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Earthquakes in India: An Overview

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Abstract – Several parts of the Indian subcontinent, especially the Himalayas, are well known to be seismic, but data on earthquake prior to the colonial period are scarce. Needless to say that such data is essential for reliable seismic hazard estimation. Recent earthquake of Uttarkashi, Killari, Jabalpur, Chamoli, Bhuj and Sikkim underline the need for collecting information about earthquake in the historic past. The present work is a significant effort in this direction. India has a very high frequency of moderate and high intensity earthquakes (magnitude 6 to 8); for instance, during 1967 to 2015, the country was hit by many earthquakes. Moderate earthquakes create awareness and lead to improvements in construction at a low human cost. An earthquake of more than VIII or IX intensity in the last 40 years has not recorded. Sikkim earthquake (2011) has led to complacence in our earthquake preparedness. We have now higher levels of man-made construction and a significantly larger population than what we had at the time of great earthquakes of 1897, 1934, or 1950; hence, we are much more vulnerable to earthquake disasters.

Keywords: Earthquake, India, History, Intensity

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INTRODUCTION

An earthquake is a phenomenon that occurs without warning and involves violent shaking of the ground and everything over it. Earthquakes are tectonic in origin; that is the moving plates are responsible for the occurrence of violent shakes. The occurrence of an earthquake in a densely populated area may cause numerous casualties and injuries as well as extensive damage to infrastructure. Increasing population and extensive haphazard constructions expanding all over, including multistoried luxury apartments, huge factory buildings, gigantic malls, supermarkets as well as warehouses and masonry buildings keep - India at high risk. During the last 15 years, the country has experienced 10 major earthquakes that have resulted in over 20,000 deaths. As per the current seismic zone map of the country (IS 1893: 2002), over 59 per cent of India's land area is under threat of moderate to severe seismic hazard-; that means it is prone to shaking of MSK Intensity VII and above (BMTPC, 2006). In fact, the entire Himalayan belt is considered prone to great earthquakes of magnitude exceeding 8.0-; and in a relatively short span of about 50 years, four such earthquakes have occurred: 1897 Shillong (M8.7); 1905 Kangra (M8.0); 1934 Bihar-Nepal (M8.3); 1950 Assam-Tibet (M8.6); 2001 Bhuj (M7.7); and 2015 India/Nepal (M7.8 - 8.1).

At one time regions of the country away from the Himalayas and other inter-plate boundaries were considered to be relatively safe from damaging earthquakes. However, in the recent past, even these areas have experienced devastating earthquakes, albeit of lower magnitude than the Himalayan earthquakes. The Koyna earthquake in 1967 led to revision of the seismic zoning map, resulting in deletion of the non-seismic zone from the map. The areas surrounding Koyna were also re-designated to Seismic Zone IV, indicating high hazard. The occurrence of the Killari earthquake in 1993 resulted in further revision of the seismic zoning map in which the low hazard zone or Seismic Zone I was merged with Seismic Zone II, and some parts of Deccan and Peninsular India were brought under Seismic Zone III consisting of areas designated as moderate hazard zone areas. Recent research suggests that as understanding of the seismic hazard of these regions increases, more areas assigned as low hazard may be re-designated to higher level of seismic hazard, or vice-versa.

The North-Eastern part of the country continues to experience moderate to large earthquakes at frequent intervals including the two great earthquakes mentioned above. Since 1950, the region has experienced several moderate earthquakes. On an average, the region experiences an earthquake with a magnitude greater than 6.0 every year. The Andaman and Nicobar Islands are also situated on an inter-plate boundary and frequently experience damaging earthquakes.

The increase in earthquake risk is due to a spurt in developmental activities driven by urbanization, economic development and the globalization of

India's economy. The increase in use of high-technology equipment and tools in manufacturing and service industries has also made them susceptible to disruption due to relatively moderate ground shaking. As a result, loss of human life is not the only determinant of earthquake risk any more. Severe economic losses leading to the collapse of the local or regional economy after an earthquake may have long-term adverse consequences for the entire country. This effect would be further magnified if an earthquake affects a mega-city, such as Delhi or Mumbai.

