake.

Even such nonstructural components as glazing systems can create additional hazards. Although damage patterns for glazing systems have not been well researched, glass breakage is related to support conditions, the temper of the glass and its thickness and size, and the type and direction of loading. Large windows usually break at somewhat lower loads than smaller windows since large windows behave like a membrane or diaphragm. With sufficient space for movement within the frame, a frame that does not rack, low glass loading, and reasonably careful design and placement, good performance can be expected. Glass joint treatment also is a factor in the overall performance of a curtain wall or window unit system; if the edges are restrained, failure is likely. In this context, it also should be remembered that the sealants and gasket materials providing flexibility can lose their resiliency with age and exposure and therefore may require periodic replacement.

**Post-Earthquake
Egress Problems**

Egress complications can be summed up by a statement made in a report on the 1964 Alaska earthquake:

...the final measure of a well constructed building is the safety and comfort it affords its occupants. If, during an earthquake, the occupants must exit through a shower of falling light fixtures and ceilings; maneuver through shifting and toppling furniture; stumble down dark corridors and stairs; and then be met at the street by falling glass, veneers, or facade elements...then the building certainly cannot be described as a safe building.

The problems of egress are most critical in multistory buildings and therefore, tend to apply to larger lodging facilities. With elevators most likely to be inoperative for at least some time, stairs are the critical means of egress out of a multistory hotel or motel during and after an earthquake, but several things can happen to stairwells during an earthquake (Figures 30-31):

- Stairs tend to act as diagonal bracing between floors, and damaging loads and racking induced in them by interstory drift may result in collapse or failure.
- Stairs usually are anchored to the floors and their stiffness tends to attract forces that may cause severe damage or collapse.
- Masonry or concrete fire walls surrounding the stairs can fracture leaving the egress pathway littered with debris that may be impassable.

*FIGURE 30
Stairway failure.*

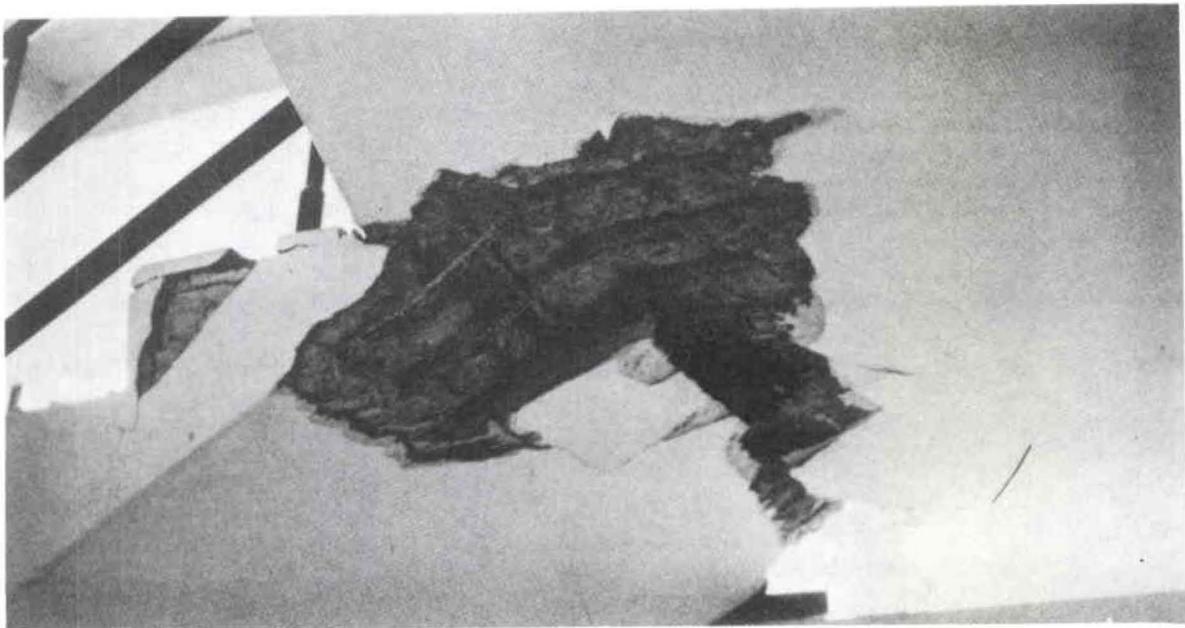


FIGURE 32
Collapsed parking canopy.



**Disruption of
Post-Earthquake
Operations**

Disruption of operations due to property damage often occur after an earthquake. These disruptions may involve partial closing of certain areas of the hotel, limited closing for debris removal or minor repairs to nonstructural components and building equipment, prolonged closing for major repairs, or permanent closing for demolition and replacement.

It is obvious that such disruptions can be very costly and even damage that is not critical (in terms of life safety) can cause an inordinate delay in reopening the hotel and can adversely affect the public's perception of the hotel's problems (e.g., lobby repairs and debris removal can generate a public perception that the building is unsafe and major glass damage can stimulate the perception that the building is both unsafe and uncomfortable).

The experience of the hotels in Ixtapa, Mexico, after the 1985 earthquake illustrate just how disruptive such damage can be (see Appendix A). This Pacific Coast resort town contained 10 modern high-rise hotels when the earthquake occurred. All experienced extensive architectural damage to internal walls, exterior curtain walls, and exterior finishes, but there was little major structural damage. Nevertheless, only one of these hotels was able to remain open continuously after the earthquake (a low-rise multibuilding facility also was able to keep operating because of the number of buildings it had).

4

THE NEHRP RECOMMENDED PROVISIONS AND LODGING FACILITY DESIGN

Achieving Good Seismic Design

In order to achieve good seismic design:

- The design team needs to be both experienced in and supportive of earthquake design, and
- Building owners must require such design as an integral part of the design of their buildings.

Although building owners obviously cannot and do not need to understand all the technical aspects of earthquake design, they should be familiar with the range of strategies and solutions that are available to protect their buildings.

The *NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings*, developed by recognized researchers and practitioners of seismic design and having the consensus approval of the BSSC membership, provides an authoritative set of seismic design concepts and details. The *Provisions* covers the following major topics:

- Earthquake design characteristics,
- Structural design requirements,
- Procedures for analysis of building response to earthquake forces,
- Soil-structure interaction,
- Foundation design requirements,
- Nonstructural component design, and
- Basic materials of construction--wood, steel, reinforced concrete, and masonry.

The discussion that follows is a broad look at the strategies expressed in the *NEHRP Recommended Provisions* that are aimed at providing an acceptable and affordable level of safety for hotels and motels. For a general description of some of the fundamental principles of earthquake effects and seismic design, see the BSSC's *Seismic Considerations for Communities at Risk*; technical issues are explored in the *Provisions* document itself and in the BSSC's *Guide to Use of the Provisions in Earthquake-Resistant Design of Buildings*. All BSSC publications are available free upon request.

The differences in the two maps relate to whether they show effective peak accelerations (which generally are less than the peak or maximum accelerations that may occur) or effective peak velocities (which represent another aspect of ground motion that is mathematically derived from acceleration).

