Session Summary

by

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A strong motion earthquake can be seen from the engineering point of view as a full scale experiment providing us with a crucial test of man made structures. To study the nature of such earthquake motion and the behaviour of structures in the event and to turn the resulting sacrifice to account should be our response to this providence. Session V of this conference is dedicated to this subject.

E. Rosenbleuth of the University of Mexico presented a paper on "The Earthquake of 28 July 1957 in Mexico City". This earthquake took place at 2:40 a.m. 358km south of the city, and the average intensity outside the city at similar distances was IV in the Modified Mercalli scale. But the intensity in some parts of the city reached between VII and VIII on the same scale. The maximum acceleration of the earthquake within the city was estimated to vary from less than 10 gals to over 100 gals. Such a high enhancement of over ten times is a result of the soft deposite in the old Texaco lake. There we find from 30 to more than 700 feet of highly compressible volcanic clay strata. Its average water content is 300%, while the mean compressible strength of the upper layers is 0.6kg/cm$^2$. Base rock is found at 1,000m or more below the surface. In the hilly zone on the slope of the Sierra, the subsoil consists of volcanic tuffs, conglomerates and cemented or dense sands, etc., the unconfined compressive strength exceeding usually 5kg/cm$^2$ in this zone. The relative damage in the hilly, transition and lake bed zones was in the ratios 1.4:18: 100. Of total damage within the city, the death toll was estimated at 54 and the total number of damaged buildings at 1,000, and the material loss was between 25 and 160 million dollars.

Owing to this subsoil conditions and to the large epicentral distance, motions of longer period seem to have predominated in the old lake bed area. It is noteworthy that the distribution of severely damaged buildings as a function of their number of storey gave a peak at 14 storeys, and that all the buildings that collapsed or were condemned lay in the old lake zone. It was also noted that older buildings fared better than some modern buildings, which fact being accounted for by the sizeable energy absorption and shorter natural period of the old massive edifices and stocky colonial buildings, to say nothing of the neglect of the lateral force provision in some of the modern buildings. Anyhow this earthquake offered a unique chance to reconsider on the modern methods of building design and construction. The author analysed the principal causes of damages into the following classes: disregard on relative rigidity, lack of aseismic design, insufficiency in reinforcement, pounding, previous differential settlement, resonance, excessive sway, whip effect, foundation failure and overturning, and explained them by actual examples.

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Four members of the Earthquake Engineering School of the University of Roorkee, India, presented a report on the Kapkote Earthquake of Dec. 28, 1958. This earthquake took place at 11:16 a.m. near the town of Kapkote. The epicentre was located at 30°00'N, 79°58'E in the Central Crystalline Zone of the Inner Himalayas. The magnitude of this shock is reported to be 6.25, but the macroseismic effects observed at distant places from the epicentre seem to the reviewer to indicate larger magnitude ($7\frac{1}{4}$ or so) unless the geological conditions at all the distant places are unusual as in Mexico City. A fairly detailed description of the geology in the epicentral tract is given to show that the fault found in the calcarious rocks is still active. Stone masonry buildings in the area suffered marked damage if lime or mud mortar had been used while only minor damage was observed even at Kapkote in cement mortar buildings.

Y. Sakabe's paper "On the Damage of Fukui Earthquake and the Destructive Power of Such Kinds of Earthquakes" is reviewed in the Summary of Session III.

Two papers were presented on the Maipo Valley Earthquakes of September 4, 1958. C. Lomnitz of the Institute of Geophysics, University of Chile reported the result of the seismological study of these earthquakes. Three earthquakes of nearly the same magnitude 1) 6.9; 2) 6.7 and 3) 6.8 took place at 21:51; 21: 52 and 21: 55 respectively in the Maipo Valley at a distance of about 60km to the SE of Santiago. They were accompanied by fore-shocks and after-shocks. The epicentral intensity was estimated at X in M. M. scale, and the meizoseismic area was 10km in radius, from which the hypocentral depth could be inferred to be of the same order. The comparatively few victims (4 dead and several dozen wounded) were partly owing to prior warning by fore-shocks and the fact that the day was Election day and the greater part of the population of the valley had gone to the cities to vote.

Fault plain solutions from observations at distant seismological stations proved a fault with a strike of N 13°E and a dip of 78° towards the West, in harmony with the geology. Detailed study of the after-shocks are also reported.

The engineering aspects of the earthquakes were reported at this conference by Rodrigo Flores, Santiago Arias, Victor Jenschke and Luis A. Rosenberg in a paper entitled "Engineering Aspects of the Earthquakes in the Maipo Valley, Chile, in 1958".

The description of the damage was given under three categories; 1) damage from landslides, 2) damage caused by avalanches, and 3) damage directly related to earthquake waves. The epicentral area lies in steep valleys in the Andes, and heavy land slides and large rock falls took place and caused considerable damage to the canals of the hydroelectric power station and aqueducts supplying water to the City of Santiago and other engineering works. Valuable description of failures and its repair works are given. Some precautions for the prevention of future damage by these causes are also given.