Objective of the Study

The main objective of this paper is to study the moderate to high intensity earthquakes and damage made by them in Indian context in a historical perspective.

Indian Earthquakes

All the damaging earthquakes in the recent years are rather moderate in size as compared to the great earthquakes discussed above. Nevertheless, these too have had some interesting characteristics which are briefly discussed here; some of these are discussed in greater details in the accompanying papers.

Koyna Earthquake (1967)

This was a magnitude 6.5 earthquake that took place close to the 103 metre concrete gravity dam at Koyna (Berg et al., 1969). Prior to this earthquake, the area used to be considered aseismic. However, after the construction of dam and filling up of reservoir in 1962, the seismic activity increased significantly. The main shock of December 10, 1967 caused widespread damage, killing about 200 persons and injuring more than 1500 persons. The maximum shaking intensity was assigned as VIII on the MM scale. This earthquake provides one of the important instances of the reservoir-induced seismicity. A strong motion accelerograph located in the gallery at mid-height of the dam recorded peak vertical acceleration of 0.36g and peak horizontal acceleration of 0.45g and 0.39g. The dam, designed for a seismic coefficient of 5% g by the pseudo-static analysis, performed quite well with only nominal damage to the dam. This earthquake lead to the revision of Indian seismic zone map wherein the area around Koyna was brought in zone IV from zone I, and seismic zone for Bombay was upgraded from zone I to zone III.

Bihar - Nepal Earthquake (1988)

This magnitude 6.6 earthquake shook northern Bihar and Nepal on August 21, 1988 at 04:39 hours (e.g., GSI, 1993; Jain, 1992; Jain et al., 1991, Subramanyam, et al., Thakkar et al.). About 1004 persons died (282 in India and 722 in Nepal) and more than 16,000 injured; casualties were significantly reduced since in the summer time most people sleep outdoors. Significant damage was caused in three distinct regions: the area nears the epicenter, and the areas around Munger (India) and Bhaktapur (near Kathmandu in Nepal); this damage pattern due to peculiar geology of the area is exactly similar to that of the 1934 Bihar-Nepal earthquake.

Uttarkashi Earthquake (1991)

An earthquake of magnitude 6.6 shook the districts of Uttarkashi, Tehri, and Chamoli in the state of Uttar Pradesh on October 20, 1991 at 2:52 hours (GSI, 1992; Jain et al., 1992). The death toll was estimated to be around 768 persons, with about 5,066 injured. The area has one of the lowest population density in the state, and hence the rather low number of deaths and injuries. The maximum intensity of IX on the MM scale was assigned to an area of about 20 square km. This earthquake provided excellent ground motion records (acceleration versus time history) in the area (e.g., Jain and Das, 1993): maximum peak ground acceleration of about 0.31g was recorded at Uttarkashi. Ground motion records showed that in the Himalayan region, the motion has significantly higher amount of high-frequency contents. During the earthquake, collapse of houses with R.C. roof slab supported on weak random-rubble stone masonry clearly demonstrated the disastrous results of often neglected walls and columns vis-à-vis slabs and beams.

Latur Earthquake (1993)

On September 30, 1993 a magnitude 6.4 earthquake shook the area near village Killari in Latur district killing about 8,000 persons (GSI, 1996; Jain et. al, 1994; Seeber et al., 1993, 1996). The maximum intensity of shaking was about VIII to IX. Until this earthquake the area was considered non-seismic and placed in the lowest seismic zone (zone I) by the Indian code (IS:1893-1984). Most of the damage was contained in a relatively small area of 20 km x 20 km.

The affected area did not have any modern towns, modern buildings or major industries. In some of the villages more than 30% of the population was killed. This earthquake will be known for outstanding rescue, relief and rehabilitation carried out for any earthquake in recent Indian history; perhaps outstanding by even international standards.