In any specific location, the map showing A_v (effective peak velocity) or A_a (effective peak acceleration) may govern, the choice being primarily related to the size of the building involved. The accelerations shown on both maps range from 5 to 40 percent and are illustrated in the form of contour lines indicating areas of equal acceleration (similar to elevation contours on a topographical map). Figure 33 is a small-scale reproduction of one of these maps. The large-scale maps supplied with the *Provisions* superimpose contours on a background of county lines to clarify jurisdictional issues.

Although based on extensive studies, these maps reflect a number of assumptions. The general criterion is that the risk at any location has only a 10 percent probability of being exceeded in 50 years, which translates into a mean recurrence interval of 475 years. This is a statistical number, however, and unfortunately there is no assurance that at a given location the given ground motion will not occur at any time. Studies are constantly being conducted in an effort to provide more accurate information on this crucial point, and new maps reflecting the results of these studies are being developed.

In order to determine the degree of protection to be provided the building and its occupants, a building is assigned to a Seismic Hazard Exposure Group based on its occupancy or use. The intent is for important buildings--such as hospitals or police stations--and for buildings with large numbers of occupants or where the occupants' mobility is restricted--such as auditoriums, schools, and hotels--to receive a higher standard of seismic protection than other buildings where the seismic hazard is less critical. Thus, every building is assigned to one of three Seismic Hazard Exposure Groups (identified as I, II, and III). Hotels and motels over four stories are assigned to Group II and the rest to Group I.

These two factors, effective peak velocity and Seismic Hazard Exposure Group, lead to identification of the building's Seismic Performance Category, the level of seismic performance to which the building must be designed. This is done using the following table that relates the location's effective peak velocity, A_v , to the building's Seismic Hazard Exposure Group (I-III):

Effective Peak Velocity	Seismic Hazard Exposure Group		
	I	II	III
$0.20 \leq A_v$	D	D	E
$0.15 \leq A_v < 0.20$	C	D	D
$0.10 \leq A_v < 0.15$	C	C	C
$0.05 \leq A_v < 0.10$	B	B	C
$A_v < 0.05$	A	A	A

It can be seen that east of the Rockies, where A_v is nearly always less than 0.20 (Figure 33), hotels and motels will belong to Seismic Performance Category A, B, C, or D (1988 Edition of the *NEHRP Recommended Provisions*). This procedure provides reasonable seismic protection for all buildings and reflects the varying hazards for alternative locations around the country.

Site Geology

The use of the design ground motion shown on the *NEHRP Recommended Provisions* maps is sufficient for most design purposes. For large or important buildings or where significant earthquake activity is suspected, the building owner should require that geological surveys be performed on the building site to evaluate more accurately the level of seismic hazard to be expected.

It is convenient to classify earthquake effects into four distinct categories:

- When faults shift, causing an earthquake, the split in the fault often appears as a crack or vertical step on the earth's surface. Major displacements (movements of up to 21 feet have been recorded) can occur along the fault line. No economical building design can withstand displacements of this magnitude. Nevertheless, many buildings are located and continue to be located astride faults because of lack of fault identification. Where fault locations are accurately mapped, as is the case in California, the building owner should make certain that the building is not located over a fault and geological studies should be undertaken before making the final site decision.
- The second category of earthquake effects involves ground motion. Ground motion does not damage a building by externally applied loads or pressure as in gravity or wind loads, but rather by internally generated inertial forces caused by vibration of the building's mass. The natural tendency of any object to vibrate back and forth at a certain rate (generally expressed in seconds or fractions of a second) is its fundamental or natural period. Low- to mid-rise buildings have periods in the 0.10 to 0.50 second range while taller, more flexible buildings have periods between 1 and 2 seconds or greater. Harder soils and bedrock will efficiently transmit short period vibrations (caused by near earthquakes) while filtering out longer period motions (caused by distant earthquakes) whereas softer soils will transmit longer period vibrations.

As a building vibrates under ground motion, its acceleration will be amplified if the fundamental period of the building coincides with the period of the vibrations being transmitted through the soil. This amplified response is called resonance. Natural periods of soil are usually in the range of 0.5 to 1.0 second so that it is entirely possible for the building and ground to have the same fundamental period and, therefore, for the building to approach a state of resonance. This was the case for many 5- to 15-story buildings in the 1985 earthquake in Mexico City. An obvious design strategy, if one can predict approximately the rate at which the ground will vibrate, is to ensure that buildings have a natural period different from that of the expected ground vibration to avoid amplification.

Following this approach, the *NEHRP Recommended Provisions* identifies three Seismic Hazard Exposure Groups:

- Group III includes those buildings having essential facilities that are necessary for post-earthquake recovery.
- Group II includes those buildings having a large number of occupants and those buildings in which occupants' movements are restricted or their mobility impaired.
- Group I includes all other buildings not included in Groups III and II.

As noted above, hotels and motels are assigned to Group I or II.

Building Configuration

One set of decisions most critical to the ability of a lodging facility building to resist earthquake damage is, as noted earlier, the choice of building configuration: its size, shape, and proportion. Since the shape of the site, functional requirements, and community aesthetic aspirations can present constraints to an optimal configuration for seismic safety, it is important to understand how the building's form affects the building's earthquake performance.

Some of the major issues were outlined in Chapter 3. The basic problem can be expressed by focusing on two conditions that have consistently caused severe damage and collapse:

- The unbalanced plan resistance of the building--Any plan configuration that has a center of rigidity (resistance) that does not approximately coincide with the center of mass (weight) will undergo significant torsional rotation during an earthquake (Figure 34).
- Unbalanced or random rigid resisting elements--Any configuration that concentrates forces on a small number of rigid element(s) of the building risks failure of those elements (Figure 35).

FIGURE 34
Centers of mass and resistance do not coincide causing torsion under earthquake motion.

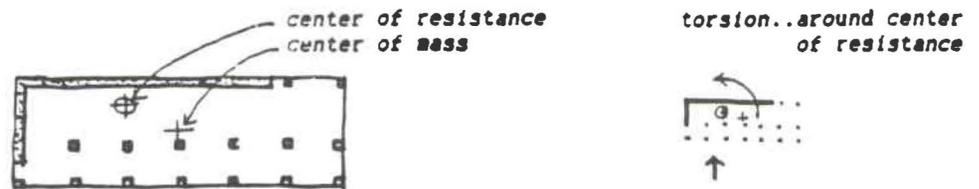
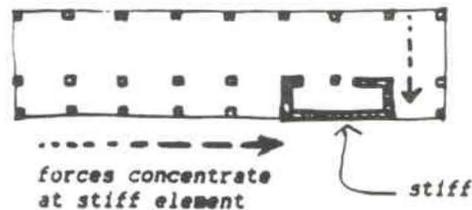


FIGURE 35
Rigid elements in plan will attract earthquake forces.



Structural Systems

Selecting and designing a structural system that will perform well within the range of unknowns of earthquakes is a demanding task:

- The goals for the performance of the structure must be established,
- The geological and site characteristics must be considered,
- An appropriate building form responsive to the needs of the potential users and to earthquake-resistance requirements must be developed,
- A structural system compatible with these needs must be selected and analyzed,
- The structural details must be developed, and
- The structure must be correctly constructed.

