SYNOPSIS OF PANEL DISCUSSION ON EARTHQUAKE STRUCTURAL DESIGN, PRACTICE AND OTHER SEISMIC MATTERS

This synopsis is transcribed from recordings taped during the Panel Discussion.

SYNOPSIS OF PANEL DISCUSSION

ON EARTHQUAKE STRUCTURAL DESIGN, PRACTICE

& OTHER SEISMIC MATTERS

Moderator: Mr. J.E. Rinne
Panelists: Symposium Lecturers

Question: What relationship, if any, has been established between strong motion characteristics and weak motion characteristics?

Dr. Hudson: We have had very little opportunity to compare directly the distribution of measured ground motions on different kinds of soils in both strong and weak motions. However, there has been one notable case in which this could be done and that was in the San Francisco earthquake of 1957 in which there were simultaneously recorded five strong motion records on instruments located on differing soil conditions, including rock. This gives us some available data to compare with similar measurements made for very small ground motions due to small natural earthquakes. While general conclusions cannot be drawn, there is some evidence to suggest that in stronger ground motions you do not see as big a difference in ground response in the differing soil conditions as you do with the very small motions. That is about all that can be said at the present time. It is a very important question which needs much more work. It is one of the main reasons why we are hopeful that the network of strong motion accelerographs can be much increased.

Question: In the design of subaqueous traffic tunnels against earthquake forces, do the experts consider that post tensioning or prestressing offers any advantage over conventional reinforced concrete?

Dr. Newmark: I would expect that prestressed concrete would offer some advantages and, under most conditions, it probably would be less expensive than ordinary reinforced concrete. There would be some advantages in prestressed concrete in ensuring water tightness and in keeping cracks closed, although if the stress levels were high enough to overcome the prestress then there might be more serious effects than in ordinary concrete. Thus, if the design level were set at the appropriate factor, I think there would be a range in which the prestressed sections would be more satisfactory and then for over-stressed conditions might be less satisfactory. It is a matter of judgment as to what hazards the designer estimates the tunnel will be subjected to and what he tends to do.

Question: Forces induced by an earthquake are essentially dynamic. The peak force is often reached within one second. Closer to the epicenter of an earthquake the force peak can be reached within a tenth of a second. The plastic behavior of material is usually observed under a low rate of loading or essentially a static rate of loading. Can one assume that plastic deformation or yielding still takes place at a high rate of loading?

Dr. Newmark: I would disagree with the comment that the peak stress is reached within a tenth of a second necessarily. The peak stress in a building with a period of several seconds would be reached within at least a second or so after the maximum excitation reaches the base of the building, which may well be during the middle part of the earthquake. What I think the questioner had in mind perhaps was something about the rate of loading, and this is not necessarily related to the time at which the peak stress occurs after the onset of the earthquake. The rate of loading in a structure under earthquake conditions is determined by the characteristics of the structure, the period of the structure primarily. None of the rates are fast enough to increase substantially the yield level of steel or the strength of concrete. We have increases in these yield levels under dynamic loading conditions arising from blast, where stresses sometimes reach their maximum, in the very stiff structures that are designed for blast resistance, in a matter of a tenth of a second or somewhat less. Even here the increases are not tremendously large as they might be in some other dynamic applications where peak stresses are reached in a matter of hundredths or thousandths of a second. Ordinarily we can neglect the change in strength, or increase in strength, and should neglect the increase in strength in concrete, steel, wood and other structural materials under earthquake motion conditions.

Question: One of the most important parameters influencing the response of a structure to an earthquake is the frequency of the structure. Can any guide be given on determining the frequency of structures with various geometrical proportions or different materials like steel, concrete, etc.?

Dr. Housner: There are, of course, methods for calculating the periods. If you know the force-displacement properties of the members of the structure and you know the mass of the structure you can calculate the period to an accuracy acceptable for engineering purposes. This is not too elaborate a calculation. However, reliable simple formulas for complicated structures are not available.

Mr. Rinne: There are a number of references in various technical journals and texts which would be helpful in this regard.