Jabalpur Earthquake (1997)

The 1997 Jabalpur earthquake occurred on May 22, at 04:21:31 AM in Jabalpur District in the Indian state of Madhya Pradesh. The epicenter of the earthquake was located near Koshamghat village. The earthquake was caused by movement on the Narmada Fault (Geologist Dr V. Subramanyan). Major damage occurred to structures in the Jabalpur

District, Mandla District, Seoni District and Chhindwara District in Madhya Pradesh. Jabalpur and Mandla were the worst affected districts. A total of 887 villages were affected. Approximately 8,546 houses collapsed and nearly 52,690 houses were partially damaged. Some aftershock activity occurred, but they did not cause any additional damage. Longitudinal ground cracks were observed in some locations of the affected area. The affected region consisted of both rural and urban areas and the campus of the Jawaharlal Nehru Agricultural University was the worst affected structure in the urban area. Diagonal cracks occurred in walls, buildings were partially collapsed and the hostel for postgraduate students was severely damaged. Approximately 1,500 houses owned by the Indian Railways were damaged. In Jabalpur, a 500,000 gallon-capacity shaft-supported water tank for storage and distribution of drinking water sustained both horizontal cracking and diagonal cracking. Some earthen dams located in the districts of Jabalpur and Mandla reportedly developed longitudinal cracks.

Chamoli Earthquake (1999)

The 1999 Chamoli earthquake occurred on 29 March in the Chamoli district in the Indian state of Uttar Pradesh (now in Uttarakhand). The earthquake was the strongest to hit the foothills of the Himalayas in more than ninety years. Approximately 103 people died in the earthquake. The magnitude of the earthquake was 6.8 on the Richter scale. Apart from the Chamoli district, the quake also affected five other districts of Uttar Pradesh viz. Rudraprayag, Tehri Garhwal, Bageshwar, Uttarkashi and Pauri Garhwal (all are in Uttarakhand now). Among these, Chamoli and Rudraprayag were the most affected districts. Aftershocks continued and most of the aftershocks occurred in the east of Chamoli. Severe ground deformations resulted from the earthquake. Formation of ground fissures were reported from many areas. Landslides and changes in the groundwater flow were also reported. Well-developed ground cracks were seen in Gopeshwar, Chamoli and Bairagna. Cracks were observed in asphalt roads at several locations. Landslips cut off parts of Mandakini valley and Mandal valley and many major roads.

The death toll was 103. Several hundred people injured and approximately 50,000 houses were damaged. Over 2,000 villages were affected by the earthquake. correspondent for the BBC News, Chamoli suffered most damage and almost all the houses and shops built on slopes in the lower part of the town were destroyed

Bhuj Earthquake (2001)

The 2001 Gujarat earthquake, also known as the Bhuj earthquake, occurred on 26 January, India's 52nd Republic Day, at 08:46 AM IST and lasted for over 2 minutes. The epicentre was about 9 km south-southwest of the village of Chobari in Bhachau Taluka of Kutch District of Gujarat, India. The intraplate earthquake reached 7.7 on the moment magnitude scale and had a maximum felt intensity of X (Extreme) on the Mercalli intensity scale. The earthquake killed between 13,805 and 20,023 people (including 18 in southeastern Pakistan), injured another 167,000 and destroyed nearly 400,000 homes. The death toll in the Kutch region was 12,300. Bhuj, which was situated only 20 km away from the epicentre, was devastated. Considerable damage also occurred in Bhachau and Anjar with hundreds of villages flattened in Taluka of Anjar, Bhuj and Bhachau. Over a million structures were damaged or destroyed, including many historic buildings and tourist attractions.

In Ahmedabad, Gujarat's commercial capital with a population of approximately 7 million (according to data in 2018), as many as 50 multi-storey buildings collapsed and several hundred people were killed. Total property damage was estimated at $7.5 billion. In Kutch, the earthquake destroyed about 60% of food and water supplies and around 258,000 houses, 90% of the district's housing stock. The biggest setback was the total demolition of the Bhuj Civil hospital.