Ke-Cieh Cheng of the National Taiwan University gave a "Report on the 1951 Earthquake in Taiwan" which occurred on October 22, 5:34 a.m. at Chengkung town, Taitung. This earthquake was followed by a series of severe earthquakes, 1) in Hwalien city at 11:30 a.m. on the same day, 2) in Taitung longitudinal valley at 2:47 a.m. on Nov. 25, and 3) at Taitung on Dec. 5, at 2:58 p.m.

Destructions to buildings caused by these earthquakes were studied and the antiseismic behaviour of each kind of building was investigated and various pertinent recommendations for future constructions were given.

Roger Diaz di Cossio of the University of Mexico presented a paper on "Foundation Failures During the Coatzacoalcos (Mexico) Earthquake of 26 August 1959". This earthquake occurred at 2:30 a.m. in south-eastern Mexico around the towns Jaltipan, Chinameca, Cosoleacaque and Acayucan. The coastal City of Coatzacoalcos was also afflicted. Twenty persons were killed. The magnitude was 6.5, and the hypocentre was located at 18°27'N, 90°16'W with a depth of focus of 15-20km. This earthquake offered a good opportunity to study failures in buildings with foundations on widely different soils.

In the Coatzacoalcos area which is underlaid by a sandy silt layer more than 10m thick, severe foundation failures of structures were observed, while in the inland area structures founded on soils with good bearing capacities mostly underwent only vibration failures.

The results of the mechanical tests on these soils clearly showed the possibility of the silt layers in the former area being liquified under the action of repeated vibrations and causing foundation failures before the structure itself fails owing to the earthquake loads.

Karl Von Steinbrugge and Vincent R. Bush of the Fire Rating Bureau California reported "Earthquake Experience in North America, 1950-1959". This paper is a critical review of the information obtained and conclusions presented by various authors as a result of their field investigations of 13 important damaging earthquakes that occurred in North America during this decade starting from 1950.

Field observations of buildings and allied structures and observations of ground intensity form the subject matter of this paper. Difficulties arising from definition, for VIII degree in M. M. scale which includes "Damage slight in structures (brick) built especially to withstand earthquakes" prompted the authors to demand that isoseismal maps always be prepared by the one agency in each country. Examples (the 1952 Kern County Earthquake in Los Angeles, and 1957 Mexico shock in Mexico City) are given from the facts that long period ground motions at large epicentral distances selectively damage multi-storey buildings but relatively few low rigid buildings.

An empirical correlation with the Richter Magnitude of an earthquake and the maximam Modified Mercalli intensity are given. But it is for rough use only in ordinary ground conditions in metropotitan centres in California.

Examples of some limitations are also given.

Ground effects on damage were specially considered, most important ones being 1. surface faulting, 2. surface effects due to slides, lurching and slumping, and 3. vibratory effect with respect to foundation material; the one outstanding example of the last being the 1957 Mexico shock in Mexico City. The energy dissipation from the building into the ground is proved by the rocking motion clearly observed in the pounding of nearby buildings.

It is also suggested on definite observation (in the 1959 Hebgen Lake Shock) that vibration intensity adjoining a fault zone need not be significantly different from that which is several miles distant, provided geologic conditions are uniform.

Next the bearing of the types of construction with respect to damageability was analysed carefully.

Rigid concrete structures with well-balanced shear walls behaved well although an unbalanced layout of them added serious tortional stresses.

Flexible monolithic constructions showed spectacular damage and several collapses in the 1957 Mexico Earthquake. Steel frame buildings have performed better than have reinforced concrete structures in cases where neither were designed to resist strong earthquakes. No steel frame building collapses are known. An interesting fact is revealed by an example which occurred in Los Angeles as the result of the 1952 Kern County shock. A 15 story steel frame earthquake-resistive hotel suffered non-structrual damage of a percentage not significantly different from many nearly non-resistive steel frame structures.

Masonry walls have suffered severely when not specifically designed to be earthquake resistant. (Current interest is now directed to the effectiveness of modern techniques for making the unit masonry into an earthquake-resistant material.) Re-inforced grouted brick masonry and re-inforced hollow concrete block masonry have proven effective in resisting earthquake forces.

Roof and floor diaphragms have had damage along their boundaries, but X-bracing instead of diaphragms was satisfactory, but the connexion to masonry walls were critical. It is suggested in the conclusion that competent full time inspection should be provided on all work for all major construction.

