HAZARD REDUCTION THROUGH EARTHQUAKE RESISTANT DESIGN

by

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SYNOPSIS

Acceptable levels of Earthquake Hazard Reduction are most difficult to establish for life and safety. Much of the modern construction practices have not been tested by a great earthquake. However, recent earthquakes, and particularly the San Fernando Earthquake, have provided substantial evidence that there is a vital need for revisions in earthquake resistant design standards of building codes.

Hazard reduction is also most important if the insurance industry is to maintain and broaden protection for properties at affordable rates. A great deal can be accomplished through the joint efforts of the industry, engineers and scientists in quickly implementing recognized improved design standards which will reduce hazards to life, safety and financial loss.

INTRODUCTION

Through the years, there has been considerable question about an acceptable level of risk for the earthquake hazard as related to public safety and financial loss. For other hazardous risk exposures, the insurance industry has made major contributions in establishing acceptable levels for life, safety and economic loss through the development of standards for health, accident and fire prevention. The industry must and will assume a more active role in establishing and securing acceptance of standards for earthquake hazard reduction.

Because there is no precise means for predicting the time, place, and size of a future earthquake, determination of hazard is difficult. Seismologists are able to provide data for certain parts of the world indicating an eminent potential for major earthquakes. The coastal region of California, U.S.A., which will be referred to at considerable length, is an area with a high potential. Although there is extensive monitoring of seismic activity in the Los Angeles and San Francisco metropolitan areas, there is no precise means for determining the earthquake hazard as related to public safety and financial loss.

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Once it is acknowledged that the catastrophic nature of an earthquake cannot be determined, it becomes obvious that the best means for attaining acceptable levels of risk is by placing greater emphasis on hazard reduction.

In order to avoid misunderstanding of the terminology "hazard reduction," it must be defined as it relates to the subject. The word "hazard" has a number of applications; however, for our purposes Webster's definition, "Risk of loss or harm; peril, jeopardy" provides the meaning best suited. Our first concern is the degree of harm caused to individuals, be it death or physical injury, and finally the degree of financial loss from damage to structures. One must recognize that without adequate adherence to hazard reduction the entire welfare of a community or numerous communities may be placed in jeopardy or peril.

The word "reduction" pertains to bringing the hazard down to a lower level. In determining acceptable levels of hazard, seismic activity, population density, and economic welfare of the area must be considered. For example, in California, which has a severe seismic exposure with a number of densely populated centers, earthquake resistant design standards for adequate hazard reduction may have to be higher than required for many other parts of the world.

In analyzing the earthquake hazard, it quickly becomes obvious that structures are the primary risk to life, safety and financial loss. Therefore, meaningful progress in hazard reduction is dependent on the earthquake resistant design standards for structures. Acceptance of this assumption leads to the next question, which is how adequate are the building codes for design criteria.

During the past decade, there have been several earthquakes which have made it obvious that building codes do not provide adequately for the stresses to which a structure may be subjected. The first evidence of such deficiencies in existing codes was observed in damage patterns resulting from the 1964 Alaskan Earthquake. The 1967 Caracas Earthquake also indicated serious problems in design criteria. Although there had been some question whether deficiencies existed for structures in California, these doubts were eliminated to a great extent by the 1971 San Fernando Earthquake.

There have been a number of reports since the San Fernando Earthquake attesting to the need for code changes. In one study it was pointed out that earthquake forces in the heaviest shaken area of the San Fernando Valley far exceeded building code earthquake design parameters and were considerably beyond those anticipated by engineers and scientists. Further, modern earthquake resistive structures collapsed or were severely damaged. Steinbrugge, et al, August 1971 (Ref. 1 Summary vii)

Highrise buildings vibrated as expected, and calculations of response to recorded ground motion were in agreement with recorded response. However, it must be acknowledged that the structures were not in the area of heaviest shaking, so they were not tested to their ultimate strength. Further, at the location of some structures, ground accelerations were strong enough to produce amplitudes of shaking that caused stresses that approached yield points, although the structures were not near the point of failure. Also, peak accelerations at the tops of many highrise structures were in the range of 20%g. to 40%g., which exceeded the design accelerations provided for in the code. Housner, June 1971 (Ref. 2, p. 38).

The National Bureau of Standards, Dec. 1971 (Ref. 4, p. 403-404) made a comprehensive study of damage patterns for a substantial cross section of various types of construction and fully supported the conclusions of other reports that there was a vital need for changes in building codes. Based on their findings and evaluations of the existing seismic code requirements, they made recommendations for code revisions and land use for all seismic prone areas of the United States and stated: "An immediate review should be made of the adequacy of present design requirements for seismic design."