This process must be a joint effort between the three main parties involved: the building owner, the architect, and the consulting engineer.

Earthquake lateral loads are resisted by three alternative vertical structural systems: shear walls, braced frames, and moment frames. A fourth system for lateral load resistance, the so-called dual system, is a combination of moment frames and shear walls or braced frames. Horizontal diaphragms (floors and roofs) connect the individual shear walls and frames and assist in transferring the loads to the foundation.

Each of the four vertical structural systems has certain characteristics:

- Moment frames resist earthquake forces by providing strong joints. This system, with its absence of structural walls, provides great interior planning advantages but also can result in a more flexible structure that may contribute to nonstructural and contents damage. Because of the importance of the joints, their construction tends to be expensive.
- Shear wall systems provide very stiff structures. Unless the shear walls can be confined to the exterior envelope and the communication cores, they represent an impediment to the interior planning flexibility provided by the favored open floor spaces of modern buildings.
- Braced frame systems combine some of the features of the two other systems. They provide a more open structure than one based on shear walls, but the braces may be some impediment to interior planning. The system may not be as stiff as a shear wall system, but it can be more economical than a moment frame system.
- In a dual system, a moment frame provides a secondary defense with a higher degree of redundancy and ductility. The prescribed forces are assigned either to the overall system or to the shear walls/braced frames alone. The dual system offers certain advantages in that it provides high stiffness for moderate earthquakes and an excellent second line of defense for major earthquakes.

The performance of poured-in-place reinforced concrete buildings in past earthquakes has ranged from very poor to excellent, depending on the type of structural system and the quality of detailing. Buildings with well designed shear walls can be expected to perform well, particularly if openings are small relative to the wall. In moment resisting frames, detailing has proven to be a critical aspect of performance. Particularly important is adequate confinement of the concrete through the use of spiral or closely spaced stirrup ties (reinforcement), which increases the system's ductility (the ability of the system or material to distort without collapsing). Major problems with reinforced concrete buildings have occurred in frame structures with inadequate ductility where system collapse occurred after some seconds of earthquake motion.

The expected good performance of modern reinforced masonry buildings contrasts with the highly publicized and dramatic failures of older unreinforced masonry buildings. The proper design and construction of walls and the proper connection of walls to floor and roof diaphragms are critical to the successful performance of these materials during an earthquake. Precast concrete elements, whether they are conventionally reinforced or prestressed, have exhibited significant structural failures in earthquakes, primarily because they were not fastened together sufficiently to provide the equivalent of monolithic construction. Since these systems are often used for long spans, issues of redundancy and concentration of stresses must be given serious consideration.

The *NEHRP Recommended Provisions* contains specific seismic design and detailing requirements for wood, steel, reinforced concrete, and reinforced masonry.

Connections

Recognizing the fact that few buildings are designed to resist severe earthquake loads elastically (the ability of the structure to deform, absorb the earthquake energy, and return to its original condition), ductility must be provided whenever the elastic resistance is expected to be exceeded. The need for ductility applies not only to the structural elements but also to the connections between the elements.

Where ductility has not been provided, failures have occurred in connections where the capacity of ductile structural elements was reached or in connections that were too weak to transfer the forces developed in the structural elements. Specifically, connection failures have occurred in inadequately anchored exterior precast panels, between walls and diaphragms, between beams and walls, between columns and beams, and between columns and foundations--indeed, at any location where two or more different structural elements interact in transferring the loads.

It should be possible to follow direct paths for the vertical and horizontal forces all the way through the building to the foundation and for this path to be thoroughly tied together at each intersection. What those responsible for a lodging facility must recognize is that this type of design and detailing process is not normally a consideration when architects and structural engineers design a nonseismic building.

For relatively little cost in the design and construction of a new building (or even in the remodeling of an existing building), considerable potential injury and costly damage (including loss of function) can be avoided. The more common nonstructural elements in hotels and motels that should be given special design attention include:

Appendages	Entrance canopies, overhangs, balconies/roof-mounted mechanical units and signs/roofed walkways
Enclosures	Exterior nonbearing walls/exterior infill walls/veneer attachments/curtain wall system attachments
Partitions	Stairs and shafts/horizontal exits/corridors/fire separation partitions
Ceilings	Fire-rated and non-fire-rated
Doors/Windows	Room-to-hallway doors/fire doors/lobby doors and glazing/windows and curtain walls/atrium spaces and skylights/glass elevator enclosures
Lighting	Light fixtures/emergency lighting
Emergency	Structural fireproofing/emergency electrical system/fire and smoke detection system/fire suppression systems (sprinkler)/smoke removal systems/signage
Mechanical	Large equipment including chillers, heat pumps, boilers, furnaces, fans/smaller equipment including room air conditioning or heating units/cooling towers/tanks, heat exchangers, and pressure vessels/utility and service interfaces/ducts and diffusers/piping distribution systems
Electrical	Communications systems/electrical bus ducts and primary cable systems/electric motor control centers, transformers, and switchgear
Contents	Kitchen and laundry equipment/computers, printers, and copying equipment/filing cabinets and bookcases/stage and curtain equipment/retail merchandise/guest valuables

The *NEHRP Recommended Provisions* establishes minimum design levels for architectural, mechanical, and electrical systems and components that recognize occupancy use, occupant load, need for operational continuity, and the interrelation of these elements. The design strategies presented in Figure 37 and discussed briefly below should be evaluated to determine the correct one for protecting a particular nonstructural system or component given its physical characteristics, location, and importance.

Relocation--Changing the location of a component in order to reduce its vulnerability or threat to occupants (e.g., moving a heavy tank from roof to basement).

Construction Quality

Building failures during earthquakes that are directly traceable to poor quality control during construction are innumerable. The literature is replete with reports pointing out that collapse could have been prevented had proper inspection been exercised to ensure that construction was in accord with building plans and specifications.

Severe building damage and collapse have been caused by poorly executed construction joints in reinforced concrete, undersized welds in steel construction, and the absence of nuts on anchor bolts in timber construction, to name just a few deficiencies. Recognizing that there must be coordinated responsibility during construction, the *NEHRP Recommended Provisions* delineates the role each party is expected to play in construction quality control:

- The building designer is expected to specify the quality assurance requirements,
- The contractor is expected to exercise the control to achieve the desired quality, and
- The owner is expected to monitor the construction through independent special inspection to protect his own as well as the public interest.

It is essential that each party recognize its responsibilities, relationships, and procedures and be capable of carrying them out.

Concluding Note

The *NEHRP Recommended Provisions* is concerned only with those components that are directly affected by earthquake motions and whose response could affect life safety. The requirements are minimum and the lodging facility decision-maker should give consideration to formulating an earthquake quality assurance plan that covers all other components during all phases of construction throughout the project. For lodging facilities, the cost of doing this should be minimal and the potential savings in terms of increased life safety, reduced property damage, and continuing operation both during and after an earthquake could be enormous. Finally, good seismic design also provides better assurance that other types of catastrophic failure (e.g., those caused by explosions or unexpected large storms) will not occur.