Question: Dr. Ward has stated that the base shear value given by the National Building Code and the Uniform Building Code are quite close to each other. However, because of the absence of allowable overstress in the National Building Code, this Code may give bracing members, for example, 33% heavier than the Uniform Building Code. Is the National Building Code in its present form, therefore, too severe?

Dr. Ward: It is rather difficult to assign a level which we should design for in the Building Code. The forces according to the National Building Code and the Uniform Building Code are the same, but as far as the stress is concerned the former is the more severe code. This is presently a matter being reviewed by the different committees that are responsible for the National Building Code.

Question: We have a twenty-seven storey reinforced concrete building resting on twenty feet of clay which in turn overlies bedrock. Our investigations indicate that the use of a raft foundation or a foundation supported by piles or caissions to bedrock are economically equivalent. In this case, should the building be founded on firm bedrock rather than on alluvial soil?

Dr. Seed: I do not believe that putting the building on piles through clay down to bedrock would influence the overall effect of the ground motion on the building since most practical pile systems are so flexible that they will simply deform with the clay. Precisely how stiff the piles would have to be to become stiff enough to have a significant influence is, I think, unknown. An even better question is whether it is worth putting a mat foundation on bedrock through the clay. Then, of course, the whole building acts as a stiffer unit. I do not think anyone has analyzed that question to be able to answer whether it would be stiff enough to have a significant influence.

Question: What secondary effects of earthquakes, such as fires, are likely to be serious? Are any authorities taking precautions to safeguard hydrant lines? Can the panel suggest any practical and reasonable economic means to minimize damage from secondary effects?

Mr. Steinbrugge: The problem with respect to fire is to see that the water system and the gas and underground facilities are protected. Areas must be valved in such a manner that in the event of a major earthquake any intensified breakage of water lines or gas lines can be quickly valved off and bypassed if need be. Wherever lines are still in operation it is possible, by an adequate valving system, to make use of whatever is available and minimize the fire hazard. I think what is called for is that each municipality should look at its own particular problems - what would they do, what lines would they have available, etc.

Question: What is the maximum recommended ratio of overturning moment to stabilizing moment about the edge of the footing of a shear wall?

Dr. Barnes: To obtain complete stability, of course, our safety factor should be one if you are sure of the case, but I think you would probably be into a soil problem if you got all your force of any magnitude on the corner of a shear wall, and you would probably have considerable foundation settlement unless you were on bedrock.

Mr. Rinne: I might add that in our California Structural Engineers Code we deliberately avoid the matter of the stability ratio for earthquake forces, which is what this amounts to, feeling that the soil pressure and stress situation would be the controlling influence and not the stability ratio per se. Wind, however, is another matter and there we have retained the one and a half ratio.

Mr. Barnes: As to what the factor of safety should be in the Code, that is something else again. For wind, most codes provide something like a factor of safety of one and a half for overturning. We have heard it said that in an earthquake there is not time to overturn. I would not want to count on that. There are times when you get tension on one side. This can be developed by bell-bottom piles, or caissons, or skin friction, etc. If it is not in the Code, I think the engineer should use good judgment in this sort of thing.

Question: Can the order of magnitude of ground displacement in an alluvium be predicted for an earthquake of given intensity and direction of propagation?

Dr. Seed: The amount of displacement can be estimated rather than predicted. One can divide a layer of soil into a number of slices, for which it is assumed that the deformations are pure shear. The real system can then be represented by a discrete parameter idealization which consists of a series of discrete masses connected by non-linear hysteretic type linkages. The basic soil parameters characterizing these linkage systems can then be established from soil test procedures. Any calculation of this type is necessarily based on a number of assumptions in the first place, and upon the accuracy with which soil properties can be measured in the second place. So that while a calculation can be made it is really only, I think, an estimate of the motions which would probably be found at the ground surface; local geologic effects would obviously have an influence on the ground behavior.

Question: Ground accelerations occur in the north-south direction at the same time as vibrations in the east-west direction. Is this taken care of in the current building codes by increasing the design forces? Also, would you comment on the nature of horizontal ground motions in perpendicular directions?

