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Earthquake Disaster Management in Different Countries - Influence of Culture of Region

S.K. Prasad*

Abstract

This paper attempts to provide an insight to some of the problems associated with infrastructure from earthquakes and the performance of infrastructure during earthquake all over the globe. The Indian scenario is briefly discussed in comparison to other countries and hence emphasis is made to enhance practices of earthquake resistant construction in the country. Some of the concepts of earthquake engineering are explained through pictures from past earthquakes. It is emphasised that the places where the seismic design is followed, the damaging effects of earthquake are minimum. It is also stressed that earthquake disaster management in India should further improve so as to reduce loss of life and economic loss during disasters. Besides, the influencing effects of culture of the region on effective earthquake disaster management are briefly discussed. It is inferred that cultural barriers may hinder the disaster management process at least in the present situation. However, gradually disaster management is likely to become global and reduce the inter-cultural barriers.

Key Words & Phrases: *Performance of structures, cultures& liquefaction*

Introduction

Earthquakes are perhaps the most unpredictable and deadliest of all the natural disasters. It is impossible to predict when the next big earthquake strikes, for how long and at what location. Fig. 1 and Fig. 2 indicate the disastrous effects of earthquake compared to other natural disasters such as cyclone, flood, volcanic eruption, forest fire etc. Both the total number of deaths and economic loss to build environment exceed 50 % of total during earthquake. The Fig. 3 and Fig. 4 present the catastrophic effects of earthquake. Bhuj earthquake of 2001 that struck the western part of Gujarat on the republic day resulted in about twenty thousand loss of life. Most of the infrastructure suffered serious damage and many towns and villages were reduced to rubble. Fig. 3 presents a small town called Rapar close to Bhuj immediately after the earthquake that was reduced to ruins. The situation of Port Au Prince, the capital city of Haiti (near West Indian Islands) is even worse. Out of the total population of 30 lakh people in Port Au Prince, 2.5 lakh people perished during one earthquake of 10th January 2010. Can we imagine any other disaster taking away so many lives (one out of twelve)? Infrastructure was completely reduced to devastation and life of the people was in dire state. Fire in the city could not be extinguished for days as there were no fire personnel

* *Professor of Civil Engineering, S. J. College of Engineering, Mysuru 570 006.*

to fight fire, dust in the atmosphere created by falling concrete and masonry structure could not be removed for days. Even the presidential palace could not survive the jolt. Worse was the fact that even after two years of the event, much of the debris was not removed indicating poor effort by the government to bring back the normalcy.

At this moment, it is useful to look at Table 1. The table compares the performance of different countries, namely, Haiti, India and Japan during different earthquakes. The damaging effect is measured in terms of loss of life. The earthquakes are so chosen that their effect at the ground level in terms of energy released or power generated is nearly the same. For this purpose, earthquakes of similar magnitude and similar focal depths are chosen. Though there can be other factors affecting the performance, the comparison clearly shows that loss of life is exorbitant in Haiti and is hardly anything in Japan. Loss of life in India lies in between.

This indicates the importance of practice of earthquake engineering. Japan has good awareness of earthquakes and is affected by many big earthquakes often. Hence, research in the area of earthquake engineering is substantial permitting the construction of engineered structures. However, the knowledge of earthquake engineering is poor in Haiti and India has a long way to catch up with Japan.

Table 1 : Comparison of Damaging Effects of Earthquakes in Different Countries

HAITI	INDIA	JAPAN
Haiti Earthquake	**Bhuj Earthquake**	**Ryukyu Island Earthquake**
Port Au Prince	Bhuj, Gujarat	26 February, 2010
12 January, 2010	26 January, 2001	Mw 7.0, **1 Death**
Mw 7.0	Mw 7.3	**Izu Island Earthquake**
MM X	MM X	9th August, 2009
Focal Depth 13 km	Focal Depth 15 km	Mw 7.1, **0 Death**
2.5 Lakh Deaths	**20,000 Deaths**	**Iwate Miyagi Nairiku Earthquake**
3 Lakh Injured	1.67 Lakh Injured	14 June, 2008
1.3 Lakh Displaced	-	Mw 6.9, **12 Deaths**
1.0 Lakh Houses Destroyed	2.0 Lakh Houses Destroyed	**Noto Peninsula Earthquake**
2.0 Lakh Houses Damaged	4.0 Lakh Houses Damaged	25 March, 2007
		Mw 6.9, **1 Death**
		Kuril Island Earthquake
		15 November, 2006
		Mw 7.9, **0 Death**

