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An overview on the seismic zonation and microzonation studies in India

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ABSTRACT

The present study presents a review on the progressive development of the seismic zonation map of India both from official agencies and also from independent individual studies. The zonation map have been modified and updated regularly with the occurrence of major destructive earthquakes over the years in the Indian subcontinent with the addition of new data. This study discusses the criteria chosen for the progressive zonation and the major earthquakes that were responsible for retrospection of the earlier published maps. The seismic zonation maps of India have also been prepared by various independent workers by adopting different approaches to achieve the purpose of the zonation. Despite the endeavors from various sources to provide a solution for the problem of earthquake hazards in India, there were many limitations on the zonation map as it gives the picture at a regional scale mostly on the bedrock level without addressing the local site conditions. But nevertheless, the seismic zonation map gives basic guidelines for any region to know the hazard scenario and if any city or urban population is under threat from seismic point of view, further site specific seismic microzonation may be carried out. In the International scenario, the Global Seismic Hazard Assessment Program (GSHAP) in 1999 prepared a hazard map for world in terms of peak ground acceleration (PGA) with a 10% probability of exceedance in 50 years, but it turned out to be an underestimation of the hazard parameter when compared with the observed PGA. To tackle the problem of seismic hazards, there was a need to have a detail study on the local site conditions in terms of its geological, geophysical and geotechnical properties. With the advent of better instrumentation and knowledge on the mechanics of earthquakes, it was possible to identify zones of hazards at a local level and this gives rise to the study of seismic microzonation. Seismic microzonation work has been carried out in India in some of the strategic important mega cities and industrial build up that has the potential of being damaged from future earthquakes, as has been shown in the past. Though the microzonation map is not the final output map, as it can still be updated at later stage with more input data, it does provide a more realistic picture on the site specific seismic hazard.

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1. Introduction

Earthquake is one of the most devastating natural phenomena. The evidences of the earthquake damages in the past are well demonstrated or observed through the tectonic features such as fault, shear zones, fault scraps etc. or from historical documented records/chronicles of eye witness accounts. There are many historical and recent earthquakes that are well-known, not only for its magnitude but also for the casualties it brought forth. A detailed account on the significant global earthquakes, from historical times to the most recent one, is listed in Table 1. The loss of human lives and property damage is evident from these earthquakes. On an average, about 17 000 persons per year were killed in the twentieth century (Chen and Scawthorn, 2003). Among all the natural disasters faced by man in the twentieth century, more than 50% of the casualties are inflicted by earthquake (leaving out the fatalities caused by drought and famine). The pie chart depicted in Fig. 1 is a representation of that and most of these casualties can be seen in the region of Asia and Pacific with the deaths amounting to more than 85% of the total loss by earthquake. The recent damaging earthquakes of the decade from this region are the 2001 Bhuj (M_w: 7.6), 2004 Sumatra (M_w: 9.1), 2005 Kashmir (M_w: 7.6) and 2008 Sichuan (M_w: 7.9).

The damage incurred in an earthquake depends not only on the size of the earthquake magnitude (*source*) but also, to a large extent, on the medium through which the seismic waves propagate (*path effects*) and the socio-economic development of the settlement (Panza et al., 2001). The number of occurrences of large earthquakes has remained fairly constant but the loss of life and property during the recent earthquakes has increased in manifolds due to the urbanization and increase in the human population. In the developed countries, the new constructions have better earthquake resistance but, not so, for the other developing or underdeveloped countries. So, there is an increase in the casualties even for the same size earthquakes depending upon the constructions. Hough and Bilham (2005) gave a simple relation discerning between the earthquake magnitude since 1900 and the number of deaths per earthquakes (gray zone) (Fig. 2) but the consequences of large earthquakes depend on the proximity to urban areas, vulnerability of the dwelling inhabitants, time of the day and on the energy released.

