

EARTHQUAKE ENGINEERING

by

John E. Rinne*

EARTHQUAKES DO OCCUR

We are heirs to an adverse natural phenomenon we call earthquake. Like it or not, we have to learn to live with it. Like other unwelcome afflictions, we can best do so by understanding and counter-acting it by appropriate action.

The causes of earthquakes are one thing; what to do about them is quite something else. We know considerable about the nature of the earth's movements, qualitatively at least, thanks to the fine work of the geologists and seismologists. We will be privileged to hear from eminent scientists who may cast some doubts on the legendary causes of earthquakes such as the movements of a catfish in the bowels of the earth, or a shaking invoked by an angry Maori god, Ruauumoko, as we heard in New Zealand earlier this year. Today's scientific explanations will have more plausibility.

Our sensitive seismological instruments pick up rumbles of many earthquakes of light to moderate magnitude. Less frequently, the instruments record major earthquakes - - ones that could be damaging to man-made structures if these should be in the zone of influence. These major shocks are recurring often enough so that no one will be so bold, in the face of the record, to predict that earthquakes are a thing of the past. If he did, it is unlikely that he would have many believers, any more than we seriously heed the warnings of impending earthquakes forecast by some extrasensory perceptive powers presumed by some sincere but misguided forecasters.

THE HAZARDS

Those of us who live in the seismically active circum-Pacific rim are conscious of the risk we live under. It is however, no worse than many hazards we accept daily. In fact, it need not be nearly as bad as it is made out to be. Robert Iacopi, in his book "Earthquake Country," makes the observation that "the dangers involved are more a result of man's ignorance than of nature's destructive force." In a

* Civil and Structural Engineering Consultant,
Standard Oil Company of California, San Francisco.
President, International Association for Earthquake Engineering.

sense it is ignorance, perhaps, but the hazards are greatly magnified over what they need to be because of public apathy and neglect. But additionally, the engineering profession has a responsibility to apply our ever-increasing understanding toward creating earthquake-resistant structures. This is a professional responsibility that can only be discharged effectively in a climate tolerant to achieving this standard of construction. We know how to do the job technically. We need public as well as professional acceptance and application of our understanding. This is fundamental to our answer to the question: what do we do about earthquakes?

SUBJECTIVE INTEREST

The general interest of the public in earthquakes, while it waxes and wanes, is most clearly reflected by the fact that few scientific-engineering phenomena are more likely to make front page headlines. I was in New Orleans on April 29 when the Pacific Northwest area was hit by a moderate earthquake. The event made newspaper headlines even though the Gulf of Mexico area of the United States has not been subjected to earthquake in our too-short historical record and is complacent in its knowledge that "it won't happen here." The subject has a fascination even, or especially from afar.

WHAT IS ENGINEERING?

Before looking into the interest of the engineer in this phenomenon, we might recall the definition of engineering. Borrowing the definition adopted by the Engineers' Council for Professional Development which definition has been endorsed by ECPD's constituent societies covering the broad fields of engineering:

"Engineering is the learned profession in which a knowledge of the mathematical and natural sciences gained by study, experience, and practice is applied with judgment to develop ways to utilize, economically, the materials and forces of nature for the progressive well being of mankind."

There is an implication here that all forces of nature can be harnessed for the good of mankind. Such is certainly not the case. It would be rather farfetched to consider the "forces" of earthquake would normally be positive factors for good. Like ocean waves on man-made structures, or wind forces in their more usual application, earthquake ground motion or forces are forces of nature to be designed against.

Besides this interpretative comment, there are several words in this definition that have direct significance to the work of the earthquake engineer. Specifically, these are "study, experience, practice, judgment, and economically." In recent years we have developed our understanding of earthquakes from a scientific standpoint with outstanding

success. Analytical tools for supporting engineering designs have been honed to razor sharpness. But in this scientific and mathematical effort, we seem to have lost sight of our main engineering objective toward creating reasonably earthquake resistant structures with a background of "study, experience, practice, judgment, and economy." This is a problem that taxes all the engineering capabilities we have at our disposal. It requires more than applied science and mathematics. Equally important are the other mental disciplines and trained-in aptitudes which, by definition, are basic to engineering. They are equally basic to the earthquake engineer.

WHO IS THE EARTHQUAKE ENGINEER?

The earthquake engineer, usually though not exclusively a structural engineer, is interested and concerned in the design and construction of facilities to resist earthquake. There is an anomaly here that causes some bewilderment. Generally the modifier of the word "engineer" denotes the field of creativity. The highway engineer creates highways, the structural engineer creates structures, the mechanical engineer creates machines, etc., but the earthquake engineer does not usurp the Ruamoko function of creating earthquakes. "Aseismic engineer" would be more consistently appropriate but "earthquake engineer" is now thoroughly entrenched in the professional jargon. As long as we know what we are talking about, it makes little difference.

