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Damage to Tall Structures Situated at Long Distance from Epicenter Due to Long Period Seismic Waves and Effect on Structures on Filled Lands

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DAMAGE TO TALL STRUCTURES SITUATED AT LONG DISTANCE FROM EPICENTER DUE TO LONG PERIOD SEISMIC WAVES AND EFFECT ON STRUCTURES ON FILLED LANDS

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ABSTRACT

Damages during earthquakes are mostly confined to few tens of kilometer radiuses from epicenter and are located within the highest Intensity Isoseismal. In addition to this it has been seen that the Long Period Surface Waves cause heavy damage to tall structures (height > 17 m). Such damages have been observed during Mexican Earthquake of 1985, Bhuj Earthquake (India) of 2001 and Pakistan Earthquake of 2005. The destruction had occurred at 520, 310 and 150 km distance from the epicenters of the above three earthquakes. The damage is accentuated if the structures happen to be located on the filled land. With increasing urban expansion a number of cities are now becoming seismically vulnerable.

INTRODUCTION

Occurrences of destructive earthquakes have been a periodically occurring disaster in the active seismic belts. It has been observed that though the magnitude and intensity of moderate size earthquakes of the order of 5.5 to 6.5 and Intensity VII have been causing more damages in some Asian, Latin American countries such as India, Iran, Pakistan, Papua New Guinea, Costa Rica, Ecuador etc. Damages in the vicinity of epicenter are called as Epicentral damages while damages due to Long Period Surface Waves are called as Distant Damage. The Distant Damages are more predominant in the case of large to very large magnitude earthquakes of magnitude more than 7.5 or so. The large magnitude earthquakes cause epicentral and distant damages. During last thirty years following destructive earthquakes, about 50,000-deaths have occurred. All these damages are epicentral damages. (Balakina)

No.	Date	Location	Magnitude	Death
1	31 May 1970	Chimbote	7.9	50,000
2	27 Jul 1976	Tang Shan	7.5	655,000
3	20 Jun 1990	Iran	7.4	48,000
4	26 Dec 2004	Indonesia	9.1	285,000
5	08 Oct 2005	Pakistan	7.4	95,000

Table 1. Some destructive earthquakes during 1970 - 2005 Having death more ≅ 50,000.

The epicentral damages have been observed, studied and reported since long. Developments in Earthquake Engineering, Soil Structure Interaction, Liquefaction, Aseismic Design and Construction have been useful in making structures safer from seismic forces. It has been observed especially in America and Japan that the buildings are able to withstand the seismic forces. During the Bhuj (Gujarat) earthquake of magnitude 7.8 in India on 26 January 2001 about twenty thousand people died. But during a similar magnitude earthquake in Seattle within one month from the Gujarat earthquake had no casualty.

CASE HISTORIES OF DISTANT DAMAGES

The oldest record of distant damage due to Long Period Surface Waves is available from India. During an earthquake of magnitude around 7.0 to 7.5 in the Himalayas a tall Monument in Delhi known as Qutab Minar lost its upper three floors (Oldham, Bapat et al). The height of this world's oldest brick minaret is 72.5 meters. The base and top diameters are 14.3 and 2.7 meters respectively. This is shown in Fig.1

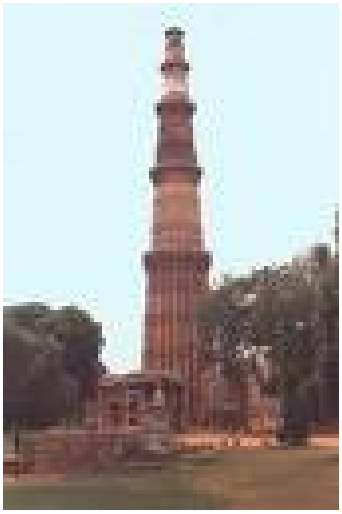

Fig.1 Qutab Minar at New Delhi. Height 72.5 meters.

During an earthquake of magnitude around 7.0 in the Himalayas on 01 September 1803 the minaret had lost upper three floors. The distance of the epicenter in the Himalayas from Qutab Minar in Delhi is estimated to be around 300 km. This was subsequently repaired and the structure was brought to its original condition.

The recent contemporary example is from Mexico City. During the 19 September 1985 earthquake on the Pacific Coast of Mexico, the tall buildings in Mexico City suffered heavily. See Fig 2. The figure shows photo of a hotel building constructed in 1950. The resonant frequency of building coincides with the ground vibration leading the large amplification. (Singh S.K.).

Fig.2 Failure of Hotel Continental in Mexico City. Site located at 410 km from epicenter.

While two or three story buildings had not suffered any damage. The distance between the epicenter and the Mexico City is about 410 km. The magnitude of the earthquake was 8.1. This was the most destructive earthquake in recent times in Mexico. It had taken a death toll of about 25,000 lives and huge economic loss to the country.

