BRIEF REVIEW OF MODERN EARTHQUAKE ENGINEERING

J. Ferry Borges, J. Despeyroux, Y. Maeda, P. Mazilu, J. R. Robinson

"Working Group on Information on Earthquake Engineering"

for International Association for Bridge and Structural Engineering

1. Introduction

This review is a brief survey of the present status of Earthquake Engineering. It contains information on earthquake hazards, main Earthquake Engineering problems, safety of structures under the action of earthquakes, Earthquake Engineering research and education, and international collaboration.

The review is prepared in accordance with a decision by the International Association for Bridge and Structural Engineering to set up a working group for dealing with "Information on Earthquake Engineering". The decision to create this working group was supported by the "Comité de Liaison", which co-ordinates the activity of several international associations dealing with Structural Engineering, such as the International Association for Bridge and Structural Engineering, the European Committee for Concrete, the International Federation for Prestressing, the International Council for Building Research Studies and Documentation, the European Convention of the Associations for Steel Construction, and the International Association for Shell Structures.

2. Earthquake Hazards

Earthquake hazards are among the most serious dangers that mankind has to face. In fact, referring only to the second quarter of this century, between 1926 and 1950, over 350,000 people were killed and the damage to buildings and public works is estimated in nearly 10,000 million U.S. dollars (1).

The number of casualties due to a large earthquake may be tremendous. It has ranged, for the most severe ones, from 100,000 to 200,000. In the future, if no special precautions were taken, an earthquake hitting a large town could kill millions. On the other hand owing to the increasing density of construction, a single earthquake could result in a tremendous loss of property. Avoiding such catastrophes is the task of Earthquake Engineering.

Fig. 1 shows a map of world seismicity compiled by the United States Coast and Geodetic Survey (2). This map refers to the period 1961-1967 and includes earthquakes having depths between 0 and 100 km. Owing to the modern seismographic networks and to the modern data processing techniques the definition of hypocentre data is now much more accurate than it was years ago. This accuracy will increase in the near future, so that very reliable data will be available for studying the mechanisms of earthquake generation and defining regional seismicity.

Recently the direct forecast of earthquakes has aroused much interest among researchers (3). It must be noted however that such a forecast may help to reduce casualties but not substantially to reduce the amount of damage.

Anyhow the information provided by such studies is of foremost interest for a better understanding of earthquake generation, even allowing us to dream of avoiding strong earthquakes by a man-controlled release of energy along fault zones. In fact, by slowly releasing the stresses that produce the rupture of the crust, the cause of some types of earthquakes might be eliminated. This however is a very remote possibility only potentially applicable in a small number of cases.

The real challenge within our present possibilities is to design and to build earthquake-resistant constructions. This has to be done in economic terms, which implies an accurate estimate of the seismic risk.

3. Earthquake Engineering Problems

There is a large variety of problems to be studied in Earthquake Engineering. Some of the most important ones are:

- Frequency of earthquake occurrences on the whole earth and at localized sites.
- Measurement of strong earthquakes including engineering definition of earthquake ground motion.
- Dynamic soil mechanics ; study of earthquake disasters due to soil conditions.
- Application of the stochastic method in Earthquake Engineering, including the simultaneous consideration of physical, economic, and social phenomena in engineering.
- Experimental studies and theoretical analysis of safety of members and structures.
- Survey of earthquake damages, particularly in relation with soils and foundations.
- Prevention of earthquake disasters including installations, plannings, shelters, relief, temporary repairs, rehabilitation.
- Prevention of disasters due to tidal waves.

These problems are being studied all over the world as indicated below. The present review particularly emphasizes structural safety problems.

4. Safety of Structures

Structural safety under earthquake loads has to be dealt with according to the general safety principles used for other types of loads (4). According to simple economical criteria, one engineering objective is to minimize the total long-term cost of providing earthquake resistance and repairing damage, both resistance and damage being considered in a very broad sense. Achieving this goal and expressing it in statistical terms involves a statistical estimate of seismic loads and a statistical estimate of the behaviour of the different types of structures when subjected to seismic vibrations (5). The modern principles of structural safety cannot be applied without accurate information of these two types.

The statistical estimate of seismic loads requires a quantitative definition of the seismicity of the regions. For this purpose, information on the historical occurrence of earthquakes has to be combined with the information gathered in studies on geophysics, geology, rock mechanics and soil mechanics.

Fig. 2 shows the probability of yearly observing an earthquake with a magnitude higher than M in the whole earth, in California, and in Portugal. Within the range of interest the observed data fit double exponential extreme distributions, which are represented by straight lines in the diagrams.

On the other hand, for quantifying earthquake loads, seismic vibrations have to be duly idealized and defined by a convenient number of parameters. The theory of stochastic processes provides the most powerful means for obtaining this idealization.

The statistical distribution of the intensity of the earthquakes in a given region being thus defined, it has to be combined with the statistical distribution of the response of the structures to allow the definition of the statistical distribution of seismic loads. This last distribution is the one to be used in the design.

