RECENT STRONG MOTION EARTHQUAKES AND RESULTING DAMAGE

(SESSION V)

NOTE: Only questions answered in written form by the author are included in the discussion.

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THEME V

RECENT STRONG MOTION EARTHQUAKES AND RESULTING DAMAGE

by

Karl V. Steinbrugge
Reporter for Theme V

The purpose of this paper is to present a consolidated report of the other papers which are to be given under the theme of "Recent Strong Motion Earthquakes and Resulting Damage".

Papers in this theme have included 8 destructive earthquakes, or sequences of earthquakes, that have occurred around the world since the Second World Conference on Earthquake Engineering. The magnitudes of these earthquakes have ranged from 5.0 (Barce, Libya, in 1963) to 7.2 (Iran, 1962).

Additionally, two earthquakes of exceptional interest occurred in 1964. Alaska, USA and Niigata, Japan suffered most interesting damage to structures designed under building codes having modern earthquake resistive provisions. These earthquakes are being treated at a special session, and therefore they will receive no further comment in this report.

It is also the purpose of this paper to look broadly at the findings and observations made by the various authors, and their individual papers should be referred to for details.

Two of the papers report incidents where subsequent earthquakes damaged or destroyed buildings that seemingly withstood earlier earthquakes successfully. Binder states that "It is interesting to note that----the damage in Mexico City resulting from the May 19th tremblor was limited to buildings already cracked on May 11th, and that in many instances cracks reopened and widened on May 19th where they had been painted or repaired with plaster." He also gives several pictures where collapses occurred in the May 19th shock where structures had been only partially damaged in the earlier, stronger May 11th shock. Similarly, Cavallo and Penta in describing Italian experiences mention the progressive weakening of certain old buildings in earlier earthquakes which finally collapsed, and the difficulties caused by superficial repairs after earlier earthquakes. The hazards connected with cumulative earthquake damage are too often overlooked.

Kodera in his observations on bridge failures noted that one of the most prevalent failures is that of anchor bolts even when their capacity is greater than the weight of the girder ("the seismic coefficient is larger than 1."). It is interesting to speculate on the comparison of this effect with the recently adopted building code requirement in a large American city, requiring anchorage for 30% of gravity and how effective this requirement may be in preventing earthquake damage of precast or prefabricated assemblies.

A most interesting table on the frequency of earthquakes in different villages is presented by Cavallo and Penta and should give the American and Canadian engineers cause to speculate on the reliability of their commonly used seismic probability maps and their short historical basis. The most frequently affected village Ariano Irpino had 100 years of quiescence although three earthquakes affected other villages within that period. Also, considering the villages hit worst in 1962, it would seem necessary to go back to 1732 to experience an earthquake of similar broad area effect.

The lack of a good relationship between magnitude (as defined by the Richter scale) and maximum intensity (as defined by the Modified Mercalli Scale) is illustrated by data presented in the various papers. We have the following:

Earthquake	Magnitude	Highest Intensity	Reference
Badgam	5.5	VIII to IX	Krishna
Libya	less than 5	IX	d'Albe
Skopje	6.1	IX or less	d'Albe
		VIII	Berg
Iran	7 to 7-3/4	IX	d'Albe
		VIII	Ambraseys
		VIII	Mohajer
		IX	Omote, et al
		XI plus	Abdalien

It would therefore appear to be a questionable practice to try to relate magnitude and intensity using empirical formulas developed under other geologic conditions, earthquake focal depths, and the like.

As earthquake experience in the past has shown, buildings of large mass performed poorly when compared to those of small mass unless special earthquake bracing measures were included. In Iran in 1962, Ambraseys found that houses of adobe-brick or mud-wall construction with heavy roofs of tamped earth performed very badly; he also reported the life loss at 12,000 persons. Cavallo and Penta found in their 1962 Italian earthquake studies that masonry buildings were severely damaged, and stated that "the mortar in houses was found to be completely lacking in cohesion". Krishna, in discussing the 1963 Badgam shock in India, found that the older structures which were "constituted of compacted earth or brick masonry duly reinforced by timber framing" performed better than the "modern" construction of the same earth or masonry materials which lacked in timber bracing. Zuei-Ho Tsai's report on the 1964 Taiwan earthquake is somewhat different, but it does still fit into the general pattern. Minami, in discussing the 1963 Libyan earthquake, states that "construction using rubble stone embedded in mud (terra rossa) suffered the heaviest damage and the collapse of these buildings was responsible for most of the casualties"; however, reinforced concrete structures did perform well.

The earthquake records going back to earliest history have always shown that mud, adobe, stone and similar heavy masonry have always been associated with large life loss when these materials were used in a manner in which they were not reliable in tension and shear as well as in compression. Normally, but not exclusively, reinforcing steel in masonry and earthen construction materials often makes them reliable in tension and shear.

The question has been raised on numerous occasions in recent years regarding the value of repeated studies of construction types which have always fallen down in severe earthquakes. Too often the critics have been justified to some extent since the studies came to the invariable and inevitable conclusion reached many times before that property destruction and life loss was to have been expected. On the other hand, a careful description of the extent of the damage is a guide to the severity and magnitude of the shock, and this is important in seismicity studies. Secondly, it should lead to better methods of constructing buildings.

To recommend better construction is easily stated, but the recommendations are not easily put into practice. Ambraseys in his paper on the Iranian earthquake has outlined the problem rather well:

> It cannot be sufficiently stressed how important it is to give solutions applicable to local materials and methods of construction, when considering this problem of building for earthquakes in developing countries. A purely theoretical solution based on materials unobtainable locally, financially will become impracticable and would merely result in the repetition of earthquake disasters.