LIFE AND SAFETY

Based on studies made of recent earthquakes, particularly the San Fernando, a tremendous amount of data has become available facilitating the development of improved earthquake resistant design criteria and techniques. However, this knowledge will have little value if it is not used and positive action taken in securing greater Hazard Reduction for life, safety and economic welfare of society. Our first concern, of course, has to be attainment of acceptable levels of risk for life and safety of the individual. Obviously, there is much to be accomplished and time is short; therefore, major efforts must be directed to areas where the greatest hazard to society exists.

Dwellings - 1 to 4-Families

In considering structures that involve the greatest number of individuals, habitational properties are most important because they involve the greatest number of people at any time of day. Fortunately, the majority of United States citizens live in one to four-family frame dwellings. Seismic history has indicated that such structures perform exceptionally well requiring a minimum of earthquake resistant design. It is felt that the San Fernando Earthquake produced some credible figures as respects the risk level for frame residences. As pointed out by Steinbrugge-Schader Report, August 1971 (Ref. 1, p.18-24), in the heavily hit area of the San Fernando Valley, which has a population of 1,284,200 within a radius of 289 square miles, according to United States census figures there were 302,619 dwellings (one-unit

structures) within the area. Although 25% of all of these dwellings suffered damage in excess of 5%, fortunately there were only four lives lost. Data from the Hospital Council of Southern California records (Ref. 1) indicated that there were 2,543 injuries and related problems. Of the total cases, 215 were serious enough to require hospitalization. As the earthquake occurred at 6 a.m., when the great majority of people were at home, it was reasonable to assume most of the injuries occurred in residences.

From the above data it would appear exposure to life and safety in California is at a reasonable hazard level and much less than would be anticipated from other types of structures. However, studies made by various organizations do indicate there is a need for improvement in earthquake resistant design.

The Los Angeles County Earthquake Commission Report, Nov. 1971 (Ref. 3, p. 4) indicated that some modern, non-typical houses were seriously damaged by earth-shaking and recommended that studies be made of the present building codes and practical revisions be made to improve the earthquake resistance of such structures. Also, the reports of the PFRB, August 1971 (Ref. 1, p. 23) and National Bureau of Standards, Dec. 1971 (Ref. 4, p. 409) pointed out the need for better seismic design where large openings exist in walls and where changes occur in the configuration of dwellings. It was also indicated that a number of single family dwellings collapsed or were near collapse, which was due to inadequate tying together of adjacent joints. Therefore, it is obvious that a review of code requirements for such features is necessary.

Dwellings - Multi-Family

Recent earthquakes indicate a comprehensive evaluation should be made of the earthquake resistant design provisions of building codes for multi-family residential properties. A report prepared by the Office of Emergency Preparedness, U.S.A., 1972 (Ref. 5, p. 111-119) projects a higher ratio of deaths and injuries for such structures than for 1-4 family dwellings. The greatest hazard exists in the older buildings, many built prior to present-day codes. The damage patterns to certain modern highrise structures which have been built in accordance with recent codes also cause considerable concern. Probably the most alarming damage patterns occurring to highrise multi-family dwellings developed in the 1964 Caracas Earthquake. Four major buildings collapsed, others were severely damaged, and a number condemned.

Because structures often involve a large number of people, stricter seismic design criteria and supervison to assure compliance during construction, is very important. Another reason for the importance of

stringent earthquake resistant design codes is the fact that many multi-family dwellings are speculative investments; requiring construction costs to be kept to the minimum. Therefore, unless positive hazard reduction standards are established for such structures, the level of risk for life and safety will exceed tolerable limits in many parts of the world.

Commercial, Industrial and Public Structures

It bears repeating that although there has been very substantial progress made in earthquake resistant design for modern structures, many of these techniques have not been truly tested in a great earthquake. Although Los Angeles, California has one of the best building codes, the 1971 San Fernando Earthquake provided strong evidence that it does not have adequate earthquake resistant design standards for structural elements of certain business and public facilities. Secondly, it proved that building codes must provide earthquake provisions for non-structural elements of such buildings, i.e., partitions, ceilings, windows, electrical and mechanical equipment. Damage which occurred to these elements was costly and potentially hazardous.

Finally, there was evidence that furniture, machinery and other equipment in many commercial and industrial buildings are also very hazardous to life and safety if not properly placed and secured. There should be some ordinance establishing basic standards to reduce this serious hazard.

All experts agree that if the San Fernando Earthquake had occurred two hours later at 8 a.m., injury and loss of life would have been very high in commercial and public buildings largely due to failure of non-structural elements. Fortunately, most earthquakes causing major damage in the United States have occurred during non-business hours. Because of this, there is a degree of complacency and a tendency to minimize the potential hazard to life and safety in business properties. It must be recognized that the tremendous business complexes and highrise office buildings literally house thousands of people. The potential hazard in highrise structures is most difficult to evaluate. Based on the best knowledge available, there appears to be considerable confidence that highrise steel-frame structures will perform well and do not present a collapse hazard.