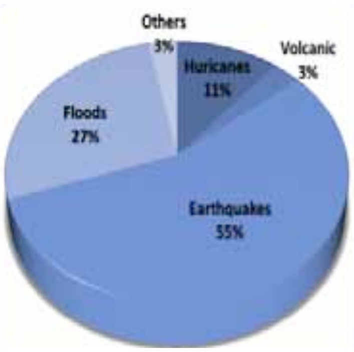

Fig. 1: Loss of life from natural disasters

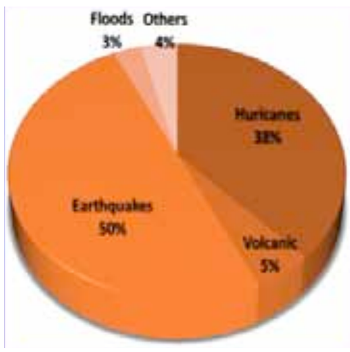

Fig. 2 : Loss of built environment from natural disasters

The Table 2 provides another important statistics of damage during different earthquakes in terms of loss of life and other loss. It is interesting that the countries where the knowledge of earthquake engineering is substantial suffered fewer loss of life. Countries like India, Indonesia, Iran, Turkey and Haiti suffered big loss of life. Japan was vulnerable in 1920s, but is equipped to handle big earthquakes better. Presently, Japan, USA, New Zealand produced well engineered structures under all circumstances, while others are behind. The Table 3 presents the top ten earthquakes ever recorded globally. It is interesting that among them five were experienced in the last nine years, six of them generated tsunami and vulnerable countries suffered more damage in terms of loss of life.

Fig. 3: Rapar town in Gujarat reduced to rubble after the Bhuj earthquake of 2001

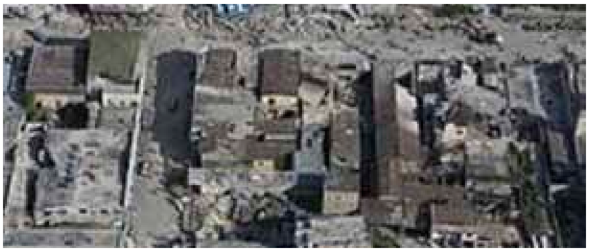

Fig. 4: Down town area of Port Au Prince, capital city of Haiti after the earthquake in 2010

Table 2: Country-wise damage assessment in terms of loss of life during earthquake

Region	Date	M	Death	Injured & Homeless
Kanto, Tokyo	1st September, 1923	7.9	123000	381000 houses burnt, 694000 houses damaged
Nicaragua	23rd December, 1972	6.2	8000	20000 injured, 260000 fled from city
Izmit, Turkey	17th August, 1999	7.8	18000	50000 Injured
Chi Chi, Taipei	21st September, 1999	7.3	2500	Thousands Injured
Gujarat, India	26th January, 2001	7.9	20000	12 Lakh Homeless
Seattle, USA	28th February, 2001	6.8	1	272 Injured
Kaman, Iran	26th December, 2003	6.6	20000	80000 Casualties in 1 Lakh Population
Sumatra, Indonesia	26th December, 2004	9.1	226000	Huge loss
Ryukyu Island, Japan	26th February, 2010	7.0	1	Insignificant
Haiti	10th January, 2010	7.3	250000	300000 injured, city reduced to rubble
Canterbury, New Zealand	4th September, 2010	7.1	185	Many buildings collapsed

