Preparing for Earthquakes :: Where India Stands

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You must know this… earthquakes take place at locations where there are mountains. If you want to know the exact locations, take the relief globe from your drawing room and run your finger along the mountain line. You now have the complete data on where most earthquakes have been occurring in the world. Now, that is not the end of it. Earthquakes can and have been occurring at other locations too, particularly where there are not necessarily any major mountain ranges; the 1993 earthquake in Deccan plateau of Marathwada in central India is a recent example of this from our country. This means that in India, virtually over 60% of the area is under the threat of moderate to strong earthquake shaking.

The Earthquake Hazard

Understanding earthquakes is an on-going process. Two questions are most frequently asked: (a) Why do earthquakes occur? and (b) Can we predict earthquakes? Let us address the first one. There is a large differential pressure and temperature between the center of the Earth and its surface; the pressure inside is about 4 million atmospheres and the temperature about 6000°C. So most matter inside the Earth is in the hot molten form of lava. This gradient coupled with the presence of magnetic field of the Earth, generates a circulation of the Earth's mass - from the North Pole to the South Pole along the axis and from South Pole to the North Pole along the surface. Of course, the rate of this motion is very small, on an average of about 2 inches per year in active earthquake areas. The journey of the Earth's mass from the South Pole to the North Pole is what all of us participate in. Understandably, since the pace of motion is not uniform across the entire Earth, some parts move faster than the others do. Consequently, the Earth's surface can be visualised to consist of a number of pieces, called tectonic plates, which move towards the North Pole. Also, the motion of these plates is not a smooth one but happens in fits and starts, thanks to the limited strength of the Earth's material to resist the strains generated by these relative motions. So, every time a tectonic plate moves more than its neighbour and slips over it, large amount of strain energy is suddenly released and there is a tremor of the Earth, which we call as an earthquake. The junctions of these plates are named as faults. Again, many of these faults lie along the mountains that all of us observe.

Now, coming to the second question on predicting earthquakes, it is virtually impossible to predict when and where the next earthquake will occur in the world. Reports of having predicted earthquakes are very hotly debated even today. Most prediction studies are based on a presumed structure of the Earth's cross-section and on very simplified models of the movement of the earth's crust. These developments are based on a limited data that too from the top few kilometers of the Earth's crust. Therefore, prediction studies have effectively not taken off.

The Earthquake Preparedness

But whether earthquake prediction is possible or not, one has to learn to live with them if one insists on living in areas with earthquake hazard. So, most effort of scientists and engineers is focused on earthquake preparedness, from both engineering and sociological points of view.

To prepare facing earthquakes, we must know two basic characteristics of earthquakes, namely Magnitude and Intensity. The former is a measure of the amount of energy released by the earth during the earthquake. It is represented on a numerical scale of Richter Magnitude using the natural logarithm of maximum displacement experienced by the ground. An earthquake of Richter magnitude around 5.0 releases as much energy as that discharged by the Hiroshima nuclear bomb. As the magnitude goes up by 1.0 on the Richter scale, the energy release increases by about 30 times.

On the other hand, the consequence of the above energy released by the earth is the damage and destruction to natural and man-made facilities. Understandably, the damage will vary depending on the proximity of the facility to the region where the slip has taken place along the earthquake fault. The extent of this damage is measured on another scale called the Modified Mercalli Intensity scale. This scale is a qualitative one and represented on a Roman scale I to XII. Shaking from about intensity IV is felt by all human beings. Shaking intensities VIII and IX reflect heavy damage in buildings. When shaking of the Earth reaches the upper end of XII on the Modified Mercalli intensity scale, the surface of the Earth is severely distorted.

Based on the occurrence of earthquakes in the past in and around India, the country is divided into five seismic zones, namely zones I, II, III, IV and IV, where I is the least severe and V is the most severe. Based on this zoning, about 60% of India's land area is under moderate seismic threat or more, i.e., under seismic zone III or above. In fact, the 1993 Killari earthquake in which over 10,000 persons died, occurred in an area that was considered to be non-seismic, i.e., in seismic zone I. After this, the seismic zone map has been revised to have only four seismic zones, with zone I merged to zone II. Even now, amongst our four mega-cities, Delhi is in seismic zone IV, while Bombay, Calcutta and Madras are in seismic zone III. Despite this level of seismic hazard, little is being done, particularly in these cities, to make the development akin to earthquake shaking. The quality of both design engineering and construction is way behind the expected seismic standards.

Earthquake-Proof *versus* Earthquake Resistant Constructions

The common man concept of an earthquake-proof house is only heuristic. If one attempts to make a house that will not incur any damage during a large earthquake, it is very likely that another pyramid will be built, though not of the Egyptian scale. Yes, it is very uneconomical to build houses, or any structure for that matter, that don't incur any damage during strong earthquake shaking. Therefore, some amount of damage is permitted in structures, the extent being decided based on the performance demand on the damaged structures. Hence, engineering effort is to balance the cost of the structure with the controlled-damage in it during an earthquake. The very engineers who are already well conversant with making structures for non-earthquake conditions, can design such structures, termed as earthquake-resistant structures, with a little additional education

Design of structures for earthquakes is different from that for any other natural phenomenon, like wind and wave. An earthquake imposes displacement on the structure, while winds and waves apply force on it. The displacement imposed at the base of the structure during an earthquake causes inertia forces to be generated in it, which are responsible for damage in the structure. As a consequence of this, the mass of the structure being designed assumes importance; the more the mass, the higher is the inertia force.

