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Earthquake Disaster Risk Management in India

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Abstract: *Physical Infrastructure is built across the world with an intent to meet the needs of people. However, often, sufficient attention was not paid on safety of these structures at the time of design and construction. In addition, natural hazards such as floods, cyclones, fires and earthquakes are also disrupting these threats. Some of the significant and devastating disasters include, but not limited to, 2004 Asian Boxing Day Tsunami killing 2,30,000 people across 14 countries, 2004 floods in Pakistan affecting 20 million people, 2010 Haiti earthquake causing in a human life loss of 3,16,000 (Cross 2016). Countries like USA, Japan and New Zealand, have taken steps to reduce the seismic risk (earthquake risk), yet many seismically active countries (a place where earthquakes are occurring frequently) are still working in that direction. According to Tucker et al., 1994, the number of deaths is reduced significantly in developed countries in the second half of the 20th century whereas the number is same in both, developed and developing countries for the first half of 20th century. Figure1.1 shown below indicates that the threat to urban population has drastically decreased in developed countries in the last decade (Tucker, Trumbull and Wyss 1994).*

Keywords: Earthquake

I. INTRODUCTION

In the last few decades, India has witnessed many devastating earthquakes which caused significant loss of human life as well as physical infrastructure. Several moderate earthquakes, (Bihar-Nepal border (M6.4) in 1988, Uttarkashi (M6.6) in 1991, Killari (M6.3) in 1993, Jabalpur (M6.0) in 1997, Chamoli (M6.8) in 1999, Bhuj (M6.9) in 2001, Sumatra (M8.9) and Kashmir (M7.6) in 2005), caused around 40,000 fatalities due to collapse of buildings. Major reasons for such huge casualties are low earthquake awareness and poor construction practices. Hence, for rational understanding of the complex problem, it is necessary to carry out Earthquake Disaster Risk Index of cities and districts and use the same for disaster risk mitigation and preparedness efforts. It is common practice in India that most houses are constructed by individual owners without much guidance on the seismic safety measures that are required while constructing a house or a building. The contractor construct houses to meet the demand and conveniences of owners, without the involvement of engineers or architect. Such houses or buildings are called Non-engineered constructions which demonstrate poor behaviour during earthquake shaking, leading to severe damage or even collapse of structures. Table 1.1 shows the overview of several earthquake incidents that caused devastating building collapses in India.

Table 1 Brief overview of earthquake incidents in India

Date	Location	Magnitude / MSK Intensity	Remarks
8 February, 1900	Coimbatore	6.0/VII	Shock was felt throughout south India. Coimbatore and Coonoor worst affected.
4 April, 1905	Kangra	8.0/X	~19,000 deaths. Considerable damage in Lahore. High intensity around Dehradun and Mussorie VIII
15 January, 1934	Bihar-Nepal	8.3/X	~7,000 deaths in India and ~3,000 deaths in Nepal. Liquefaction in many areas.
26 June, 1941	Andaman & Nicobar Islands	7.7/VIII	Triggered Tsunami-1.0m high on the east coast, causing many deaths.
15 August, 1950	Assam-Tibet	8.6/XII	About 1,500 deaths in India and ~2,500 in China. Caused huge landslides which blocked rivers and later caused flood.

21 July,	Anjar (in Kutch)	6.1/IX	1956 About 115 deaths. Part of Anjar on rocky sites suffered much less damage comparatively.
10 December, 1967	Koyana, Maharashtra	6.5/VIII	About 180 deaths. Caused significant damage to the concrete gravity dam.
21 August,1988	Bihar-Nepal	6.6/IX	About ~709 deaths.
20 October, 1991	Uttarkashi	6.4/IX	~750 deaths. 56m span Gawana bridge 6 km from Uttarkashi collapsed.
30 September, 1993	Killari, Maharashtra	6.2/IX	~8,000 deaths. Most deadly earthquake in India since Independence.
22 May, 1997	Jabalpur	6.0/VIII	~40 deaths and ~1,000 injured. Concrete frame buildings with open ground storey suffered damage.
26 January, 2001 damaged.	Bhuj (Kutch)	7.7/X	~13,800 deaths. Numerous modern multistorey buildings collapsed. Number of medium and small earth dams severely
26 December, 2004	Sumatra	9.4/VI	(in Andaman) Caused most devastating Tsunami in the history resulting in ~2,27,898 deaths in 14 countries.
8 October, 2005	Kashmir	7.6/VIII	Poor performance of masonry buildings caused many life losses. Unique construction found in this region Dhajji Diwari showed very good seismic performance.
28 September, 2011	Sikkim	6.9/VI	~80 deaths. Large number of landslides, significant damage to the buildings and infrastructure.

Source: (S. K. Jain 2016)

The table indicates the likely potential seismic areas of the country. Considering the potential of such seismic areas, hazardous zones were identified by categorizing the different parts of the country. According to the guidelines issued by Bureau of Indian Standards, the country is divided into 4 seismic zones; namely zone II, III, IV and V in the increasing order of the intensity and frequency of occurrences of earthquake incidents. The key observation in those severely affected areas was lack of earthquake resistant features in the buildings or lack of awareness among people on the consequences of earthquakes. For instance, the 2001 Bhuj earthquake (Gujarat, India) (M7.7) incident caused about 13,800 deaths whereas 1993 Killari (Latur, India) (M6.4) earthquake caused 8,000 deaths. In both the cases, the severe loss of human life is mainly because of collapse of houses [(Jain, Lettis, et al. 2001), (S. K. Jain, C. V. Murty and N. N. Chandak, et al. 1994)].