Table 3: Top Tem earthquakes ever recorded based on magnitude

Sl. No.	Magnitude	Date	Place	Damage
1	9.5	22/05/1960	Chile	5000 deaths, 20 Lakh homeless
2	9.2	28/03/1964	Alaska	125 deaths, Tsunami
3	9.1	26/12/2004	Indonesia	2.26 Lakh killed, Tsunami
4	9.0	04/11/1952	Russia	0 death, Tsunami
5	9.0	11/03/2011	Japan	15000 deaths, Tsunami
6	8.8	27/02/2010	Chile	500 deaths, Tsunami
7	8.8	31/01/1906	Ecuador	1000 deaths
8	8.6 – 8.9	11/04/2012	Indonesia	0 death
9	8.7	04/02/1965	Alaska	0 death, Tsunami
10	8.6	28/03/2005	Indonesia	1300 deaths

Indian Scenario

India is not free from earthquakes. India has suffered many big earthquakes in the past. Many earthquakes of magnitudes 7 and above have hit Gujarat, Kashmir, North East and Andaman Islands. Latur earthquake of 1993, Jabalpur earthquake of 1987, Uttarakashi earthquake of 1991, Chamoli earthquake of 1999, Bhuj earthquake of 2001, Sumatra earthquake of 2004, Kashmir earthquake of 2005 and Sikkim earthquake of 2011 are the more recent ones to cause damage to infrastructure and loss to built environment in addition to taking away many lives and injuring many. Considering the seismic activity, closeness to Indo-Australian Plate Boundary and vulnerability at different locations, India is divided in to four seismic zones. Zone II is seismically least active and Zone V is seismically most active. In seismically most active zones, earthquakes generating higher levels of shaking are expected more often. Hence, the structures are to be designed for bigger horizontal force to take into effect the shaking. Many builders always argue that cost of construction increases by considering earthquake force. It should be noted that the present day's emphasis is not on economy, but on safety. By constructing structures considering all unexpected and extreme loadings, we will let the occupants of the building have a lot of confidence to live in. Further, it should be noted that we normally spend 70 % of total expenses on construction towards cosmetics such as wooden fixtures, granite cladding and other beautification measures. The increase in cost is only for the structural members that amount to about 30 % of total cost. Even if the cost increase is 15 % of structural cost due to consideration of seismic effects, the resulting increase in total cost is less than 5 % which should easily be affordable. Another issue with most architects is saving in space with reduced size of members such as columns or concealing the column inside the wall. This amounts to putting narrow columns with stiffness different in different directions. If earthquake strikes in the direction of highest stiffness, it is definitely advantageous and the structure performance well. However, in other directions structure will be vulnerable. Hence strong columns with equal stiffness in all directions are the best solutions for structures in seismically active zones. Hence, there is an urgent need for proper coordination between policy makers, architects, structural engineers and builders to aim at very strong foundation, strong columns and not so strong beams and slabs that provide overall ductility and flexibility to structures.

Issues on Performance of Structures During Earthquakes

As it is well known, earthquakes induce horizontal, dynamic and oscillatory force. Earthquake force is totally unpredictable. Many peculiar things happen because of lack of knowledge about nature's behaviour under extreme loading. All structures are built on ground and hence performance of ground during earthquake requires extra care. Soil is perhaps the most complex and most used among all construction materials. But, it possesses many interesting characteristics. It exists in different colours, it is sensitive, it possesses memory and it changes its properties with time. All these properties match those of human beings. Hence, soil should be treated as a material with life. Any mistake committed on part of engineer may result in a huge problem. We should therefore avoid abusing soil.

Structures built on and with soil may be referred to as geotechnical structures. Foundations, slopes, retaining walls, embankments, earth and rockfill dams, tunnels are such structures which are in direct contact with soil. Soil is a complex material and earthquakes are unpredictable. Hence earthquake geotechnical engineering deals with highly complex and unpredictable aspects and it is therefore a big challenge to engineers to understand the performance of different geotechnical structures during earthquakes. Some of peculiar performances of these structures during earthquakes are presented in the photos.