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To obtain the information needed to define precisely a location's seismic situation: contact local academic institutions for geologists, geophysicists, and seismologists; state geologists; regional offices of the USGS and FEMA, national earthquake information centers, and state and regional seismic safety organizations.

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**Nonstructural
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in Earthquakes**

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GLOSSARY

General Terms

ACCELERATION The rate of increase in ground velocity as seismic waves travel through the earth. The ground moves backward and forward; acceleration is related to velocity and displacement.

ACCEPTABLE RISK The probability of social or economic consequences due to earthquakes that is low enough (for example, in comparison with other natural or man-made risks) to be judged by appropriate authorities to represent a realistic basis for determining design requirements for engineered structures or for taking certain social or economic actions.

AMPLITUDE The extent of a vibratory movement.

ARCHITECTURAL SYSTEMS Systems such as lighting, cladding, ceilings, partitions, envelope systems, and finishes.

COMPONENT Part of an architectural, electrical, mechanical, or structural system.

CONNECTION A point at which different structural members are joined to each other or to the ground.

DAMAGE Any economic loss or destruction caused by earthquakes.

DEFLECTION The state of being turned aside from a straight line. See drift.

DESIGN EARTHQUAKE In the *NEHRP Recommended Provisions*, the earthquake that produces ground motions at the site under consideration that have a 90 percent probability of not being exceeded in 50 years.

DESIGN EVENT, DESIGN SEISMIC EVENT A specification of one or more earthquake source parameters and of the location of energy release with respect to the site of interest; used for earthquake-resistant design of a structure.

DIAPHRAGM A horizontal or nearly horizontal structural element designed to transmit lateral or seismic forces to the vertical elements of the seismic resisting system.

DRIFT Lateral deflection of a building caused by lateral forces.

DUCTILITY Capability of being drawn out without breaking or fracture. Flexibility is a very close synonym.

FRAME SYSTEM, DUAL A structural system with an essentially complete space frame providing support for vertical loads. A moment resisting frame that is capable of resisting at least 25 percent of the prescribed seismic forces should be provided. The total seismic force resistance is provided by the combination of the moment resisting frame and the shear walls or braced frames in proportion to their relative rigidities.

FRAME SYSTEM, MOMENT RESISTING A structural system with an essentially complete space frame providing support for vertical loads. Seismic force resistance is provided by special, intermediate, or ordinary moment frames capable of resisting the total prescribed seismic forces.

INTENSITY The apparent effect that an earthquake produces at a given location. In the United States, intensity is frequently measured by the Modified Mercalli Index (MMI). The intensity scale most frequently used in Europe is the Rossi-Forell scale. A modification of the Mercalli is used in the Soviet Union. See the following section of this Glossary, "Measures of Earthquake Magnitude and Intensity."

JOINT A point at which plural parts of one structural member are joined to each other into one member.

LIQUEFACTION The conversion of a solid into a liquid by heat, pressure, or violent motion.

LOAD, DEAD The gravity load created by the weight of all permanent structural and nonstructural building components such as walls, floors, roofs, and the operating weight of fixed service equipment.

LOAD, LIVE Moving or movable external loading on a structure. It includes the weight of people, furnishings, equipment, and other things not related to the structure. It does not include wind load, earthquake load, or dead load.

LOSS Any adverse economic or social consequences caused by earthquakes.

MASS A quantity or aggregate of matter. It is the property of a body that is a measure of its inertia taken as a measure of the amount of material it contains that causes a body to have weight.

MERCALLI SCALE Named after Giuseppe Mercalli, an Italian priest and geologist, it is an arbitrary scale of earthquake intensity related to damage produced. See the following section of this Glossary, "Measures of Earthquake Magnitude and Intensity."

PERIOD The elapsed time of a single cycle of a vibratory motion or oscillation.

RESONANCE The amplification of a vibratory movement occurring when the rhythm of an impulse or periodic stimulus coincides with the rhythm of the oscillation (period). For example, when a child on a swing is pushed with the natural frequency of a swing.

TORSION The twisting of a structural member about its longitudinal axis. It is frequently generated by two equal and opposite torques, one at each end.

VALUE AT RISK The potential economic loss (whether insured or not) to all or certain subsets of structures as a result of one or more earthquakes in an area.

VELOCITY The rate of motion. In earthquakes, it is usually calculated in inches per second or centimeters per second.

VULNERABILITY The degree of loss to a given element at risk, or set of such elements, resulting from an earthquake of a given magnitude or intensity, which is usually expressed on a scale of from 0 (no damage) to 10 (total loss).

WALL, BEARING A wall providing support for vertical loads; it may be exterior or interior.

WALL, NONBEARING A wall that does not provide support for vertical loads other than its own weight as permitted by the building code. It may be exterior or interior.

WALL, SHEAR A wall, bearing or nonbearing, designed to resist seismic forces acting in the plane of the wall.

WALL SYSTEM, BEARING A structural system with bearing walls providing support for all or major portions of the vertical loads. Seismic force resistance is provided by shear walls or braced frames.

WAVES A ground motion best described as vibration that is created or generated by a fault rupture. Earthquakes consist of a rapid succession of three wave types: the "P" or primary wave followed by both the "S" or secondary wave and a surface wave.

**Measures of
Earthquake
Magnitude and
Intensity**

The following excerpt from the 1976 thesis, *Seismic Design of a High-Rise Building*, prepared by Jonathan Barnett and John Canatsoulis at the Worcester Polytechnic Institute explains the Richter magnitude scale and the Modified Mercalli Intensity (MMI) scale:

There are two important earthquake parameters of interest to the structural engineer. They are an earthquake's magnitude and its intensity. The intensity is the apparent effect of an earthquake as experienced at a specific location. The magnitude is the amount of energy released by the earthquake. The magnitude is the easiest of these two parameters to measure as, unlike the intensity which can vary with location, the magnitude of a particular earthquake is constant. The most widely used scale to measure magnitude is the Richter magnitude scale. Using this scale, the magnitude, measured in ergs, can be found from the equation $\text{Log } E = 11.4 + 1.5 M$, where M is the Richter magnitude.

- VII. Difficult to stand. Noticed by drivers. Hanging objects quiver. Furniture broken. Damage to Masonry D, including cracks. Weak chimneys broken at roof line. Fall of plaster, loose bricks, stones, tiles, cornices also unbraced parapets and architectural ornaments. Some cracks in Masonry C. Waves on ponds, water turbid with mud. Small slides and caving in along sand or gravel banks. Large bells ring. Concrete irrigation ditches damaged.
- VIII. Steering of cars affected. Damage to Masonry C; partial collapse. Some damage to Masonry B; none to Masonry A. Fall of stucco and some masonry walls. Twisting, fall of chimneys, factory stacks, monuments, towers, elevated tanks. Frame houses moved on foundations if not bolted down; loose panel walls thrown out. Decayed piling broken off. Branches broken from trees. Changes in flow or temperature of springs and wells. Cracks in wet ground and on steep slopes.
- IX. General panic. Masonry D destroyed; Masonry C heavily damaged, sometimes with complete collapse; Masonry B seriously damaged. General damage to foundations. Frame structures, if not bolted down, shifted off foundations. Frames racked. Serious damage to reservoirs. Underground pipes broken. Conspicuous cracks in the ground. In alluviated areas, sand and mud ejected, earthquake fountains and sand craters.
- X. Most masonry and frame structures destroyed with their foundations. Some well-built wooden structures and bridges destroyed. Serious damage to dams, dikes, embankments. Large landslides. Water thrown on banks of canals, rivers, lakes, etc. Sand and mud shifted horizontally on beaches and flat land. Rails bent slightly.
- XI. Rails bent greatly. Underground pipelines completely out of service.
- XII. Damage nearly total. Large rock masses displaced. Lines of sight and level distorted. Objects thrown in the air.