Dr. Hudson: Most past recorded strong motion earthquakes show about equal motions in the two horizontal directions and ordinarily slightly less amplitudes and higher frequencies in the vertical direction. In particular earthquakes, because of particular local geology, there may be some directional effects but ordinarily this is not the case.

Dr. Housner: The question of combining the horizontal motions for design purposes is a very pertinent one for some structures. For example, in a rectangular building, certain walls may be called on to resist only one component of motion. The question then is, of course, academic because you would design such walls so that they were capable of resisting either component. But there are some structures in which the same element has to resist both motions, and a good example would be a chimney-type structure. If you look at that question you will find that you must provide in the same member for both motions. There are several papers in the Proceedings of the Third World Conference which discuss this question.

Mr. Rinne: Our Codes indicate that the design earthquake forces are applied independently in the direction of the two principal axes. They also go on to state that the effects of the two should be combined to achieve the most adverse result. In a square building, for example, you analyze the two directions separately and while the principal forces are carried by the walls parallel to the direction of the forces, it behooves us to examine the conditions at the corners which could become quite vulnerable since they are acted upon by forces in two directions.

Question: What should be the approach of a rock mechanic's engineer who is asked to determine the probable frequency of an earthquake of given intensity in a particular location?

Dr. Hudson: I think about all one can do at the present stage of the subject is to examine carefully past records obtained from strong motion instruments located on rock and on fairly solid foundations and the spectrum curves that have been calculated from them. This should give a pretty good guide as to the frequencies that are likely to be encountered. There is a fair volume of literature reporting the records obtained from strong motion earthquakes, from underground explosion tests and from quarry blasts, that could be very profitably consulted.

Question: How may the vibrations in steel structures be damped to low intensity?

Dr. Housner: There have been cases where concrete or gunite linings have been put in steel stacks, precisely for the purpose of providing greater damping than the steel itself provides. However, in terms of a bare, steel, skeleton frame, I don't know of an inexpensive way of increasing the damping.

Dr. Barnes: The double arch sections above the restuarant at the Los Angeles airport are diamond shaped steel boxes. In a 23 m.p.h. wind velocity these sections began vibrating up and down with an amplitude of about one foot. Although designed for wind, as far as strength was concerned, the aerodynamic effect was overlooked. This problem was solved by using stainless steel guy wires at an added cost of about $7,600.

Dr. Ward: The towers for the Firth of Forth suspension bridge vibrated in the wind with a peak-to-peak amplitude of about seven feet at the top.

The emplitudes were reduced to about nine inches by attaching big concrete blocks to ropes which were connected to the top of the towers.

Question: What influence does a building have on ground motions as measured by a strong motion instrument located in its basement? Is this really the motion we are interested in?

Dr. Hudson: Most of the spectra that we have obtained are to a reasonable degree of accuracy really representative of the ground motion itself. There have been cases in which the motions have been simultaneously measured in the basement of a building and at a point in the ground at some distance away, where the motion could not possibly have been influenced by the building, and the spectra turned out to be virtually identical. In some cases, as for buildings on quite soft soils, it is evident that the motion measured in the basement of a building is not really the ground motion of the earthquake. In other words, the foundation material itself introduces a few extra degrees of freedom into the dynamics. However, I think in all cases in which this happens, you can recognize this clearly from the spectrum curves. You will find peaks on the curves corresponding to the building periods.

Question: Could you briefly comment on the type of earthquake problems considered in the design of the San Francisco vehicular tunnel?

Dr. Housner: The tube itself will be placed in the so-called mud under the bay, which has a thickness from 100-150 feet; the tube is about 30 feet deep and has a length of approximately 20,000 feet. The primary consideration was whether the soft soil in which the tube is to be placed would behave adversely during an earthquake, that is whether it would suddenly liquify to give permanent displacements which would damage the tube. Secondarily, when the ground vibrates it swings back and forth essentially like a bowl of jelly. You must estimate the amplitude of motion and the curvatures put into the tube to see that the tube is not overstressed or pulled apart. These things were considered in the design of the tube.

Question: What are some of the unresolved or controversial problems in earthquake engineering?

Dr. Housner: In my opinion, the chief earthquake engineering problem now is the manner in which soil behaves during earthquakes. The magnitude of that problem, compared to the small amount of study that has gone into it, makes that the crucial problem.