It is the writer's firm opinion that damage studies must be so written that the reasons for the damage are understood and that these reasons can be the firm basis for improving construction practices.

Masonry materials which have been strengthened so as to be reliable in shear, tension and compression can be earthquake resistive, and their earthquake performance requires special study. Brick masonry and hollow concrete block, when reinforced, have performed well in the 1952 Kern County (California, USA) earthquakes and the 1964 Alaskan (USA) earthquakes. Words alone are rarely adequate in delineating damage and the reasons for this damage (or lack of damage). Extensive use of photographs and diagrams are necessary. From personal experience, the writer is well aware that diagrams of the actual construction and its earthquake damage are difficult to obtain. Also, construction drawings too often do not reflect the actual construction. Material quality must also be stated in terms that have meaning, such as pounds per square inch, etc., rather than such subjective terms as "good" or "bad".

When any material, or various types of materials, has been so assembled as to be earthquake resistive to some degree, then the field inspections of the undamaged as well as the damaged structures must be done by a structural engineer who is experienced in earthquake resistive design if maximum benefit is to be obtained. It is much to the point to state that seismologists, mathematicians, geophysicists, and geologists, however competent in their respective fields, can not adequately describe and interpret damage to earthquake resistive construction.

The preceeding paragraphs have dealt with damage as a result of an earthquake. An equally important problem is to determine the potential seismic hazard in any area. Ambraseys states that the region which experienced the 1962 earthquake was the least seismic in Iran, there having been no earthquakes as strong as that of 1962 in at least the past two centuries. Minami states that Barce in Libya had been considered earthquake free based on historic records of more than 2000 years. Berg, in discussing the Skopje earthquake, lists disastrous earthquakes in that city in 518 AD, 1555 AD, and 1963. In view of the foregoing, what is the basis for establishing earthquake frequency, which in turn is a major factor in establishing the seismic risk as defined by building codes in their earthquake provisions?

The historic earthquake record is at present our most useful tool in earthquake frequency studies. But this record usually is not accurate. For example, the author of an earthquake catalog of China pointed out that earthquakes seemed to occur principally in the capitol or provincial capitol; one may conclude that damage and loss of life outside of the capitols were often not considered worth recording. Another factor is the time distribution of earthquakes. For example, Imamura has divided the earthquake history of Japan into 3 periods of heavy seismic activity: 684 to 887, 1586 to 1707, and 1847 to the present time. The seismic history of an area such as California, USA, which is less than 200 years old, must be used with caution and judgment. One must also be careful in relating frequency of small earthquakes to the frequency of large earthquakes. In some areas, geologists are able to be of assistance in seismicity studies from their studies of prehistoric movements on faults. But at best the problem of earthquake frequency can be only approximately solved on the basis of seismic history and geology. The solution lies in the field of seismology and geophysics where, in studying the forces and stresses within the earth, man may be able to predict earthquakes in the future. It is interesting to note that research activity is greatly increasing in the field of earthquake prediction.

Another problem confronting city planners and architects, as well as structural engineers, is the problem of building in the proximity of an earthquake fault. There is a natural desire to be as far away from a known active earthquake fault as possible. But field evidence, both in United States and elsewhere, indicates that damage and earthquake intensity in the immediate vicinity of a fault is not particularly different from that 5 or 10 miles away, assuming similar geologic conditions. Indeed, there is a belief in some quarters that the intensity may be less in the immediate vicinity of a fault than that several miles away.

The development and increasing use of strong motion seismic recording instruments holds the future in earthquake engineering. Binder, in his paper on the Acapulco, Mexico, earthquakes of 1962, makes a strong case for the need of a vastly expanded network of strong motion recording instruments. The writer wholeheartedly agrees. Fournier d'Albe, in his summary paper on UNESCO activities, outlines the possibility of UNESCO work in this field.

It is only through the recordings made from these strong motion instruments that the actual forces in buildings will be determined, from which meaningful calculations can be made of the dynamic characteristics and mechanics of damage. Also, the effects of soil types can only be answered from these recordings.

It is at this point that attention should be called to the microtremor work being done primarily by the Japanese. An example of the work of a Japanese team is given by S. Omote, et al, in their paper on the Iranian earthquake of 1962.

Recognizing the problems of the field investigation of earthquakes, the Earthquake Engineering Research Institute of United States has recently published a "Guide for the Observation of Earthquake Damage to Buildings". This pamphlet, on display at this Conference, was intended for use in connection with United States earthquake studies, but undoubtedly it could be adapted for use in other countries.

The writer would like to acknowledge the assistance given by Mr. Henry Degenkolb, Deputy Reporter for Theme V of this Conference, in the preparation of this paper.

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BY KARL V. STEINBRUGGE

QUESTION BY: G. LENSEN - NEW ZEALAND

I fully appreciate the honest report given by Mr. Steinbrugge, especially with regards to progressive damage by a sequence of earthquakes. Would the speaker please tell us how in California you make your Civil Authorities aware of such instances and how do you make them take action upon this?

AUTHOR'S REPLY: Progressive earthquake damage is called to the attention of the Civil Authorities through the published reports which become available a year or two after the earthquake. Additionally, lectures and seminars are given very soon after a destructive earthquake and building department officials are usually present. There is no direct method requiring building officials to take action on partially damaged buildings when in the official's opinion the damage is not sufficient.

COMMENT: In reply to a question from the floor to Mr. Steinbrugge re resulting resistance of buildings due to successive earthquakes, Mr. Steinbrugge referred the question to Mr. Monning. Mr. Monning spoke of retroactive legislation in the City of Los Angeles re change of occupancy voiding the non-conforming rights in underdesigned buildings; retroactive parapet and appendage legislation; and legislation requiring instrumentation of buildings.