Masonry definitions, from C. F. Richter's 1958 book, *Elementary Seismology* (W. H. Freeman and Company, San Francisco, California), are as follows: Masonry A--good workmanship, mortar, and design; reinforced, especially laterally; bound together by using steel, concrete, etc.; designed to resist lateral forces. Masonry B--Good workmanship and mortar; reinforced but not designed in detail to resist lateral forces. Masonry C--Ordinary workmanship and mortar; no extreme weaknesses like failing to tie in at corners but not reinforced or designed against horizontal forces. Masonry D--Weak materials such as adobe, poor mortar, low standards of workmanship; weak horizontally.

APPENDIX A

EARTHQUAKE EXPERIENCES OF LODGING FACILITIES

The Problem

Hotel and motel owners are presented with earthquake risks involving possible life loss and injury, property damage, and disruption of their operations. The experiences of hotels and motels in the 1985 Mexico City earthquake and the 1986 El Salvador earthquake, illustrate the potential problems.

1985 Mexico City Earthquake

An earthquake of magnitude 8.1 occurred in the state of Michoacan, Mexico, in September, 1985. Extensive damage occurred in concentrated areas of Mexico City where hundreds of multistory buildings collapsed, thousands were damaged, and several thousand lives were lost (estimates range between 5,000 and 20,000). Several hotels either collapsed or experienced major damage while others suffered no damage, leading one to understand the difference between good seismic design and poor design.

In order to review the performance of hotels on a broad scale, however, it is interesting to explore what occurred in the Pacific coast resort town of Ixtapa, which contained 10 new high-rise hotels when the earthquake occurred. Because Ixtapa is located in one of the major areas of seismic activity in Mexico, the hotels were designed to the most current building codes based on earthquake provisions developed in the United States. Although no major structural damage was reported, most of the hotels were closed for repairs. Because the earthquake occurred during off-season, occupancy levels were low and there was enough time to repair most of the damage before the new season began, thereby avoiding a major economic disaster as a result of relatively minor damage.

Hotel Riviera del Sol is a 480-room, 9-story hotel of three-towers built in 1975. During the 1985 earthquake, it experienced major cracking in exterior infill panels and interior walls, and some damage and disruption to the mechanical/electrical system (Figures A-1).

Hotel El Presidente is a 12-story hotel of 453 rooms built in 1980. During the earthquake, it experienced major cracking of the exterior panel system, interior walls, lobby floor, and structural connections (Figure A-2). The hotel was closed for 75 days for repairs.

Club Mediterranee is a three story horizontal beach hotel of 350 rooms. It closed for 60 days for repairs to the walls and interior furnishings (Figure A-3).

FIGURE A-2
Hotel El Presidenta-
Ixtapa.

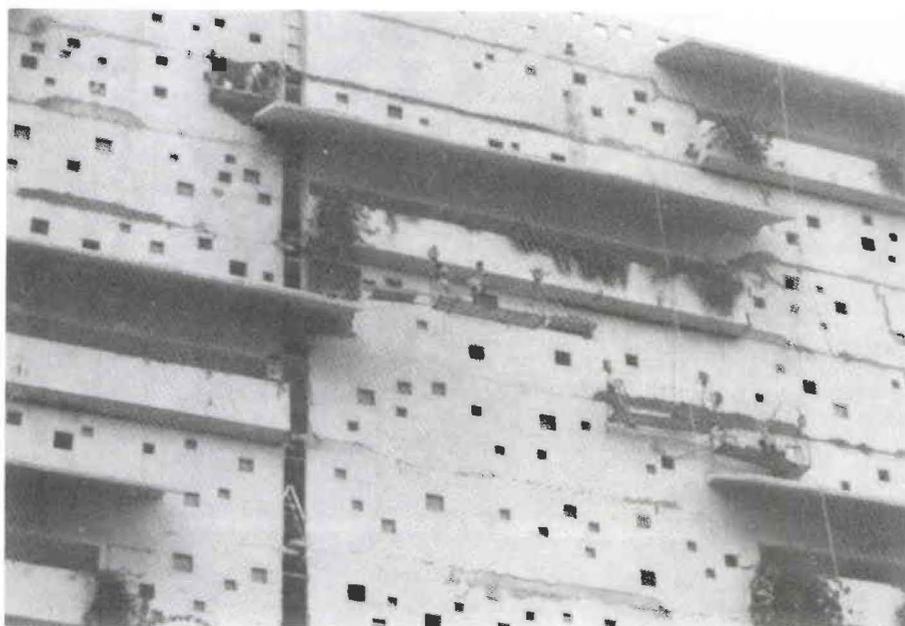


FIGURE A-3
Club Mediterranee-
Ixtapa.



**1986 El Salvador
Earthquake**

In October 1986, a 7.5 magnitude earthquake occurred in San Salvador, El Salvador. The center of the city experienced severe damage causing more than 1,000 deaths and many collapsed buildings. Among the damaged buildings were the Gran Hotel San Salvador with 11 dead and serious damage and the El Salvador Sheraton with no deaths but considerable damage.

The earthquake experience of the El Salvador Sheraton was witnessed by Eberhardt H. Rues, the General Manager of the hotel. In his words:

The concept of acceptable damage can involve monetary loss, however the loss of human lives is, in general, not acceptable. The responsibility of a Hotelier to prevent fatal accidents and to minimize all risks in terms of life safety, equipment, the facility and the business, is enormous. The earthquake resistant design of the structure and facilities of a hotel, located in a seismic risk area, has to provide within human possibilities, the utmost protection and safety of its guests and employees.

Any loss, especially of human lives, will turn into multiple negative results: loss of prestige, image, profit, business, credibility and confidence. If the hotel happens to belong to an international chain, the same losses consequently can affect the other properties.

I have experienced various types of catastrophes in hotels including those taking human lives and those causing great economic losses including fires and inundation. However, the October 10th earthquake was by far, the saddest and most catastrophic experience I have witnessed in my over 30 years of hotel experience.

As a Hotelier, security and safety play an important role. It goes along with social responsibility, to care for people and to prevent accidents and provide utmost security to the guests and employees. In view of the potential loss of lives and possible great economic losses that earthquakes can cause, it is important the Hoteliers, Hotel Owners, Hotel Management Companies, Engineers and Architects make the necessary efforts to mitigate the hazards of earthquakes, by developing safe and economical methods of earthquake resistant design and construction for hotels.