Indian Ocean Earthquake (2004)

The 2004 Indian Ocean earthquake was an undersea mega thrust earthquake with an epicentre off the west coast of Sumatra, Indonesia, and it is known asSumatra–Andaman earthquake or 2004 Indian Ocean tsunami or South Asian tsunami, Indonesian tsunami, and the Boxing Day tsunami. It killed 230,000 people in fourteen countries, and inundating coastal communities with waves up to 30 meters.

Sikkim Earthquake (2011)

The 2011 Sikkim earthquake (also known as the 2011 Himalayan earthquake) occurred with a moment magnitude of 6.9 and was centered within the Kanchenjunga Conservation Area, near the border of Nepal and the Indian state of Sikkim, at 18:10 IST on Sunday, 18 September. The earthquake was felt across northeastern India, Nepal, Bhutan, Bangladesh and southern Tibet.

At least 111 people were killed in the earthquake. Most of the deaths occurred in Sikkim, with reports of fatalities in and near Singtam in the East Sikkim district. Several buildings collapsed in Gangtok. Eleven are reported dead in Nepal, including three killed when a wall collapsed in the British Embassy in Kathmandu. Elsewhere, structural damage occurred in Bangladesh, Bhutan, and across Tibet; another seven fatalities were confirmed in the latter region. The quake came just a few days after an earthquake of 4.2 magnitude hit Haryana's Sonipat district, sending tremors in New Delhi. The earthquake was the fourth significant earthquake in India of September 2011. Exactly a year after the original earthquake at 5:55 pm on 18 September 2012, another earthquake of magnitude 4.1 struck Sikkim, sparking panic among the people observing the anniversary of the original quake

2015 India/Nepal Earthquake

The April 2015 Nepal earthquake (also known as the Gorkha earthquake) killed nearly 9,000 people and injured nearly 22,000. It occurred at 11:56 Nepal Standard Time on 25 April 2015, with a magnitude of 7.8Mw or 8.1Ms and a maximum Mercalli Intensity of VIII (Severe). Its epicenter was east of Gorkha District at Barpak, Gorkha, and its hypocenter was at a depth of approximately 8.2 km (5.1 mi). It was the worst natural disaster to strike Nepal since the 1934 Nepal–Bihar earthquake. The ground motion recorded in the capital of Nepal was of low frequency which, along with its occurrence at an hour where many people in rural areas were working outdoors, decreased the loss of property and human lives.

The earthquake triggered an avalanche on Mount Everest, killing 21, making 25 April 2015 the deadliest day on the mountain in history. The earthquake triggered another huge avalanche in the Langtang valley, where 250 people were reported missing. Hundreds of thousands of Nepalese were made homeless with entire villages flattened, across many districts of the country.

CONCLUSION

In the last 100 years since we had four events of magnitude greater than 8.0 in that period. Clearly, we have had far less number of moderate earthquakes. This illustrates an interesting aspect of Indian seismicity: India has relatively high frequency of great earthquakes and relatively low frequency of moderate earthquakes. Moderate earthquakes create awareness and lead to improvements in constructions at relatively low human costs, which could be very effective in the long run. Due to rather infrequent moderate earthquakes, the Indian earthquake problem does not receive the attention of the country that it deserves considering our overall seismic potential, and this is a tragedy. For a poor country, the focus of political priorities anyway remains on day-to-day problems of poverty, shelter, law and order, health, sanitation, and it is as such difficult to seek priorities to once-in-a-while problems of natural disasters. Nevertheless, just like one takes a life insurance policy for unexpected disasters, the country needs to invest a small fraction of priorities towards earthquake disaster mitigation; the consequences otherwise could be truly unimaginable should a major earthquake cause severe shaking in highly populated areas of the country.

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