Theme Report on Topic 1
RECENT DESTRUCTIVE EARTHQUAKES

by

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Since the last World Conference it has become increasingly evident that the site of a damaging or destructive earthquake constitutes a full-scale laboratory in which significant discoveries may be made by keen observers: seismologists, geologists, engineers, sociologists and economists. As our knowledge of the complexity of earthquakes increases, we become more and more aware of the limitations which nature has imposed on our capacity to predict on purely theoretical bases the performance of engineering structures, of the ground itself or of a community.

Any advancement of our knowledge about the assessment and mitigation of earthquake risk must be based on a growth of our body of reliable observational data; it is the only way of approaching the ideal state in which we can use our theoretical knowledge to full advantage without risk of being occasionally misled by it. This can be achieved through the field study of earthquakes.

The field study of an earthquake offers a unique opportunity to develop an intimate knowledge of the actual situation created by an earthquake disaster, and above all an understanding of the real problems that need immediate solution. Such an understanding cannot be gained simply from lectures or by reading reports. Field missions allow an interchange of ideas between members of the mission coming from different disciplines and the testing in situ of theories.

From the scientific, technical and economic point of view, a field study of an earthquake is fully justified by the value of the information which may thus be made available for the mitigation of future disasters. The assessment of earthquake risk, much needed in most parts of the world, cannot be achieved by relying solely on the local or world-wide seismograph data. In most countries the few seismic stations in operation are inadequate to locate with accuracy the local earthquakes which can be just as damaging as larger shocks. Field studies of these events not only contribute to the information available, but are invaluable, in combination with instrumental data, in reducing bias in the determination of focal parameters.

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It is only through properly-run field studies that ground deformations or faulting associated with an earthquake can be discovered and studied, and the bearing on local risk assessed. Existing building codes and regulations, as well as the efficacy of their enforcement and implementation, can only be tested after an earthquake. It is through well-designed and efficient field studies that the economic and social repercussions of an earthquake disaster can be identified so as to avoid undesirable results from future events.

During the period that has elapsed since the last World Conference there have unfortunately been nineteen earthquake disasters. The effects of a few of these events are dealt with in this Session.

The effects of the Honomu (Hawaii) earthquake of the 26th April 1973 are described by Nielsen, Furumoto et al. This was a low stress earthquake of magnitude just over 6 that caused widespread but otherwise not very serious damage within a radius of a few tens of kilometres from the epicentre. It is not clear whether the focal depth of the event is 50 kilometres, as reported by the Authors, or only 10 kilometres as re-computed by the International Seismological Centre. However, the (S - start) time recorded at Kilauea by a strong-motion instrument is about 6 seconds, which suggests a focal distance of the order of magnitude reported by the Authors. The maximum recorded acceleration at focal distances of 50 and 300 kilometres is 17%g and 3%g respectively. A pair of sensitive instruments installed on weathered lava flow and on a volcanic ash-bed of 200% water content recorded aftershocks the velocity spectra of which show a pronounced amplification of the weak bedrock motions by the ash beds and the presence of layer frequencies which are absent in the lava deposit. However, it is questionable whether the saturated ash-bed will contine to show the same response characteristics at higher levels of bedrock motion approaching those associated with the main shock.

Soil amplification effects are also discussed by Yarar and Tezcan* in connection with the collapse of two reinforced concrete structures in Adapazari during the Mudurnu earthquake. The Authors correctly point out that these two structures (among the very few that suffered total collapse in Adapazari which is a large town of 90,000 inhabitants) had insufficient column stiffness and ductility and that in contrast to other buildings in the

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* Refer theme 7-19

vicinity and in other parts of the town survived the shock with only minor damage. As a matter of fact these constructions were structurally sub-standard in every respect (UNESCO Earthquake Mission Report No. 622/BMS. RD/AVS June 1968, p.45, plates 124). The Authors estimate that for a magnitude 7.1 and a distance of about 20 kilometres from the causative fault the base rock acceleration was 17%g. It would be useful to learn how they arrived at this estimation.

Ohtani & Kubota discuss the damage to structures caused by the earthquake of 8th May 1974 at 23h33m25s (GMT) in which 27 people were killed. This is an interesting summary of the effects of the earthquake in a rural part of Japan where landslides and slumping of the ground were the main causes of damage.