It is my personal opinion (after some serious study and research), that only a miracle saved the hotel during the earthquake of October 10. Fortunately there were no losses of human lives, however, the main part of the hotel with 213 rooms did suffer considerable damage to the structure. It is my assumption that if the earthquake had lasted a few more seconds, the hotel probably would have collapsed. Luckily the hotel did not collapse, however the damage caused the closing of the entire operation of the main building after the earthquake. The emotional and human impact of the earthquake had caused a tremendous impression on me and I was deeply affected. However, my personal feelings had to be kept completely apart, because the main problem was how to repair the damaged structure and how to avoid any further loss of business.

Appendix B

SEISMICITY OF THE UNITED STATES

Introduction

The U.S. Geological Survey (USGS) conducts the major national effort in earthquake-related studies in seismology, geology, and geophysics. At present, the USGS has identified nine areas in the United States as priority study areas:

- The Wasatch Front of Utah
- Puget Sound, Washington
- Anchorage, Alaska
- Southern California
- Northern California
- The central Mississippi Valley
- Charleston, South Carolina
- The northeastern United States including Massachusetts and New York
- Puerto Rico

A considerable amount of data on the earthquake hazard in these areas is available from the USGS and ongoing studies are continually adding to the store of information. Studies of seismicity provide answers to the questions where, how big, how often, and why earthquakes occur.

The remainder of this appendix features information on U.S. seismicity produced by S. T. Algermissen of the U.S. Geological Survey in 1983 and presented in a 1987 paper by Walter W. Hays of the U.S. Geological Survey, Reston, Virginia (the paper appears in its entirety in Volume 6 of *Abatement of Seismic Hazards to Lifelines: Proceedings of a Workshop on Development of an Action Plan* (FEMA Earthquake Hazard Reduction Series No. 31).

This seismicity information is presented to alert the reader to the national nature of the seismic hazard. Detailed information about specific areas can be obtained from geologists, geophysicists, and seismologists affiliated with area academic institutions; the regional offices of the USGS and FEMA; the national earthquake information centers; and state and regional seismic safety organizations.

Terminology

The Modified Mercalli intensity, MMI, scale is used in the seismicity information presented here as the reference when instrumental data to define Richter and surface wave magnitudes were unavailable. Refer to the Glossary for a brief explanation of these terms.

**Southeast
Region**

The southeastern United States is an area of diffuse, low-level seismicity. It has not experienced an earthquake having an MMI of VIII or greater in nearly 80 years. The largest and most destructive earthquake in the region was the 1886 Charleston earthquake which caused 60 deaths and widespread damage to buildings. It had an epicentral intensity of X and a magnitude (M_S) of approximately 7.7 (Bollinger, 1977). The distribution (number) of earthquakes with respect to MMI through 1976 in the southeast region is as follows: V = 133, VI = 70, VII = 10, VIII = 2, IX = 0, X = 1. Important earthquakes of the southeast region include:

Date	Location	Maximum MMI (I_0)	Magnitude (Approx. M_S)
Feb. 21, 1774	Eastern VA	VII	
Feb. 10, 1874	McDowell County, NC	V-VII	
Dec. 22, 1875	Arvon, VA area	VII	
Aug. 31, 1886	Near Charleston, SC	X	7.7
Oct. 22, 1886	Near Charleston, SC	VII	
May 31, 1897	Giles County, VA	VIII	6.3
Jan. 27, 1905	Gadsden, AL	VII-VIII	
June 12, 1912	Summerville, SC	VI-VII	
Jan. 1, 1913	Union County, SC	VII-VIII	5.7-6.3
Mar. 28, 1913	Near Knoxville, TN	VII	
Feb. 21, 1916	Near Asheville, NC	VI-VII	
Oct. 18, 1916	Northeastern AL	VII	
July 8, 1926	Mitchell County, NC	VI-VII	
Nov. 2, 1928	Western NC		

**Western
Mountain
Region**

A number of important earthquakes have occurred in the western mountain region. These include earthquakes in the Yellowstone Park-Hebgen Lake area in western Montana, in the vicinity of the Utah-Idaho border, and sporadically along the Wasatch front in Utah. The largest earthquake in the western mountain region in historic times was the 1959 Yellowstone Park-Hebgen Lake earthquake which had a magnitude (M_S) that is now believed to be in excess of 7.3. The strongest earthquake in 24 years occurred at Borah Peak in Idaho in October 1983; it had a magnitude of 7.3. The distribution (number) of historic earthquakes with respect to MMI in the western mountain region is as follows: V = 474, VI = 149, VII = 26, VIII = 22, IX = 0, X = 1. The important earthquakes of the western mountain region include:

Date	Location	Maximum MMI (I_0)	Magnitude (Approx. M_S)
Nov. 9, 1852	Near Ft. Yuma, AZ	VIII?	
Nov. 10, 1884	Utah-Idaho border	VIII	
Nov. 14, 1901	About 50 km east of Milford, UT	VIII	
Nov. 17, 1902	Pine Valley, UT	VIII	
July 16, 1906	Socorro, NM	VIII	
Sept. 24, 1910	Northeast AZ	VIII	
Aug. 18, 1912	Near Williams, AZ	VIII	
Sept. 29, 1921	Elsinore, UT	VIII	
Sept. 30, 1921	Elsinore, UT	VIII	
June 28, 1925	Near Helena, MT	VIII	6.7
March 12, 1934	Hansel Valley, UT	VIII	6.6
March 12, 1934	Hansel Valley, UT	VIII	6.0
Oct. 19, 1935	Near Helena, MT	VIII	6.2
Oct. 31, 1935	Near Helena, MT (Aftershock)	VIII	6.0
Nov. 23, 1947	Southwest MT	VIII	
Aug. 18, 1959	West Yellowstone- Hebgen Lake	X	7.1
Aug. 18, 1959	West Yellowstone- Hebgen Lake (Aftershock)	VI	6.5
Aug. 18, 1959	West Yellowstone- Hebgen Lake (Aftershock)	VI	6.0
Aug. 18, 1959	West Yellowstone- Hebgen Lake	VI	6.5
Mar. 28, 1975	Pocatello Valley, ID	VIII	6.1
June 30, 1975	Yellowstone National Park	VIII	6.4
Oct. 28 1983	Borah Peak, ID	VII est.	7.3

**Washington
and Oregon
Region**

The Washington and Oregon region is characterized by a low to moderate level of seismicity in spite of the active volcanism of the Cascade range. With the exception of plate interaction between the North American and Pacific tectonic plates, there is no clear relationship between seismicity and geologic structure. From the list of important earthquakes that occurred in the region, the two most recent damaging earthquakes in the Puget Sound area ($M_S = 6.5$ in 1965, $M_S = 7.1$ in 1949) occurred at a depth of 60 to 70 km. Currently, speculation is occurring over whether a great earthquake can occur as a consequence of the interaction of the Juan de Fuca and the North American tectonic plates. The distribution of earthquakes in the Washington and Oregon region is as follows: V = 1,263, VI = 487, VII = 170, VIII-IX = 2, IX = 8, IX-X = 3. The important earthquakes of Washington and Oregon include:

Date	Location	Maximum MMI (I_0)	Magnitude (Approx. M_S)
Dec. 14, 1872	Near Lake Chelan, WA (probably shallow depth of focus)	IX	7.0
Oct. 12, 1877	Cascade Mountains, OR	VIII	
Mar. 7, 1893	Umatilla, OR	VII	
Mar. 17, 1904	About 60 km NW of Seattle	VII	
Jan. 11, 1909	North of Seattle, near Washington/British Columbia border	VII	
Dec. 6, 1918	Vancouver Island, B.C.	VIII	7.0
Jan. 24, 1920	Straits of Georgia	VII	
July 16, 1936	Northern OR, near Freewater	VII	5.7
Nov. 13, 1939	NW of Olympia (depth of focus about 40 km)	VII	5.8
Apr. 29, 1945	About 50 km SE of Seattle	VII	
Feb. 15, 1946	About 35 km NNE of Tacoma (depth of focus 40-60 km)	VII	6.3
June 23, 1946	Vancouver Island	VIII	7.2
Apr. 13, 1949	Between Olympia and Tacoma (depth of focus about 70 km)	VIII	7.1
Apr. 29, 1965	Between Tacoma and Seattle (depth of focus about 59 km)	VIII	6.5

**Hawaiian
Islands
Region**

The seismicity in the Hawaiian Islands is related to the well known volcanic activity and is primarily associated with the island of Hawaii. Although the seismicity has been recorded for only about 100 years, a number of important earthquakes have occurred since 1868. Tsunamis from local as well as distant earthquakes have impacted the islands, some having wave heights of as much as 15 meters (55 feet). The distribution of earthquakes in terms of maximum MMI is as follows: V = 56, VI = 9, VII = 9, VIII = 3, IX = 1, X = 1. The important earthquakes causing significant damage in Hawaii include:

Date	Location	Maximum MMI (I_0)	Magnitude (Approx. M_S)
Apr. 2, 1868	Near south coast of Hawaii	X	
Nov. 2, 1918	Mauna Loa, HI	VII	
Sept. 14, 1919	Kilauea, HI	VII	
Sept. 25, 1929	Kona, HI	VII	
Sept. 28, 1929	Hilo, HI	VII	
Oct. 5, 1929	Honualoa, HI	VII	6.5
Jan. 22, 1938	North of Maui	VIII	6.7
Sept. 25, 1941	Mauna Loa, HI	VII	6.0
Apr. 22, 1951	Kilauea, HI	VII	6.5
Aug. 21, 1951	Kona, HI	IX	6.9
Mar. 30, 1954	Near Kalapana, HI	VII	6.5
Mar. 27, 1955	Kilauea, HI	VII	
Apr. 26, 1973	Near northeast coast of Hawaii	VIII	6.3
Nov. 29, 1975	Near northeast coast of Hawaii	VIII	7.2
Nov. 16, 1983	Near Mauna Loa, HI		6.6

THE BSSC PROGRAM ON IMPROVED SEISMIC SAFETY PROVISIONS

Purpose of the Council

The Building Seismic Safety Council (BSSC) was established in 1979 under the auspices of the National Institute of Building Sciences as an entirely new type of instrument for dealing with the complex regulatory, technical, social, and economic issues involved in developing and promulgating building earthquake hazard mitigation regulatory provisions that are national in scope. By bringing together in the BSSC all of the needed expertise and all relevant public and private interests, it was believed that issues related to the seismic safety of the built environment could be resolved and jurisdictional problems overcome through authoritative guidance and assistance backed by a broad consensus.

The BSSC is an independent, voluntary membership body representing a wide variety of building community interests. Its fundamental purpose is to enhance public safety by providing a national forum that fosters improved seismic safety provisions for use by the building community in the planning, design, construction, regulation, and utilization of buildings.

To fulfill its purpose, the BSSC:

- Promotes the development of seismic safety provisions suitable for use throughout the United States;
- Recommends, encourages, and promotes the adoption of appropriate seismic safety provisions in voluntary standards and model codes;
- Assesses progress in the implementation of such provisions by federal, state, and local regulatory and construction agencies;
- Identifies opportunities for improving seismic safety regulations and practices and encourages public and private organizations to effect such improvements;
- Promotes the development of training and educational courses and materials for use by design professionals, builders, building regulatory officials, elected officials, industry representatives, other members of the building community, and the public;
- Advises government bodies on their programs of research, development, and implementation; and
- Periodically reviews and evaluates research findings, practices, and experience and makes recommendations for incorporation into seismic design practices.

Its purpose was to "...present, in one comprehensive document, the current state of knowledge in the fields of engineering seismology and engineering practice as it pertains to seismic design and construction of buildings." The document included many innovations, however, and the ATC acknowledged that a careful assessment was needed.

Following the issuance of the *Tentative Provisions* in 1978, NBS released a technical note on the document calling for "...systematic analysis of the logic and internal consistency of [the *Tentative Provisions*]" and developed a plan for assessing and implementing seismic design provisions for buildings as its final submission to NSF. This plan called for a thorough review of the *Tentative Provisions* by all interested organizations; the conduct of trial designs to establish the technical validity of the new provisions and to predict their economic impact; the establishment of a mechanism to encourage consideration and adoption of the new provisions by organizations promulgating national standards and model codes; and educational, technical, and administrative assistance to facilitate implementation and enforcement.

During this same period, other events significant for this effort were taking place. In October 1977, Congress passed the *Earthquake Hazards Reduction Act* (P.L. 95-124) and the National Earthquake Hazards Reduction Program (NEHRP) was released by the Administration on June 22, 1978. The concept of an independent agency to coordinate all emergency management functions at the federal level also was under discussion. When this concept was effected and FEMA was created, FEMA became the implementing agency with NSF retaining its research-support role. Thus, the future disposition of the *Tentative Provisions* and the 1978 NBS plan shifted from NSF to FEMA.

The emergence of FEMA as the agency responsible for implementation of P.L. 95-124 (as amended) and the NEHRP also required establishment of a mechanism for obtaining a broad public and private consensus on both recommended improved building design and construction regulatory provisions and the means to be used in their promulgation. Following a series of meetings between representatives of the original participants in the NSF-sponsored project on seismic design provisions, FEMA, the American Society of Civil Engineers and the National Institute of Building Sciences (NIBS), the concept of the Building Seismic Safety Council was born. As the concept began to take form, progressively wider public and private participation was sought, culminating in early 1979 with a broadly representative organizing meeting at which a charter and organizational rules and procedures were thoroughly debated and agreed upon.

The BSSC provided the mechanism--in essence the forum--needed to encourage consideration and adoption of the new provisions by the relevant organizations. A joint BSSC-NBS committee was formed to conduct the needed review of the *Tentative Provisions*, which resulted in 198 recommendations for changes.

In this context, basic structural designs (complete enough to assess the cost of the structural portion of the building), partial structural designs (special studies to test specific parameters, provisions, or objectives), partial nonstructural designs (complete enough to assess the cost of the nonstructural portion of the building), and design/construction cost estimates were developed.