Fig. 5 presents cars taking bath in a pond. There never was a pond before the earthquake. Effect of Hyogo Ken Nambu earthquake in 1995 in Japan was such that an underground metro station in Kobe collapsed and foundation soil experienced liquefaction resulting in ground water moving up and ground experiencing settlement. Fig. 6 presents the case of four storeyed apartment buildings in group built of Reinforced Concrete framed construction at Kawagishi Cho in Niigata. The foundation soil comprised of saturated loose silty sand that experienced liquefaction during the 1964 Niigata earthquake. This resulted in different buildings experiencing different levels of rotation and one of them almost completely toppled. The studies related to liquefaction started gaining importance after this earthquake.

Fig. 5: Effect of liquefaction and collapse of underground metro station during Kobe earthquake of 1995

Fig. 6 :Toppling of Apartment buildings at Kawagishi Cho due to foundation soil liquefaction during Niigata earthquake of 1964

The Fig. 7 presents the performances of a twenty one storeyed steel building and another multi storeyed Reinforced Concrete building in the background during the 1985 Mexico earthquake. While the steel structure was completely destroyed the other building was intact after the earthquake. This earthquake clearly brought out the site effect. The depth of overburden, number of layers, depth of ground water table and type of soil etc., provide different responses at the ground level and different structures perform differently. There are possibilities of resonance affecting a particular type of building during some earthquakes at different locations. The Fig. 8 presents the level of deformation experienced at the ground level during the Canterbury earthquake of 2010 in New Zealand. The amount of shear experienced by the ground is visible by the distortion suffered by railway track.

Fig. 7: Total collapse of 21-story steel frame office Building and building standing in background during Mexico earthquake of 1985

Fig. 8: Railway track subjected to shear due to ground movement during Canterbury earthquake of 2010

The Fig. 9 shows the performance of a two lane highway on a gentle manmade slope during the East Japan earthquake of 2011. It is interesting that the lower half of the road suffered a slide down wards along the slope while the other half remained intact. It is really difficult to answer why exactly one half experienced slope failure. Perhaps the compaction was not proper, the effect of shaking was more or soil was poor in the lower half. The Fig. 10 shows a manhole 373 km away from the epicentre of the same earthquake in Tokyo having come up as if to see what is on ground. It appears that manhole was bored to be underneath the ground. This is due to the effect of liquefaction that generated excess pore water pressure which was sufficient to lift the relatively light weight manhole up to ground level. What is surprising is how much seismic force was generated to liquefy the ground so far away from the epicentre.

Fig. 9: Half of the highway on gentle slope experienced slide while the other half was intact during the East Japan earthquake of 2011

Fig. 10: Manhole above ground during East Japan earthquake of 2011 at Tokyo 373 km away from epicentre. (Photo: Prof. Towhata)

The Fig. 11 shows the performance of two reinforced concrete buildings in Adapazari during the Izmit earthquake of 1999 in Turkey. It is interesting that the two buildings experienced lean in opposite directions as if they are angry on each other. This is the effect of liquefaction of foundation soil leading to loss of strength and stiffness. Liquefied ground resulted in the buildings to be unstable and tilt in the direction where the weight was more concentrated. The Fig. 12 shows a bus precariously standing on the elevated Hanshin express way in Kobe after the Hyogo Ken Nambu earthquake of 1995 in Japan. The movement of foundation soil below shifted the piers relative to one another resulting in the slide of top deck slab. The driver of the bus must be really praying for his luck.