In general, the statistical distribution of the response of the structure depends on several parameters. For the simple case of linear one degree-of-freedom oscillators these parameters are the natural frequency and the damping factor.

This very brief survey of the tasks necessary for a satisfactory definition of seismic loads could lead to the erroneous conclusion that these are simple tasks. In fact much work has already been done along these lines and much is still required to obtain the desired results. However, the general policy being established, sufficiently accurate practical results are already directly obtainable from the existing data.

On the other hand, final results on structural safety can only be reached if the ultimate strength is also statistically expressed. This strength may be defined in terms of ultimate forces or of ultimate displacements. The correspondance between these two concepts can be established by using the notion of ductility factor.

The information at present available on structural behaviour allows a more accurate definition of ultimate forces than of ultimate displacements. On the other hand, seismic loads are naturally expressed in terms of maximum displacements. Thus an important research task is the statistical definition of the ultimate displacements in the different types of structures subjected to seismic loads. As indicated, the results of these studies can be expressed either directly in terms of displacements or indirectly in terms of ductility factors.

It is amazing how little information of the above type can be obtained from the very large volume of structural research performed till now. It is expected that this situation will improve in a near future allowing the safety of structures in seismic regions to be completely defined on a quantitative statistical basis. Attention has to be paid to the repetitive and alternative character of this type of loading.

5. Earthquake Engineering Research and Education

It is not easy to present a complete survey of Earthquake Engineering research owing to the lack of centralized information and also to the inter-relation of Earthquake Engineering with many other scientific and technical fields. A very important contribution to this survey comes from the "International Association for Earthquake Engineering, IAEE", which publishes world directories of universities, institutions and personnel engaged in Earthquake Engineering research. The last directory (6), revised in 1970, contains 229 institutes and 1019 researchers. Although covering an important part of this activity in the world, this directory refers to 22 countries only. The world list of earthquake resistant regulations also published by IAEE (7) refers to 26 countries.

The majority of research results in this field is published in the proceedings of the world conferences: U.S.A. (1956) (8), Japan (1960) (9), New Zealand (1964) (10) and Chile (1969) (11), which include altogether about 500 papers. Although more than 400 papers were submitted to the last conference only 160 could be accepted.

In addition to the world conferences referred to several regional and national conferences (12 to 15) were recently organized and others have already been announced (16 to 18). Furthermore several journals specialized in Earthquake Engineering and many others publish papers on this subject. A recent report published by the American Committee on Earthquake Engineering Research (19) gives a broad up-to-date view of the main problems in this field.

All this activity shows that Earthquake Engineering is an attractive field of research. It is in fact so, particularly if on one hand the potential damage of earthquakes is considered and, on the other, if it is recognized that the scientific and technical tools that can avoid such damage already exist.

Specifically as concerns education and training, several international and national institutes and schools were created during the last ten years to improve the specialization in Earthquake Engineering. Among the international institutes special reference is due to the following :

- International Institute of Seismology and Earthquake Engineering, Tokyo, Japan (20).
- International Center of Earthquake Engineering "Arturo Danusso", Milan and Bergamo, Italy.
- Institute of Seismology, Earthquake Engineering and Town Planning, Skopje, Yugoslavia.

Furthermore, special courses on Earthquake Engineering are organized at several universities and national research institutes.

Nevertheless it has to be recognized that education and training in Earthquake Engineering is not yet sufficiently spread even in countries with a high seismicity. Changing the present state of things is surely the most effective way to increase the rate of progress in this field and to put in practical use the results available.

6. International Collaboration

As indicated, the International Association for Earthquake Engineering, IAEE, is particularly effective in securing international collaboration in its field. Recognizing the importance of earthquake engineering other international associations have set up special committees on this problem. Thus a close relation of these associations and their committees with the IAEE seems necessary to obtain the best co-ordination of efforts. Unhappily exchange of information and collaboration among international associations is sometimes difficult. Anyhow it seems that further increasing the number of committees on Earthquake Engineering is going to render this co-ordination even more difficult. It cannot be forgotten that in addition to the IAEE there also exist several other regional and national organizations, more or less interrelated with it.

A practical way to improve the present collaboration among international associations in Earthquake Engineering would be to include IAEE in the "Comité de Liaison" that co-ordinates the major structural engineering associations. Anyhow there is no reason to substitute IAEE in its leading position in Earthquake Engineering. Just on the contrary it seems advisable that the different international associations co-ordinate their activities in direct collaboration with the IAEE. On the other hand, information on the aims of IAEE should be made known more widely and possible adjustments in the activities of the IAEE so as to satisfy the needs of other associations should be considered.

The UNESCO, United Nations Educational, Scientific and Cultural Organisation, plays a very prominent role in the field of international collaboration and its activities in Earthquake Engineering have been very important. In fact, in addition to its wide activity in Geophysics and particularly in Seismology, special reference is due to the following actions in Earthquake Engineering: survey missions to the principal seismic zones of the world, field studies of earthquakes, technical assistance missions, working groups on special subjects such as seismic maps, principles of earthquake resistant design and measurement of strong motions, organization of intergovernmental meetings and support of international institutes and of special researches. The activity of the "Joint Committee on Seismology and Earthquake Engineering" formed under his patronage must also be mentioned.