However, there is not enough concern about the performance of architectural elements during an earthquake in regard to life and safety. For example, the San Fernando Earthquake made it clear that unless there is improved design for elevators, many will not be operative following a major quake. Also, in the 1964 Alaskan Earthquake stairways were so severely damaged, people could not use them for escape.

Finally, we must recognize the risk of fire following an earthquake, and, again, the highrise building may well provide the greatest hazard to life. Tragic examples in the United States, without the added problems that would accompany an earthquake, were the December 1972 New Orleans and Atlanta fires in which thirteen people lost their lives because there was no means for escape or rescue from the buildings.

FINANCIAL LOSS AND INSURANCE

Next in importance to life and safety in providing greater hazard reduction through earthquake resistant design are the contributions that can be attained for the economic welfare of society. When evaluating the economic risk as related to financial loss, attention must be directed to the effects on the individual, business, and the community as a whole.

The problems of design deficiencies already discussed for all classes of properties, unless corrected in many instances, have the potential for financial losses the individual or business community cannot afford. For many of these exposures, insurance can be purchased to protect against loss; however, the cost of coverage will be greatly influenced by the effectiveness of the earthquake resistant design standards to limit the damage potential.

Insurance is available in most parts of the world for property owners. Generally, coverage can be purchased from private insurance companies, with the exception of New Zealand where it is available through a governmental agency.

In the United States, coverage is readily available for most anyone wishing to purchase it. However, as in many parts of the world, there is a very limited amount of coverage purchased. Property owners seem to have developed a strong attitude of complacency in connection with the earthquake hazard, which is not the case for other types of hazards. A prime factor for public apathy, unquestionably, is the recurrence interval of major earthquakes. Other types of coverage, such as fire insurance, appear more necessary to the property owner because the frequency of loss is much greater. What the individual fails to recognize is damage from a major earthquake, when it does occur, can mean financial ruin.

Dwelling Insurance

The San Fernando Earthquake was responsible for very severe losses for a number of homeowners who had failed to protect their investment by insurance. This was most unfortunate and was due to a number of factors. A few were:

1. The homeowner's failure to recognize the need for coverage.

2. Banks and Savings & Loan Associations do not normally require insurance for Earthquake , but do for Fire and Extended Coverage (Windstorm, Hail, Explosion, Riot, Riot attending a Strike, Civil Commotion, Aircraft, Vehicles and Smoke).

3. Failure of the industry to conduct promotional sales campaigns to increase earthquake coverage.

4. An erroneous impression that the cost of coverage is excessive, which is not the case; this is confirmed by statements made by the Federal Insurance Administrator's office in their investigation of the situation.

Also, there is a misunderstanding of the need for the 5% deductible. First, it must be recognized that earthquake insurance is catastrophe coverage. Through application of the deductible, insurance companies can provide coverage at affordable rates, and the homeowner is able to protect himself against the true catastrophic loss which may jeopardize his total investment. Damage of less than 5% may cause the homeowner inconvenience but seldom will it make the property untenantable, nor is the cost of repair so great that it cannot generally be absorbed by the homeowner.

Without the deductible there can develop a number of inconsequential and controversial claims which would materially increase the cost of coverage. Generally, these claims develop from such things as plaster cracking and maintenance deficiencies, which result from settling and normal aging of a dwelling and are in no way connected with earthquake damage.

Following the San Fernando Earthquake, insurance industry studies made clear the need to promote the sale of earthquake coverage to homeowners. Since then, in an effort to create greater interest in coverage by the public, a number of companies have made coverage changes and reduced their rates for protection under homeowners policies. These rate decreases have been as much as thirty percent. Also, one company has developed a Homeowners contract with the earthquake peril actually incorporated in the basic coverage, eliminating the need of special endorsement which is used by most other companies. As a part of these programs the companies have done a considerable amount of advertising to let the homeowner know coverage is available at reduced rates.

During the latter part of 1972, the California Insurance Department requested that all insurance companies notify homeowners in writing when a new or renewal property policy was delivered that earthquake coverage was available. It is hoped that through these efforts homeowners can be made aware of the importance of protecting themselves against a serious financial loss.

