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PHILOSOPHY OF ASEISMIC DESIGN*

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The practice of designing engineering structures in seismic zones has consisted of assuming a seismic coefficient almost arbitrarily and using it as a proportion of the vertical loads of the structure to be applied as a seismic force horizontally at the centre of gravity of the mass of the structure. In each country the seismic zones are divided on the basis of frequency of occurrence of earthquakes and the seismic coefficients are adopted zonewise. These coefficients have in some countries, some experience at their back in as much as many structures designed on their basis have done well during strong earthquakes. At the same time some other structures have failed to do so. This method has, therefore, proved fairly satisfactory and is in use throughout the world for average structures. For important structures like tall buildings, dams, bridges, tall industrial containers and hydraulic structures etc , it is now increasingly realized that a more rational approach is essential. The traditional approach suffers from the obvious defect that it is independent of the type of structure and soil conditions of the site where the structure is going to be built. In some codes of practice the soil condition is taken into account by increasing the seismic coefficient in the case of poorer soils, but in most countries this is not done. It may be stated here that whatever provisions exist in this respect are really not adequate for soils having a safe bearing capacity less than about 1 ton/sft In this country very vast areas of alluvial plains are thus not covered by these provisions.

A close study of damage during earthquakes in the last 20 years has indicated that the dynamic properties of structure play a great part in determining whether it is going to be damaged or not, besides, of course, the size and position of the earthquake itself. It has been observed that near the epicentral areas, tall structures having long natural periods of vibration have suffered much less than those having short periods of vibration even though they were otherwise stronger, (for example Skopje earthquake of 1963 in Yugoslavia). Similarly, at certain distance away from the epicentre where long period waves only reach the structures, tall structures have been damaged due to large deflections although the stresses induced by the earthquake forces were small (e.g. Alaska earthquake of 1964). Other features which have resulted in damage are unequal settlement (Fukui earthquake of 1948), liquefaction of soils in the foundation (e.g. Niigata earthquake of 1964) and poor construction. A study of the examples of poor construction, particularly reinforced concrete structures, has shown that excess of steel crowded up at joints and inadequate quantity of cement in concrete have resulted in failures of otherwise very well designed sructures.

It would thus be seen that the most important factors in aseismic design namely, (i) the dynamic properties of the structure (ii) foundation behaviour and (iii) the actual earthquake motion expected at site are not taken into account in the traditional method. A structure is designed for a static 'force' which is assumed to be equivalent to a dynamic motion of random nature.

Such a practice is quite understandable in small structures or some isolated structures where a detailed examination is not feasible, but for major structures it is possible now to examine the problem somewhat more rationally.

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In the last 30 years a large number of strong motion accelerograms have become available for several conditions, namely, epicentral areas such as Koynanagar earthquake, Parkfield earthquake etc., for point 30 to 50 miles away from the epicentre on rocky soils such as El Centro earthquake and Ferndale earthquake, and on soft soils such as Seattle and Taft earthquakes etc.

It will, of course, be an ideal situation if the strong motion records for the site itself were available since that will give the most reliable shape of ground motion, but in the absence of such a record it should be possible to choose one of the accelerograms recorded elsewhere for similar soil conditions. The accelerogram may then be used to test the stability of the structure through dynamic analysis under an actual ground motion. The seismic coefficient may be used as an equivalent force for preliminary design purposes. This would give a far more realistic picture of the structure under an actual ground motion.

Another aspect of rational design is to consider the overall capacity of a structure to resist dynamic forces by taking into account the total energy absorbing capacity rather than the stress level at some special points. A structure possesses a certain capacity by virtue of the properties of materials in it, its form and the maximum limit of deformation imposed by functional requirements and permissible damage. This concept results in considerable economy in design or at least a clearer understanding of how a structure is expected to behave during an earthquake.

The two ideas explained above are in increasing use in scientifically advanced countries in aseismic design practice and I hope they will be used increasingly in this country as well.