Recently, some other international organizations - for instance NATO, North Atlantic Treaty Organization - have also decided to include in their activities the protection against natural calamities, such as earthquakes (21).

On the other hand, collaboration at associative and governmental levels between USA and Japan, both in the research field through the USA - Japan Science Council, and in the disaster prevention field through the USA - Japan Government Conference for the Natural Resources Utilization, is also bringing good results for the progress of Earthquake Engineering.

7. Conclusions

Earthquake resistant constructions are the great challenge of Earthquake Engineering. The scientific and technological knowledge already available makes it possible to reach this aim safely and economically. It is to be expected that basic and applied research carried out in a well balanced condition will improve this knowledge, notably the rational bases of design, further increasing the efficiency and the economy of constructions. In particular, patterns of earthquake damages should be analysed and understood through actual investigations of the damages.

The present high rate of progress has not been accompanied by a parallel dissemination of knowledge which would enable mankind to take full advantage of the benefits that could derive from this knowledge. Consequently, education and training actions are highly profitable and are strongly recommended.

Special attention must be paid to securing the efficiency of international collaboration, as in fact this collaboration is one of the most effective ways of accelerating progress and disseminating knowledge.

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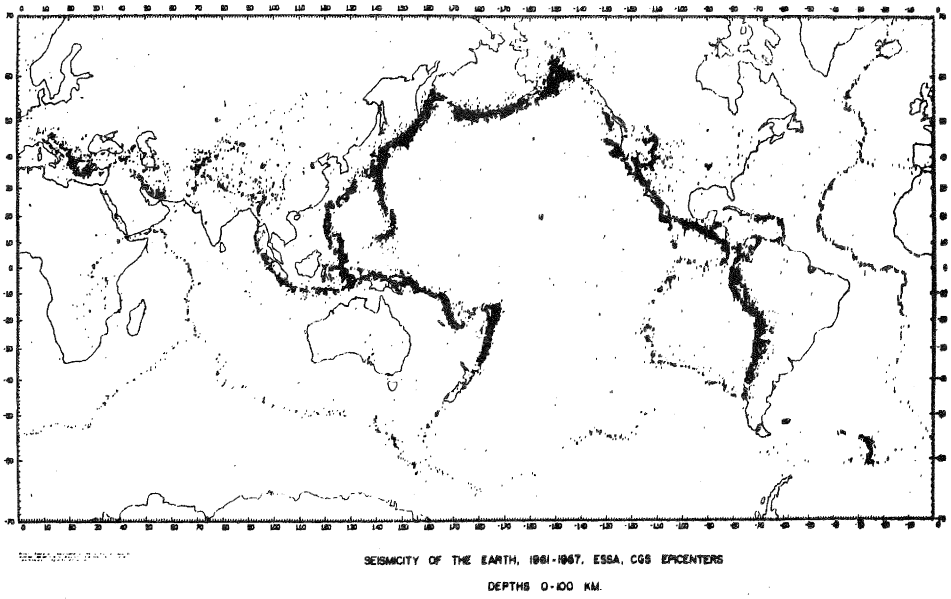

Fig. 1 – Seismicity of the earth compiled by the United States Coast and Geodetic Survey (2).

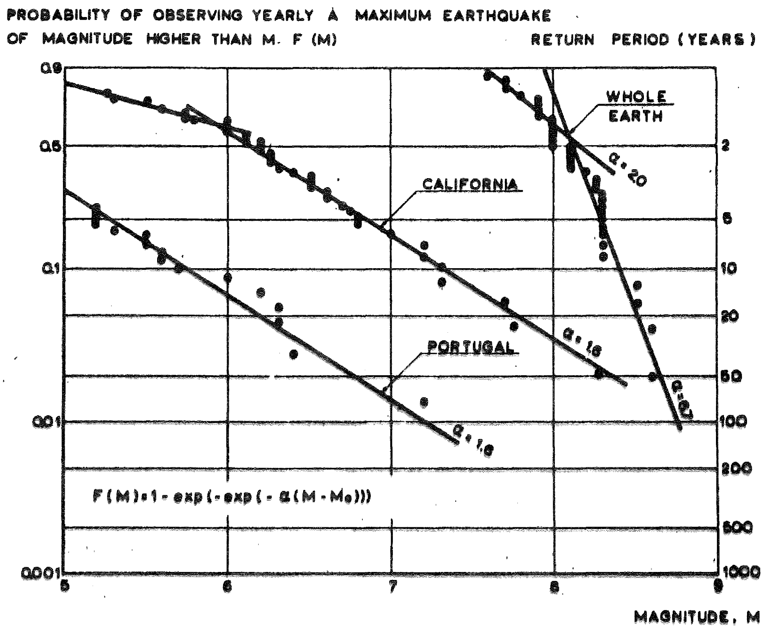

Fig. 2 – Relations between probability and magnitude.