Insurance Capacity

As people become aware of the importance of insurance, hazard reduction becomes an even more pressing necessity for the insurance industry if it is to maintain a ready market for protection at affordable rates. Needless to say, the insurance capacity and rates are controlled by the losses which are anticipated from any major hazard. The insurance industry is limited in the amount of loss it can assume for any major catastrophe because:

1. No insurance company will knowingly assume an amount of liability which will impair its financial integrity;

2. Insurance companies are limited by state regulation in the amount of net liability they can assume for any one risk. In most states this limitation is ten percent (10%) of their policyholders' surplus;

3. In the United States, it is difficult for insurance companies to establish special reserves for catastrophes. The major problems involved with reserving result from the fact that State Insurance Departments do not allow catastrophe reserves in company statements. Further, the Internal Revenue Service does not consider such reserving a valid deduction from income.

The above circumstances clearly indicate the necessity of adequate earthquake resistant design standards to insurance companies, especially regarding high value properties such as commercial, industrial and public buildings. (For these reasons, attainment of acceptable levels of loss is most important).

Commercial, Industrial and Public Properties

The underwriting of these properties, due to the many classes of construction, presents many problems for the underwriter in establishing the Probable Maximum Loss (PML) for a building. PML for earthquake insurance in California means the percentage of loss anticipated from a quake with a Richter magnitude of 8.3 (1906 San Francisco Earthquake).

In California, there are eight major construction classifications and underwriters generally establish an average PML for each of these, which is adjusted upward or downward in accordance with their evaluation of the exposure. The underwriter's analysis of a risk [II] takes into consideration seismic activity of the area, soil conditions, design, construction, and building code enforcement. The detail of the data developed will vary in accordance with the amount of liability

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Risk - (1) Any chance of loss. (2) The insured, or the property to which insurance relates.

being assumed and other pertinent factors In the case of larger risks, underwriters will often request an engineering survey of the structure. Some companies employ their own engineers and others have their surveys done on a fee basis.

Underwriters are cognizant that without code revisions, greater damage will result when a major quake occurs. Therefore, loss estimates have to be much higher for many buildings constructed to comply with present building code requirements. This may mean a reduction in the amount of liability which can be accepted and concomitant rate adjustments based on the recognized added exposure.

One of the areas of major concern for the underwriter is the adequacy of the structural frame design for certain types of buildings. Reinforced concrete frame structures are of particular concern, for where 20% to 40% loss was previously projected, the San Fernando data showed much higher losses for such structures. The Olive View Hospital is a prime example and while it did not collapse, from an insurance point of view it was a constructive total loss; in other words, the cost of repair would have exceeded the value of the building.

Steel-frame buildings, particularly the highrise structures cause concern because engineers have acknowledged that the stress of certain structural elements came close to the yield point. In cases where this happens, particularly if it is a major element, the cost of repairing it to the original condition, as required by the insurance contract, would go considerably beyond loss estimates presently being established. A basis for some of this concern is the damage reported to welds of the structural members of two 52-story towers in downtown Los Angeles where it has been indicated that cracks were increased by about 25%. Also, an article in Engineering News-Record (Sept. 21, 1972), indicated that engineers were concerned over lamellar tearing observed in structural joints of certain major structures, which could result in much greater damage to a structure during a major earthquake, if not detected and eliminated.

Another area of major concern is the lack of greater provision in building codes for design standards for the reduction of architectural damage. Underwriters have previously recognized a loss potential for non-structural features. However, based on the damage resulting from the San Fernando Earthquake, a great quake will cause major damage to these elements which can represent more than 60% of the value of the building. A number of highrise buildings experienced non-structural losses in excess of $100,000, and it is acknowledged that most of these losses were generally below the deductible. But a substantial degree of this type damage could be eliminated at little cost if greater attention is given to the design of these elements.

Intangible Losses

All major catastrophes cause financial losses that cannot be provided for completely by insurance. These include losses which are difficult to project or anticipate even if the property owner is willing to purchase

available insurance. A good example of this is the Sylmar Converter Plant which furnishes electrical power for the Los Angeles Basin. The actual property damage loss was fully insured, but for a facility such as this there is an intangible loss that cannot be provided for. Fortunately, in this case, the facility had been recently completed and was not as vital to the public as might have been the case had it been in operation for a period of years. It was built for the purpose of providing additional power for anticipated growth in the area. If it had been a situation where its full capacity was being used, there would have been a tremendous loss of needed power for a considerable length of time. The estimate for the time it was going to take to repair these facilities was fourteen months. Unquestionably, under such circumstances this would have resulted in untold inconvenience and unknown financial loss to the business community that would be dependent on power from such a facility.

SUMMARY

Improved standards for earthquake resistant design cannot be attained by engineers, scientists, public officials and the industry without the general public's support. Therefore, individuals must be made aware of the vital need for hazard reduction for public welfare. The insurance industry recognizes earthquake hazard reduction is a specialized science, requiring the expertise of engineers and scientists in establishing proper land use and adequate earthquake resistant design standards. Through closer liaison, much can be accomplished in establishing both hazard reduction levels acceptable for public safety and broader protection against financial loss.

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