The effects of a rather small magnitude event that occurred near Roorkee are described by Arya, Singh et al. The importance of this earthquake is that its occurrence suggests activity in a region which at the moment is considered to be relatively quiescent.

Where strong-motion instruments are not available, careful observations on the effects of earthquakes on simple structures are useful for the assessment of ground motions. The average acceleration of 42%g deduced from field observations by Omote and Miyake for the epicentral area of the Ohita earthquake is perfectly credible. These accelerations were deduced from overturned gravestones found over an area of 140 square kilometres. The Authors consider the acceleration thus deduced to represent the maximum ground acceleration. Should it not be the minimum acceleration rather, since, had the ground motion been more intense it could equally well have caused the over-turning of these objects ?

The papers by Tomii & Yoshimura, Tsuchiya et al., and Yamada & Kawamura examine the damage caused by the Ohita earthquake of 1975 to various reinforced concrete buildings. They conclude that as a result of excessive deformation, large changes in structural stiffness leads to premature failure.

The effects of the Kinnaur earthquake in India are described by Chaudhuri & Srivastava, by Gosavi, Bapat et al. and by Singh, Jain et al. The earthquake, which occurred on the 19th January 1975, was a relatively small event (M = 6.2) as compared with other earthquakes that have occurred in the main Himalayan area. It affected a mountainous and relatively sparcely populated area with settlements perched on steep slopes. Damage to life and property was caused both by ground shaking and by widespread and locally massive rockfalls and slides. From the three papers that describe the event it is not altogether clear whether this earthquake was in fact associated with surface faulting. Gosavi, Bapat et al. state that "a ground fissure of about 18 kilometres in length was formed which appeared to be a surface expression of the fault causing the earthquake". Perhaps the Authors could comment on this point.

A few weeks before the Kinnaur earthquake, another shock in the Northwest Frontier Provinces of Pakistan killed about 1000 people on the 28th December, 1974. This earthquake (M = 6) which occurred about 500 kilometres northwest of Kinnaur in the Pattan region caused damage in all respects similar to that described by the Authors. There is no evidence that the Pattan earthquake was associated with surface faulting (UNESCO Report. No. FMR/SC/GEO/75/134).

The paper by Stratta & Willie focuses attention to the economic vulnerability of developed and densely populated regions of apparent low seismicity such as northern Italy. It also points to the need for the application in such regions of minimum design requirements for the protection of structures against earthquake damage. As a matter of fact the total damage caused by the main shock (M = 6.3) and its belated aftershock of September 1976 (M = 6) amounts to $2,859 million, out of which loss to buildings is estimated at $1,078 million. The damage to historical buildings and works of art is inestimable (UNESCO Mission Report on Friuli, No.273.182, Paris).

The Oroville reservoir earthquake of 1st August 1975 ($M_s = 5.6$) was accompanied by surface normal faulting, a mechanism which is considered to be predominantly connected with reservoir-induced seismicity. The shock was associated with a rather small seismic moment of about 6×10^{24} dyn-cm. and with a stress drop of about 9 bars, which is almost twice as large as the apparent effective stress. This difference in stresses implies that the final stress was greater than the dynamic frictional resistance and that friction was not the controlling factor in stopping faulting. In fact, the total stress induced by impounding parallel to the fault movement was only 0.04 bar and this was found to act in a direction opposite to this movement together with an induced normal stress of 0.01 bar. In the absence of large positive pore water pressures this should have increased the shearing resistance of the fault. It seems, therefore, unlikely that the weight of the reservoir water was responsible for triggering the Oroville earthquake. It is not improbable, however, that the triggering mechanism was associated with a reduction of effective stresses and consequently of the shearing resistance along an over-stressed part of the incipient fault plane caused by a belated build-up of excessive pore water pressures. As a matter of fact, in contrast with other cases of reservoir-associated seismicity, the Oroville earthquake occurred six years after complete impounding. Unfortunately, there is no way of confirming this type of triggering mechanism from indirect measurements. The study of the Oroville earthquake presented by Beck and Housner demonstrates a continuing lack of understanding of the association between reservoir impounding and induced seismicity.