After a whole gamut of earthquake experiences collected during the 20th century from across the world, today the earthquake engineering community believes that there are four virtues of an earthquake-resistant structure. These are: (a) sufficient strength – capacity to resist earthquake forces, (b) adequate stiffness – capacity to not deform too much, (c) large ductility – capacity to stay stable even after a damaging earthquake, and (d) good configuration – features of building size, shape and structural system that are not detrimental to favourable seismic behaviour. Engineers designing structures for winds and waves, tend to mostly concentrate their attention on the first two aspects, namely strength and stiffness. However, in earthquake design, the latter two virtues assume a more important role. The following parallel helps in better remembering these four virtues. In looking for a bride-groom for your daughter, you are looking at a prospective son-in-law who (a) is rich, so that he can take care of the shopping requirements of your daughter, (b) is educated, so that he can easily find another job if the company he is working in winds up, (c) can bend-backwards, to the rather abrupt changes in mood of your daughter, and (d) has no vices (Of course, this depends on what your vices are!!).

Earthquake Engineering Education in India

India has had five moderate earthquakes (Richter Magnitudes ~6.0-6.4) since 1988 as reminders to improve the earthquake preparedness of the country. And, historically, some of the great earthquakes (Richter Magnitudes >8.0) have occurred in India and that too four in the last 115 years. The world seismic community has taken advantage of the experiences from these events, but we in India have paid no heed to these reminders. Today, the number of persons interested in improving the earthquake preparedness in the country is effectively very small. Moreover, most of these persons are in the academia. And, when members of the academia suggest steps for improving the preparedness, they are unfortunately charged with working for their own cause as they tend to be branded as benefactors of increased activities in this direction.

There is poor/no campaign of sensitising the decision-makers and Government on the need for earthquake preparedness. Moreover, in the past four decades, the earthquake engineering and preparedness education has been primarily restricted to within the classrooms. The academia has failed in guiding the country with the right inputs at the right times. Every time an earthquake took place in the country, the situation was not capitalised on. Earthquake engineering is taught as a specialisation only at the University of Roorkee and as an elective course at a few of the IITs. In fact, the subject has been so mystified that it is unfortunately considered to be very different from the mainstream civil engineering. Consequently, there is a serious shortage of trained civil engineering manpower with background in earthquake-resistant constructions.

Even today most consulting engineers do not follow even the available Indian Standard design provisions for making earthquake-resistant constructions, even in projects being executed in the Delhi, which is in seismic zone IV. But, over the last century, seismic engineering has evolved in countries like Japan, New Zealand and USA, and is reasonably well documented. The Indian professional community can learn from this vast experience available across the world.

The IIT Kanpur Effort

The first efforts of IIT Kanpur in the direction of earthquake engineering education are owing to the American earthquake-engineering specialist Professor Glen V. Berg of the University of Michigan, who visited the Institute during the late 1960s under the Kanpur India-American Program. Professor Berg with the then Indian faculty members at this Institute extensively studied the 1969 Koyna Earthquake of western Maharashtra. The visit of Professor Donald E.

Hudson (of Caltech) to the campus during the same time provided a major impetus to the activities. Ever since, the activities have grown…

Today, IIT Kanpur has state-of-the-art experimental facilities and analytical tools to conduct research and development in the area of earthquake-resistant constructions. Over the last two decades, IIT Kanpur's contribution has been multifold. The effort started with the introduction of an elective in Earthquake-Resistant Design for the M.Tech. students of the Structural Engineering stream of Civil Engineering. The second thrust provided at IIT Kanpur was in the creation of a modern earthquake engineering research laboratory, which has equipment for studying both prototype structures in the field, and the component and scale-models in the laboratory. In the past sixteen years, IIT Kanpur was awarded a significant number of sponsored research projects by various national agencies. These projects include studying the crustal structure of the Earth by field measurements, identifying the possible earthquake faults using remote-sensing data, measuring and studying earthquake ground motions, experimental studies on prototype and scale-model specimen, probabilistic studies of damage in structures subjected to earthquake shaking, and development of seismic codes. Over Rs.150 Lakhs has been received as research funding for these projects.

Amongst the most significant professional contributions made by the faculty members of the Institute are the development of Indian Standards for improved earthquake constructions, and the training of professional engineers on seismic design of buildings and bridges. Very recently, efforts are being made to set-up the National Information Center for Earthquake Engineering (NICEE) at IIT Kanpur. The center when put in place will be a clearinghouse of the precious international literature for the researchers and professionals in the country. A new area where IIT Kanpur is taking a lead is in inter-institutional collaborations. In the recent times, formal technical collaborations in the area of earthquake engineering with Central Building Research Institute, Roorkee, and with the Tribhuvan University, Kathmandu, have picked up considerable momentum.

The Nation at the Cross-Roads…

And yes, you must know this too… earthquakes don't kill people; it is the structures built by man, that kill people. With frequent reminders of moderate earthquakes staring into our eyes, India is at the crossroads of earthquake preparedness. It has only two options to choose from – prepare now or pay later. For a country with relatively fragile economy and with a very dense demographic distribution, the second option will be a very costly proposition. Even if it means an uphill task, time is ripe to take the challenge… with open arms.