The earthquake engineer is looking for the answer to the question: We have earthquakes, what should we do about them? He has more than a passing interest in the earth sciences, particularly geology and seismology, but looks to the scientists to develop data on seismicity and data on the nature of ground motions. These are basic to establishing reasonable design criteria. With all due respect to the scientists and to their contributions to our expanding knowledge in the field, the objectives of the engineer are different. The earthquake engineer is called upon to apply all of the knowledge, judgments, and skills available to him now to design and build structures that will withstand successfully the unknown earthquake of the unknown future.

A VIEW ON EARTHQUAKE PREDICTION

The earthquake engineer is less interested in the current popular pursuit of earthquake prediction. Even if successful, earthquake prediction is not likely to add or subtract materially from what needs to be done to make structures earthquake-resistant. A considerable effort is being made toward the development of a suitable and reliable warning system in the much more limited field of tsunamis. At present these are very inadequate and costly in the economic losses suffered in warnings and that fail to materialize into damaging tidal waves. When perfected technically and when it has full public confidence, the tsunami

warning systems will no doubt be very helpful in avoiding losses of life and property. With or without an earthquake warning or prediction system, however, it is the earthquake engineer's job to design and build structures capable of resisting the ground motion and to do so consistent with the risks of life and property that are involved in each particular structure. With some degree of participation in the control of the basic concepts of the particular facility, the earthquake engineer is confident that the desired resistance can frequently be built without significant premium cost - - just better planning and better execution of the planning. Then let the earthquake come when it will.

EARTHQUAKE ENGINEERING RESEARCH

Earthquake engineering research and development has progressed at an accelerated pace in recent years, quite as fast as the science and mathematics that support it. There are several factors influencing this. Basic are the development of mathematical methods and electronic computers by which theoretical solutions to heretofore "impossible" problems have been made easy, or at least practical of solution. Also, we are all aware of the ever-increasing enrollments in graduate study, providing the manpower to undertake development studies in this fascinating field of structural dynamics. This situation did not prevail a relatively few years ago. In fact, it was with the prime purpose of stimulating research that the Earthquake Engineering Research Institute was formed in the United States in 1949. While EERI cannot take credit for providing all the stimulus, it has done a fine job with the efforts of a small group of dedicated men. The technical press, sponsored now by many different groups, is giving excellent coverage of the subject. In fact, there is now so much published that no one practising earthquake engineer could possibly assimilate it all.

This brings up a very important need. This is an evaluation of the many papers that have now been written and conversion of what is today's best information into "practical design guides". It is only rarely that a comprehensive analysis of a proposed structure to an assumed ground motion can be justified as part of the design of a particular structure. This analysis is at best an approximation, both because of simplifications that must be made and also because the precise nature of the unknown future earthquake is not known. Furthermore, any so-called "rigorous" solutions take more man-hours and dollars than this part of the total design effort can justify. It becomes necessary for the usual structural practice to use shortcuts to computations, coupled with application of good judgment, to effect the kind of earthquake-resistant structure desired. The earthquake engineering researcher and analyst has been a great help in bridging the gap between theory and design. We still have a long way to go; the disparity in earthquakes still leave much to be desired.

DAMAGE SURVEYS AND JUDGMENT

Judgment can be influenced by study, by design, and by observation of earthquake damage and lack of damage. Comprehensive surveys and

analyses reported for and since the 1906 San Francisco Earthquake have provided background data on the behavior of different kinds of structures to earthquake. Recent earthquakes on a world-wide coverage have had most careful scrutiny, with financial support for these surveys coming from several sources both public and private. It is gratifying to see this interest. To an appreciable extent these surveys reveal that what has been considered to be poor-risk construction in the past is still poor-risk construction. Additionally, we have thrown in a few new construction types. Some of these have not done well; others might have done better if more attention had been paid to consistently detailing the structure and to adhering to better construction practice. I shall not attempt to go into this in detail at this time since I am sure that speakers to follow in this Symposium will bring out these points. Suffice it to say here that while we may have learned considerable about how to design for earthquake resistance, it is not so apparent that we have always applied what we have learned. I will leave unanswered for the time being, at least, the obvious question that comes to mind, how do we correct this situation? Do we have to subject ourselves to the damaging earthquake before we will pay attention to what is a joint public and professional problem?

GROUND MOTION RECORDS AND TEST CASE

Related to this matter of earthquake damage surveys is the observation that while we have had available for more than thirty years strong motion instruments for recording major earthquake ground motions, we have had the misfortune of not having them in areas of damage - - in Alaska, for example. Conversely, and probably fortunately, in those areas where we have fairly good instrumental coverage, we have not had a damaging earthquake of any great magnitude. We know only too well that these areas, although now constructing to modern earthquake codes, have their share of poor-risk construction. Knowing, then, that a major earthquake will cause considerable property damage and, realistically, fatalities and injuries, it would seem somewhat sadistic to wish that we could have a major earthquake in some of the well-instrumented areas such as in California. But a full-scale test is needed to help resolve some of the disparities and also to relate observed behavior to good ground records during the earthquake. In emphasis of the importance of strong motion instrumental installations, a recent meeting of scientists and engineers meeting in Russia under the sponsorship of UNESCO were unanimous in the opinion that a program of expanded instrumentation of this type had the highest priority and would provide most quickly some of the fundamental correlations between ground motion and effect of earthquakes.