The second contemporary example of distant damage is available from Bhuj (Gujarat) India Earthquake of magnitude 7.9 of 26 January 2001. There was heavy epicentral damage and total death toll was about 20,000. The City of Ahmedabad located at a distance of about 320 km from the epicenter. There was heavy damage to tall structures (height > 17 m) to damage to tall structure in Ahmedabad City (Iyengar). Fig.3 shows the damage of building at Ahmedabad. The latest example is from Pakistan. (Pande et al) During the 08 October 2005, magnitude 7.6 earthquake tall buildings in the town of Islamabad were destroyed. Fig. 4 shows damage to a tall building in Islamabad located at a distance of about 150 km from epicenter. The distance between epicenter to Islamabad is about 150 km.

Fig.3. Damage to tall structures at Ahmedabad (India). The City of Ahmedabad is 320 km from epicenter.

Fig. 4. Damage to tall building at Islamabad in Pakistan. The damage site located at a distance of 150 km from epicenter.

DISCUSSION

The four cases from Delhi (historical) and Mexico City, Ahmedabad and Islamabad (contemporary) have clearly indicated that the Long Period Surface Waves are extremely destructive and the tall structures are highly vulnerable to damage due to these waves. (Lomnitz) In some countries

seismic codes may or may not provide for such damage. The Mexican seismic code was revised to account for this effect. The Bureau of Indian Standards has yet to amend the code for such effect. In countries, where there is no suitable clause for the effect due to Long Period Surface Waves, suitable codal provisions may be made or the provision may be amended.

Some areas have become more vulnerable to distant damage. As a result of shrinking urban land in several Asian countries, the urban structures are having taller structures. At some locations, shortage of land has forced the planners to opt for tall or multi story structures on reclaimed lands. Cities such as Hong Kong, Mumbai (Bombay), Karachi etc have reclaimed large areas in sea by landfills. The observations during Kobe earthquake has shown that the structures on filled land suffer more damage as compared to structures on natural grounds. The Persian Gulf Countries such as Dubai, Kuwait, Bahrain, Oman, Muscat etc have undergone fast development and progress during last three decades or so. The main industry is Petroleum industry. In addition some of these locations have become a tourist attraction. Holidaying and vacationing in the Gulf has become very attractive. At a number of locations the structures are very tall. The Gulf area is almost free from major seismic activity. But since last five to ten years it has been observed that earthquakes of magnitude 6.0 and above near Bandar e Abbas in south Iran have caused shaking of tall structures in Gulf Countries. A number of countries are reclaiming land for tourists destination hotels and there are number of tall buildings on the reclaimed lands. The seismic safety of these structures and its vulnerability to Long Period Surface Waves needs to be checked.

In some Central and Latin American countries such as Guatemala, Costa Rica, San Salvador, Ecuador etc have number tall buildings in the urban areas. The reasons for having such tall structures are social, economic, developmental etc. But it is now required to assess the vulnerability of these cities and countries.

ASSESSMENT OF DISTANT DAMAGE RISK

Each country and city will need a special analysis for the assessment of distant damage. As a thumb rule, follow a simple procedure. From the available historical earthquake catalogues find out whether there was any earthquake of magnitude more than or equal to 7.0 on Richter scale, within 550 km radius from the site. If there is any record, then the site needs to be assessed for distant damage. For this purpose, theoretical seismological calculations and structural analysis are required to be undertaken. From the damage surveys of above and other large earthquakes it has been observed that the distant damage is mostly confined to tall structures of height > 17 meters. It was observed at Mexico City and Ahmedabad that constructions of height more than 17 m have suffered heavy damage. But buildings with one, two or three floors have not suffered any damage or the damage was minimal and non-structural. Constructions on filled lands could be highly vulnerable to distant damage. The filled land may undergo liquefaction and the damage could be compounded. An example from the City of Kolkata (formerly Calcutta) in India needs urgent attention. During 1970 to 1908 the authorities wanted to expand the urban limits of the city. There was no place for expansion. On the outskirts there was a lake of 15 sq. km area. This was to be converted as a new township. The Kolkata Port had been facing acuter problem of silting. On an average about five million tons of silt is being dredged from this port annually. This silt was used as landfill material. A pipeline of 8 km length was laid from port to the lake and the silt was dumped in the lake. The filling took place during 1971 to 1977. The fishing lake turned in to a beautiful new township known as Salt Lake. This site is within 550 km from the potential seismic zones and faults in Nepal, Bhutan, Sikkim, Assam, and Burma etc. It is possible that an earthquake of magnitude M $\cong$ 7.0 in the nearby areas could cause liquefaction and distant damage in the reclaimed area of Kolkata.

Similarly, reclaimed areas in Dubai and other Gulf countries need to be protected from earthquakes in southern Iran. In cities where enough land is available for constructions and which are situated in the vulnerability range of distant damage the growth may be more in horizontal direction then vertical direction.

CONCLUSIONS

The studies of some of the recent large magnitude earthquakes have focused the attention of scientists and engineers on the new concept of distant damage. It is therefore required that observational and experimental seismologists, theoretical seismologists, earthquake engineers, structural engineers, architects, insurance and banking companies, town planners, city developers etc should jointly work out a proper assessment method for this. With rising population and shrinkage of available land for habitation, construction of tall structures is unavoidable. If man has to live with this latent danger, proper assessment and mitigation measures should be developed.

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