Prediction of earthquake has been a subject of controversy with opinions divided over it. Earthquake prediction gained momentum with the successful prediction of the Blue Mountain Lake (1971) (Rajendran and Rajendran, 2000) earthquake and the success claimed at Haicheng (1975) (Zuo et al., 1995; Wang et al., 2006) but prediction proved to be short lived. Sykes et al. (1999) gives an account on the possibility and limitation of earthquake prediction. Workers like Geller (1997a,b) and Main (1997) argue that short-term prediction with certainty is inherently difficult and that very high resolution is required for mitigation measures. Generally, as a standard, a time scale is involved that corresponds to long-term prediction considering an earthquake with a return period of 50, 100 or 500 years. The prediction of individual earthquake may not be possible but the long-term rates of earthquakes can be forecasted with considerable accuracy especially in regions of high seismic activities, like the plate margins, such as Japan, Italy, India, Turkey, Mexico and California. Keilis-Borok and Soloviev (2003) discuss the state of the art of earthquake prediction methodology based on the pattern recognition concepts. With the accessibility of information of more earthquake catalogs or data completeness, it is possible to go for intermediate-term middle-range prediction (Kossobokov et al., 1999; Keilis-Borok and Soloviev, 2003; Peresan et al., 2005).

The intensity of ground motion during earthquake varies widely and efforts are being made in most countries to identify zones that are more prone to the ground motion in order to improve the safety

Table 1
Significant historical earthquakes of the world.

Date	Location	Magnitude	Loss of life and property
1775, November 1	Lisbon, Portugal	M_w: 8.7**	70 000 deaths#
1811–1812 sequence	New Madrid, USA	M: 8.7#	–
1857, January 9	Fort Tejon, USA	M: 8.3§	–
1872, March 26	Ownes Valley, USA	M: 7.8§	27 deaths#
1886, August 31	Charleston, USA	M: 7.3#	60 deaths and 2000 buildings damaged#
1906, April 18	San Francisco, USA	M: 7.9§	more than 2000 deaths△
1908, December 28	Messina, Italy	M_s: 7.5†	72 000 deaths#
1923, September 1	Kanto, Japan	M: 7.9§	143 000 deaths△
1933, March 10	Long Beach, USA	M_s: 6.3#	115 deaths#
1959, August 17	Yellowstone, USA	M_s: 7.3#	28 deaths#
1960, May 22	Chile	M_w: 9.5#	1655 deaths, 3000 injured, 2,000,000 homeless#
1964, March 28	Alaska, USA	M: 8.3#	131 deaths, 534 houses destroyed and 11 000 houses damaged#
1964, June 16	Niigata, Japan	M_s: 7.4#	36 deaths, huge property damage#
1975, February 14	Haicheng, China	M_s: 7.5†	2000 deaths#
1976, July 27	Tangshan, China	M_s: 7.5†	255 000 deaths and 799 000 people injured
1985, September 19	Michoacan, Mexico	M_w: 8.0*	9500 deaths, 30,000 injured, more than 100,000 left homeless#
1988, December 7	Spitak, Armenia	M_w: 6.7*	25 000 deaths, 19 000 injured and 500,000 homeless#
1989, October 17	Loma Prieta, USA	M_w: 6.9*	63 deaths, 3757 injured#
1994, January 17	Northridge, USA	M_w: 6.6*	30 000 deaths, 7000 injured and 20 000 homeless#
1995, January 17	Kobe earthquake	M_w: 6.8△	6000 deaths and 36,896 injured
1999, August 17	Turkey earthquake	M_w: 7.6*	17,118 deaths, 50,000 injured, about 500,000 homeless#
1999, September 21	Taiwan	M_w: 7.5△	2297 deaths, 8700 injured and 600 000 homeless△
2004, December 26	Sumatra earthquake	M_w: 9.0*	227 898 deaths, and 1.7 million homeless#
2005, October 8	Kashmir, Pakistan	M_w: 7.6*	86 000 deaths and 69 000 injured#
2008, May 12	Sichuan, China	M_w: 7.9*	69 185 deaths, 374 171 injured and 18 467 missing

(Source: †ISC: International Seismological Centre; #USGS: United States Geological Survey; *HCMT: Harvard CMT catalog; △Chen and Scawthorn, 2003; §NOAA catalog, **Vuan et al., 2008).