Another important contributing factor for such collapses of houses is the lack of professional environment in the construction field. In fact, there is no system available which enforces builders and contractors to comply with seismic codes and guidelines issued by Bureau of Indian Standards (BIS). There was also no such system exists either during construction and post construction to penalize the violators. In addition to this, adopting new construction practices, that are available in others countries, in India is proven to be disruptive. For example, most of the school buildings constructed with precast construction technology, adopted from outside the country, collapsed in most undesirable manner leading to many casualties of school children. Any such innovative technology or earthquake safety practices should align with Indian construction practices including geological conditions. Further, there are some engineering aspects of local housing typology, which require appropriate measures to be taken explicitly.

II. EARTHQUAKE DISASTER RISK INDEX

Earthquake Disaster Risk Index combines nonlinearly the earthquake hazard, vulnerability and exposure of a city. Each of these parameters is sub-divided in pointers, and depending on the location, built environment, and usage, weightages were assigned to each of the pointers, which contribute EDRI. Thus, EDRI is a composite risk index that allows direct comparison of the relative overall earthquake disaster risk of cities nationwide, and captures the relative contributions of various factors to that overall risk.

III. METHODOLOGY

Earthquake risk is represented as the product of the prevalent earthquake hazard (H) of the area, the exposure (E) of persons to the earthquake hazard, and known vulnerability (V) of the houses in that area. Of these three factors, Vulnerability plays an important role to forecast the Expected damage in a building. This vulnerability parameter is divided further into two subfactors namely, Life Threatening Factors (LTF) and Economic Loss Inducing Factors (ELIF). LTF indicates the parameters which directly related to the life loss, whereas ELIF indicates the damage expected in the building. The procedure for risk calculation of individual building involves a set of questions which need answers only in the form of 'Yes' or 'No'. Each question has a weightage. This weightage varies across questions. The questions are selected in such a way that they cover all three components of risk, i.e., hazard, exposure and vulnerability. The risk is estimated of individual building typology in a city, based on the surveyed buildings in the city and finally risk index of the city is projected using the census data of total number of buildings in that city of that typology. When more than one typology is present in the city, above procedure is employed for buildings of each typology first, and then averaged over the total number of buildings in the city.

Pilot Study In the pilot study, the cities was selected based on the population density, housing threat factor and the cities identified by Government of India to develop as Smart Cities. The major area of focus is the seismically active regions in India, i.e., seismic zones IV and V. Considering these factors, a total of 50 cities were selected. Of these, 15 cities were selected from zone seismic V, 28 cities from seismic zone IV, and remaining 7 are metro cities. A Few of the metro cities lie in seismic zone III, also but were selected considering the high population density and high housing threat factor.

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IV. RESULT & DISCUSSION

Exposure is estimated based on functional use of building surveyed and maximum FAR (Floor Area Ratio) mentioned in bye-laws of town. Larger violation of FAR by private building owners leads to higher state of exposure. Aizawl, Solan, Gangtok and Vijayawada are the four cities which have high exposure among 13 cities with High risk level. Similarly, Ghaziabad, Pune and Mumbai are three cities which have higher exposure among 30 cities with Medium risk level. Lack of space and increase in demand of functional space of town due to its economic importance in nearby area cities like Aizwal, Solan and Gangtok face challenges in strict implementation of FAR for private buildings. Whereas, remaining cities of sub-group G2A and G2B have high population density leading to higher exposure level.

Vulnerability includes items drawn from the clauses of the relevant Indian Standards, which are required to be adopted in the earthquake resistant construction of a house of the relevant housing typology. It is assessed based on: (i) siting issues, (ii) soil & foundation conditions, (iii) architecture features, (iv) structural aspects, and (v) construction details. Among 13 towns with high risk, 5 cities have higher vulnerability, and those are Shimla, Aizawl, Pithoragarh, Nainital, and Uttarkashi.

More than half of the top five vulnerable parameters in RC buildings, among all these 5 cities, belong to Architectural features. Few distinct architectural features found common among two or more cities are, about half of the openings close to corner, difference in storey height, houses touching each other, large area of door or window opening. Staircase not adequately separated from house is one of the vulnerable parameters of structural category found common in 3 cities. In case of BM buildings, in these cities, larger opening and absence of bands at different level found more common which contributes as more vulnerable among architectural and structural category respectively. Darbhanga, Patna, Mandi and Chennai found to have higher vulnerability with medium risk level. In these cities also, for RC buildings architectural parameters are found

dominant compared to structural parameters. Parameters like large projection or overhang and houses having insufficient gap found to be common vulnerable parameter among architectural

features. Staircase not being adequately separated from house is one of the vulnerable parameters of structural category, found to be common in 3 cities. Similarly, in case of BM buildings, structural features are of more concern compared to architectural features. Staircase not being adequately separated from building, and absence of bands at sill and plinth level found to be very common structural vulnerable parameters in BM buildings. Whereas, Irregular orientation of rooms found to be common vulnerable parameter under architectural category.

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