J. A. R. Jonston of the Ministry of Works, Wellington N. Z. read a paper on "A Brief History of Damaging Earthquakes in Wellington City and Development in Multi-Story Building Construction in New Zealand". In this paper a description is given of the geological and seismological feature of Wellington City, the most populous centre in New Zealand's strong active seismic zone, a brief history of earthquakes, and earthquake resistance measures together with the provisions of the N. Z. Standard Model Building By-laws. It then summarises experiences in the Wairarapa

Earthquake of June 24, 1942. Statistics of different types of buildings damaged in the earthquake in the City are given. The principal features of a number of multi-storied earthquake resistant buildings designed by officers of the Ministry of Works are described. Current trends in building construction are reviewed and unsolved structural problems such as the compaction of soils by vibro-floatation; methods of computing stresses in deep membered frames; etc, are also outlined.

N. N. Ambraseys of the University of London presented a comprehensive summary "On the Seismic Behaviour of Earth Dams". There is a great deal of divergence in opinion among engineers as to the adaptability of earth and rockfill dams in seismic regions. Many believe that in adequately designed earth dams the inherent factor for safety against slip under static conditions is ample to provide against earthquake shocks: a statement which is most probably based on the spectacular performance of the earth dams on the San Andreas fault, which although sheared during the 1906 California Earthquake, did not fail. Experience, however, has repeatedly proved that earth dams are adversely affected by seismic shocks. To clear up these circumstances the author intended to summarize the available widely scattered information. In this paper a review is presented of 58 earth dams and high embankments which in the past sixty years have been subjected to earthquake shocks. From an analysis of the cases described in this paper it appears, according to the author, that the earthquake damage, instead of being greatest close to the fault upon which a break occurs or near the epicenter, very commonly has been greatest at some localities much further away from the origin of the earthquake.

The individual behaviour and circumstances of each dam in strong motion earthquakes is well described, and summarized in a table at the end of the paper. We appreciate the hard work of the author in giving a warning against the optimistic opinion first mentioned. It is to be hoped that some generalization or formulation be drawn from this abundant evidence.

C. Martin Duke of the University of California rendered efforts of a similer nature to the work of Ambraseys in analysing the behaviour of "Foundations and Earth Structures in Earthquakes", and presented a paper in this session.

In the paper there is summarized the pertinent features of the affected systems including soil and geologic conditions, damage details, and the local earthquake intensity taken from 62 reports of earthquakes in the United States, Japan, New Zealand, as well as in Italy, Chile, Mexico and China. Based upon a considerable number of instances generalizations are drawn on the behaviour of foundations, earth dams, and tunnels. Preliminary statements on landslides are also given. Some of the important generalizations and formulations are as follows:

A. Foundations

1. The type of soil is the principal determiner of the damage. Settlement and lateral or rotatory displacement at the substructure of bridges and buildings on soft ground have occurred in nearly all of the earthquakes reported, while foundations

comprising better soils and rock have not suffered failure.

2. The smallest M. M. intensity which has resulted in bridge foundation failure is approximately VIII.

Design implications include (a) the following good practice with respect to provision for the transfer of vertical loads; (b) the design of foundation elements for seismic horizontal forces between the substructure and ground; (c) the minimizing of earthquake-induced differential settlement and the relative horizontal movement of footings; etc.

B. Earth Dams

1. Dams designed and built in accordance with modern practice, which calls for a controlled compaction of selected materials the preventing of excessive pore pressure and seepage, relatively flat slopes, firm foundations, and provision for resisting lateral seismic force have not been damaged in earthquakes.

2. Damage is inevitable when a large fault displacement crosses a dam. Whether complete failure might occur due to this effect cannot be stated from experience to date.

3. The minimum intensity of shaking which produces damage to the older dams appears to be about VII on M. M. scale.

Seven possible modes of failure are give.

C. Tunnels

1. Severe tunnel damage appears to be inevitable when the tunnel is crossed by a fault.

2. Breaks in tunnels away from faults but in the epicentral region of strong earthquakes, severe damage to linings and portals and to the surrounding rock, may be caused by shaking, when construction is of marginal quality.

3. Tunnels outside the epicentral region, and well-constructed tunnels in the region but away from fault breaks, can be expected to suffer little or no damage in strong earthquakes.

D. Landslides

1. Landslides occur as a result of many interacting causes. among which earthquakes occasionally act as the direct cause or trigger.

2. Oversteep slopes were a contributary cause of one-half of the earthquake triggered landslides considered. Incoherence of material ranked next, being noted in one-forth of the cases. Exessive water content was a factor in about one-fifth of the reported landslides.

3. Earthquake intensity VI or greater on the M. M. scale usually triggers land slides.

Summary of Session V

In this conference some papers partly related to the subject of this session were dealt with in other sessions. Reports on the most recent Agadir Earthquakes in Morroco th Lar Earthquake in Iran and the Chile Earthquake were reported in the general meetings.

The reviewer believes firmly that a conspicuous advance in earthquake engineering and the resulting promotion of the welfare of mankind are promised through the endeavours of the participants of this conference. Minimization of the earthquake hazard will be achieved if we follow the instructions of these strong motion earthquakes. With these hopes the summary is concluded.