Dr. Seed: The preceding comment is a fair statement, and to take it further I would suggest that at the moment the biggest unsolved problem involving soils is one of analysis for the stability of natural slopes -- not embankments, but slopes where there is only one face, whether it be man-made, cut or natural slope.

Mr. Rinne: A practical problem which faces us as a profession is the need to take all the wonderful information presently available and convert it into design criteria form for the structural designer.

Dr. Housner: For all communities that live on the ocean front, the tsunami waves generated by earthquakes are a serious problem. Information is needed for predicting how big the waves may be and what they may do at a particular location. This is a very important unsolved problem.

Question: Having once gone into the plastic range, does a structure still have the capabilities of resisting a future earthquake?

Dr. Housner: This is just another way of bringing in the duration of ground-shaking. It is clear that the probability of collapse increases with the duration of the earthquake. I think there is no question that after having gone into the plastic range once the structure must be somewhat less resistant than it was before.

Mr. Rinne: This question is also related to the repairability of a particular structure. Merely filling up and painting over the cracks in a wall is not repairing damage and in subsequent earthquakes much damage can be wrought. On the other hand, if you have a structure wherein such damage as may have been inflicted by the first earthquake has been adequately repaired, then I think you are starting over again.

Question: Could you comment on the effect of earthquake generated waves and surges on the stability of dams?

Dr. Housner: It is quite possible to calculate the amplitude of the waves generated in a body of water from a prescribed ground motion. Presumably, you should take this into account in stability calculations. I think that when you carry out the calculation for a large reservoir you will find the amplitude of the wave is not large and it generally would not be an important item.

Mr. Steinbrugge: While I agree with the preceding remarks there are, of course, exceptions to the rule. The 1954 Dixie Valley earthquake caused quasi-resonance to one large reservoir, breaking out concrete walls. Also, in the Eureka earthquake of 1954 the roofs of digestive tanks were made to oscillate in terms of feet and caused damage. Other examples can be quoted. These anomalies are sometimes frequent enough that we should give some possible thought to them.

Question: Does the panel consider that the modal method of dynamic analysis of structures is superior to available alternative methods?

Dr. Housner: The question becomes, essentially, what simplified method can one use if one does not have the availability of a large computer to make an accurate analysis? I think that the approach using the ductility factor and the spectrum curve is the superior method.

Question: When a ductility factor is applied for dynamic analysis in the plastic range, is a load factor applied to obtain final design loads?

Dr. Housner: If I understand the question correctly the answer would be "yes." The principle behind this theory is that if you make the analysis for the dynamic case and determine the maximum displacements and decide to design for a ductility factor of 5, then what you are saying is that you are designing the structure so that it would reach the yield point when the ground motion was 1/5 the amount used for your calculation.

Mr. Rinne: Putting it another way, there has to be a factor of safety built into your ductility factor if the earthquake that you use for dynamic analysis is the one you want to be able to resist without failure.

Question: Would you comment briefly on earthquake insurance?

Mr. Steinbrugge: There is a rating organization in Canada and earthquake insurance is available. It often becomes a part of a package insurance program in larger organizations. In general, it is a function of the damageability of the structure.

Question: In the last few days nothing has been said about suspension bridges. I suspect that there may be a special problem here -- the ratio of the natural frequency of the deck to the piers and a possible conflict with the aerodynamic requirements of frequency. Could you comment on this?

Dr. Housner: This question was investigated in the design of the Tagus River Suspension Bridge now under construction in Lisbon. In that case the natural period of the span came out close to 20 sec., so that as far as the earthquake forces were involved the span contributed very little. The worst condition in the design was on the stability of the concrete piers before the span was placed; this was the critical problem.

Question: How can the ground motion record of an underground nuclear explosion be distinguished from the record obtained from an earthquake?

Dr. Milne: The approach seems to be through the use of a seismograph array. A whole group of seismographs are placed over an area and all the seismographs are reduced to one point. The arrivals of the P-waves are then summed. When analyzed in this manner the nuclear blast and the earthquake yield slightly different results.