CODES FOR A COMPLEX PHENOMENON

Earthquake engineers in many countries have been concerned with

establishing codes to help control and encourage good earthquake-resistant practices. Once extremely simple criteria were invoked to be coupled with judgment of the designing engineer. Our current codes, while still an over-simplification of a complex phenomenon, have become increasingly complex as they attempt by pseudo-dynamic rationalization to impose design criteria that will reflect somewhat better the dynamic response of structures generally. I wish I could say that they are fully accomplishing their objectives. But this is not so, and maybe it is because we are expecting too much to be accomplished by the code. While codes are not all good - - they obviously impose undue restrictions upon the conscientious designer and also upon the creator of new concepts - - the best I can say is that a modern code ably administered in a seismic area is much better than no earthquake code at all.

U. S. CODE

In the United States, the best known earthquake code is that promulgated by the Structural Engineers Association of California and published with an explanatory commentary in 1960. In large measure, it followed and was a refinement of the code provisions recommended by a joint committee of the San Francisco Section, American Society of Civil Engineers, and the Structural Engineers Association of Northern California in 1951 in ASCE Proceedings Separate 66 of the Structural Division. The SEAOC Code is the basis for the current Uniform Building Code of the International Conference of Building Officials, and for the Los Angeles and San Francisco codes. The document is under constant review and updating and SEAOC Seismology Committee is devoting most of its time currently to the problems of aseismic design criteria for high-rise reinforced concrete buildings and is also reviewing the criteria for high-rise structural steel buildings. It is not expected that codes will ever be formulated that will stay put. We will always be faced with need for changes and updating; it is the price we pay for progress.

OTHER CODES

The United States seismic areas are not, of course, the only areas having codified their earthquake design practices and criteria. New Zealand recently adopted a new code. Japan, Chile, Mexico, India, and other countries have their codes, too. Comparisons between these codes no doubt would reveal significant similarities and areas of differences. Possibly the differences would be more striking than the similarities; if so, there would seem to be a need for reconciling these codes. For earthquakes are no respecters of international boundaries, nor are they different, basically, on different sides of these boundaries.

CODES VS NO CODE

Finally, with regard to codes, while codes are not perfect and they can both be badly administered and badly applied, it is adequately apparent that no regulation in areas subject to earthquake is not in the public interest. As an economic as well as sociological policy, laissez faire is no better in construction than in other aspects of our economic and social lives. If a code is in the public interest, then it follows that the best available code is in the best public interest. The evaluation of this is a responsibility of the local engineering profession. No one else can or should do the job. The objective should be to achieve a code, or minimum design criteria, for earthquake-resistant construction. Design itself should not be confused with design criteria. Flexibility to permit and encourage innovation - - but responsible innovation - - should be a keynote. And an appropriate administrative office should include people knowledgeable in the field who can, with the aid of professional consultants, place reasonable interpretations on the written word. It is never going to be possible to write enough words to cover every situation, nor is it desirable to try to do so. Perhaps too much has been written already into codes, and more reliance should be placed upon interpretations, preferably with the engineering profession through its recognized societies helping to provide these interpretations rather than to place this burden on the back of the building inspection department established to administer a code. I am inclined to think this is not only preferable; it is an obligation of the engineering profession.

INFORMATION AND INDIVIDUAL RESPONSIBILITY

Much has been said about the large volume of written material available today in the field of earthquake engineering. A solution involving an evaluation and condensation - - separating the wheat from the chaff has been suggested. Codes have been written, applied and abused, cussed and discussed. There is no alternative to a good code ably administered. Surveys are made, research is conducted, more reams of paper evolve. World conferences are held, regional conferences, symposia. Special reports, special discussion. All are in the interest of disseminating our ever-broadening understanding of the subject of earthquakes and how to build to resist them. All of these media are basically good. The main objective remains and that is with the help of all that is written, and with the help of all that is said, it still remains the individual responsibility of each earthquake engineer to provide the construction that will resist that earthquake that may come any day. Nothing that is written, nothing that is said, detracts one iota from that responsibility. When that responsibility is met face on by everyone so encumbered, what is written becomes incidental to the practice. In the final analysis, earthquake resistant structures are not created by talk, not created by drawings and specifications (although these help very significantly) but by what is built and how in all of its detailed ramifications. All of this basic objective is achievable by

men of good will operating in an orderly society under minimum but necessary restraints.

* * *

It has been a pleasure to have this opportunity to come to Vancouver and to participate in this international exchange of views in earthquakes and earthquake engineering, and I look forward with interest to succeeding papers and discussions.