This phase of the BSSC program concluded with publication of:

- A draft version of the recommended provisions, *The NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings*;
- An overview of the provisions refinement and trial design efforts; and
- The design firms' reports.

The draft provisions reflected the initial amendments to the original ATC document as well as further refinements made by the Overview Committee. They represented an interim set of provisions pending their balloting by the BSSC member organizations, which began in July 1984.

The first ballot was conducted in accordance with the BSSC Charter and was organized on a chapter-by-chapter basis. The ballot provided for four responses: "yes," "yes with reservations," "no," and "abstain." All "yes with reservations" and "no" votes were to be accompanied by an explanation of the reasons for the vote and the "no" votes were to be accompanied by specific suggestions for change if those changes would change the negative vote to an affirmative.

All comments and explanations received with "yes with reservation" and "no" votes were compiled, and proposals for dealing with them were developed for consideration by the Overview Committee and, subsequently, the BSSC Board of Direction. The draft provisions then were revised to reflect the changes deemed appropriate by the BSSC Board and the revision was submitted to the BSSC membership for balloting again in August 1985.

As a result of this second ballot, virtually the entire provisions document received consensus approval, and a special BSSC Council meeting was held in November 1985 to resolve as many of the remaining differences as possible. The 1985 Edition of the *NEHRP Recommended Provisions* then was transmitted to FEMA for publication in December 1985.

The BSSC's information dissemination efforts also provide for conduct of seismic mitigation demonstration projects. The goal of these activities is to enrich the ongoing information dissemination efforts by providing tangible examples of the willingness and ability of various political jurisdictions in targeted geographic areas to consider, adopt, and implement the *NEHRP Recommended Provisions*. The first such project, being conducted by The Citadel in Charleston, South Carolina, involves development, by the U.S. Geological Survey, of a site-specific seismic risk map of the area; formulation of a set of provisions for the most common types of buildings being and expected to be constructed in the area on the basis of the *NEHRP Recommended Provisions*; and use of the resources assembled to date by the BSSC and other seismic mitigation materials in a way that targets the specific needs of the community and stimulates action on the part of influential segments of that community. In September 1989, the BSSC received funding from FEMA to initiate a second demonstration project aimed at demonstrating the usability, practicability, and technical validity of the procedure in the "Appendix to Chapter 1" of the 1988 Edition of the *NEHRP Recommended Provisions* and to document the economic impact of its utilization.

Although it is difficult to determine precisely how effective these various efforts have been, the number of BSSC publications distributed certainly provides at least one measure of the level of interest generated. In this respect, the BSSC can report that more than 30,000 publication requests were filled between December 1987 and April 1990, and this number is above and beyond those requests for BSSC documents directed to FEMA.

The need for continuing revision of the *Provisions* had been anticipated since the onset of the BSSC program and the effort to update the 1985 Edition for re-issuance in 1988 began in January 1986. During the update effort, nine BSSC Technical Committees were formed to focus on seismic risk maps, structural design, foundations, concrete, masonry, steel, wood, architectural/mechanical/electrical systems, and regulatory use. The Technical Committees (TCs) worked under the general direction of a Technical Management Committee (TMC), which was composed of a representative of each TC as well as additional members identified by the Board to provide balance. It served as the effort coordinator and was charged to deal with global issues; to provide the continuing liaison between the TCs and the BSSC Board of Direction; to consider and respond to all comments and negative votes received as a result of the balloting for the 1988 Edition; and to prepare recommendations for resolving issues raised as a result of the balloting.

The TCs were composed of individuals nominated by organizations deemed by the BSSC Board to have both an interest and expertise in the various subjects to be addressed. When additional technical expertise was deemed necessary, the Board made additional appointments. Basically, the TCs were charged to consider new developments (e.g., newly issued standards) and experience data that had become available (e.g., as a result of the 1985 Mexico City earthquake) since issuance of the 1985 Edition of the *Provisions* as well as issues left unresolved when the 1985 Edition was published.

**Improving the
Seismic Safety of
Existing Buildings**

In October 1989, with funding from FEMA, the BSSC initiated a project to provide consensus-backed approval of publications on seismic hazard evaluation and strengthening techniques for existing buildings. This effort involves:

- Identifying and resolving major technical issues in ATC-22, *Handbook for Seismic Evaluation of Existing Buildings*, and a supporting engineering report on methodologies for the seismic evaluation of existing hazardous buildings prepared by the Applied Technology Council (ATC) and in *Techniques for Seismically Rehabilitating Existing Buildings (Preliminary)*, a report on procedures for seismically retrofitting existing buildings prepared by URS/John A. Blume and Associates, Engineers (URS/Blume);
- Revising the three documents as necessary for balloting by the BSSC membership;
- Balloting the three documents in accordance with the BSSC Charter;
- Assessing the ballot results, developing proposals to resolve the issues raised, and identifying any unresolvable issues; and
- Preparing copies of the documents that reflect the results of the balloting and a summary of changes made and unresolved issues.

Basically, the consensus project is being directed by the BSSC Board and a 22-member Retrofit of Existing Buildings (REB) Committee composed of individuals representing the needed disciplines and geographical areas and possessing special expertise in the seismic rehabilitation of existing buildings. Drafts of the subject documents were received in April 1989. By April 1990, the Retrofit of Existing Buildings Committee had met three times, each committee member had conducted a detailed review of the subject documents, and subcommittees had been established to address all the comments received as a result of this review. Once committee consensus on needed changes is achieved, the modified documents will be submitted to the BSSC membership for balloting.

Earlier, the BSSC was involved in a joint venture with the ATC and the Earthquake Engineering Research Institute to develop an action plan for reducing earthquake hazards to existing buildings and it was this action plan that prompted FEMA to fund development of the ATC and URS/Blume documents.

Following the workshop, the various participants further contributed to the agenda being developed by the panel or group to which they had been assigned and all the agendas were submitted to the BSSC Action Plan Committee in early 1987. They then were reviewed and refined and the final action plan document for FEMA was drafted and distributed once again to all workshop participants for comment. The final action plan report then was developed and transmitted to FEMA in May 1987. The workshop proceedings were published in six volumes--one covering each of the five lifeline categories and one covering political, social, economic, legal, and regulatory issues and including the general workshop presentations.

In recognition of both the complexity and importance of lifelines and their susceptibility to disruption as a result of earthquakes and other natural hazards (hurricanes, tornadoes, flooding), FEMA subsequently concluded that the lifeline problem could best be approached through a nationally coordinated and structured program aimed at abating the risk to lifelines from earthquakes as well as other natural hazards. Thus, in 1988 FEMA asked the BSSC's parent institution, the National Institute of Buildings Sciences, to provide expert recommendations concerning appropriate and effective strategies and approaches to use in implementing such a program. The effort, conducted for NIBS by an ad hoc Panel on Lifelines with the assistance of the BSSC, resulted in a report recommending that the federal government, working through FEMA, structure a nationally coordinated, comprehensive program for mitigating the risk to lifelines from seismic and other natural hazards that focuses on awareness and education, vulnerability assessment, design criteria and standards, regulatory policy, and continuing guidance. Identified were a number of specific actions that should be taken during the next three to six years to initiate the program.

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