Fig. 11: Two apartment buildings leaning in opposite directions because of ground liquefaction during Izmit earthquake of 1999

Fig. 12: Deck slab of elevated road displaced due to support movement during the Hyogo Ken Nambu earthquake of 1995 leaving the bus cantilevering precariously

The Fig. 13 presents the case of a collapse of multi-storeyed Reinforced Concrete apartment building during the Bhuj earthquake of 2001. While the entire building collapsed, the lift portion survived. Perhaps the designer was more cautious while dealing with the lift portion as lift generated dynamic force during its motion and provided the lift portion within four columns. What he forgot was to properly connect this portion with the neighbouring structure and did not perhaps design that portion for any lateral resistance. While the entire frame collapsed, the lift portion stood erect without any damage. This portion is the earthquake resistant construction and not the rest. The Fig. 14 presents the structure of olden days called Bunga that was common in Gujarat and Rajasthan about 200 years back. NGOs built a model of Bunga to state that such Bungas survived many earthquakes and testing time with other extreme loadings while the present day structures built by today's engineers cannot survive such lateral forces. Hence, the inference drawn by the NGOs is that it is the civil engineers who kill people and not the earthquakes. Can we accept such statements as Civil Engineers? Definitely, it is not possible to accept. Today's Civil engineer is much more knowledgeable than the one of the past. We can design and construct more complex structures under difficult conditions. However, we still have a long way to go to understand nature. As a Civil Engineer, one cannot accept that we are the killers. But, we all have to work with more caution, and proper coordination for construction under difficult situations.

Culture stands for the habit of majority of people in a region. The habits include the effects of language, religion, level of education, knowledge, whether rich or poor, influence of other places, convenience of transportation and so on. It should be noted that all forms of disaster management from Response to Recovery, Mitigation and Preparedness should address the fact that the local culture should be respected and practiced. Normally, many relief workers from across the globe will work during the event and they should be well trained to stick to the habits of the region. The dresses worn, type of food consumed, even the type of medicine administered will all have local effects. For instance, disaster management in Japan requires the provision of Japanese food with chop sticks, in Europe and America local food with spoon and fork should be served. Whereas in India, hands will act as chop sticks, spoons and forks and extreme care is necessary to maintain the hygiene. During the response period, care should be taken to not upset already suffering citizens with practices that they are not used to. Further, during the recovery stage, most important aspect is to repair, rehabilitate and retrofit the existing structures to bring back normalcy at the earliest. Familiar construction methods with locally available materials and technology should be adopted. Further, the local design methods and code provisions should be followed to effectively transfer normalcy back in the region. All these involve understanding the culture of the locality before adopting relief work for effective disaster management.

Conclusions

This paper is written to present some peculiar happenings during the earthquake with special emphasis on the performance of geotechnical structures. The following are some inferences from the paper.

1. Earthquakes are unpredictable, and most scary among all the natural disasters both in terms of loss of life and loss to the built environment.
2. The effects of earthquake are less pronounced in places where seismic design is adopted and the damage is more pronounced in countries with poor understanding of earthquake resistant design and construction.
3. Liquefaction is one of the major problems in the foundation soil. Though, not every soil experience liquefaction, soil that liquefies creates loss in bearing capacity, changes in earth pressure, and increase in stress level etc. Mitigation against liquefaction is essential.
4. Site effect is another important geotechnical aspect. Ground amplification, degradation in strength and stiffness of soil etc., should be evaluated to properly assess the performance of site during earthquake.
5. Land slide and slope failure are other problems that should be tackled considering seismic effects.
6. The overall performance of system during earthquake considering super structure – foundation – soil taking part in vibration should be given emphasis.
7. No structure can be made earthquake proof under all situations. Hence, ductility should be imparted to the structure to give sufficient warning before failure.
8. It is important to give emphasis to safety first and then economy. No sacrifice in terms of safety should be permitted to achieve economy in either cost or space.
9. Culture of a region has influencing effects on disaster management. This issue should be addressed by the policy makers and involve personnel who can understand adhere to the local culture.

Fig. 13: Lift portion of an apartment building intact while the rest of the structure has collapsed in Ahmedabad during Bhuj earthquake of 2001

Fig. 14: NGOs during Bhuj earthquake of 2001 presenting BUNGAs of past to state that Civil engineers are killers, not earthquakes

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