सत्यमेव जयते

EARTHQUAKE DISASTER RISK INDEX REPORT

50 Towns & 1 District in Siesmic Zones III, IV and V

September 2019

NATIONAL DISASTER MANAGEMENT AUTHORITY
MINISTRY OF HOME AFFAIRS
GOVERNMENT OF INDIA

Earthquake Disaster Risk Index Report

50 Towns & 1 District in Seismic Zones III, IV and V

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National Disaster Management Authority

INTERNATIONAL INSTITUTE OF INFORMATION TECHNOLOGY
HYDERABAD

September 2019

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National Disaster Management Authority
भारत सरकार
Government of India

Preface

India's hazard profile shows that about 59 percent area of India is vulnerable to moderate to major earthquakes. It is evident from past earthquakes such as Manipur (2016), Nepal (2015), Sikkim (2011), Kashmir (2005), Bhuj (2001), Chamoli (1999), Jabalpur (1997) and Latur (1993) that all type of buildings sustain damage if not designed properly. The experiences of these earthquakes have demonstrated that many typical buildings of different types have sustained significant damage in these earthquakes. More than 90% of the casualties in past earthquakes in India have occurred due to collapse of houses and structures. The loss of life and property can be minimized significantly by ensuring better code compliance of upcoming constructions and undertaking seismic retrofitting of existing buildings thereby making them earthquake resilient. Therefore, the need was felt to quantify the earthquake risk to the buildings so that decision makers put the adequate structural measures after prioritizing the buildings.

NDMA through International Institute of Information Technology (IIIT) Hyderabad has developed Earthquake Disaster Risk Index (EDRI) for 50 cities and 1 district on pilot basis. In this pilot study, the cities were selected based on the population density, housing threat factor and cities identified by Government of India as Smart Cities. The major area of focus is the seismically active regions in India, i.e., seismic zones IV and V. The EDRI report has been prepared based on the field visit of 25 cities and collection of secondary data from the remaining cities' officials.

The risk has been categorized as Low, Medium and High for easy understanding of the decision-makers and town planners. We hope that the report will be of help to concerned city officials and act as a guide towards disaster risk mitigation and preparedness efforts.

Shri Kamal Kishore	**Dr. D. N. Sharma**	**Lt.Gen.N.C.Marwah (Retd.)**	**Shri G. V. Venugopal Sarma, IAS**
Member	Member	Member	Member-Secretary

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I also acknowledge the concerned city officials for hosting the field visit by the IIIT team and providing the required data to evaluate the Earthquake Disaster Risk Index.

Efforts of Mitigation Division, NDMA officials for coordinating during the course of the project are acknowledged.

It is hoped that this report will prove to be useful to the concerned city officials, town planners and other stakeholders to undertake the mitigation measures for earthquake risk reduction.

(Sandeep Poundrik)
Advisor (Mitigation)

Executive Summary

Background

The Disaster Mitigation Act, 2005 (DM Act, 2005) seeks a paradigm shift from the hitherto relief-centric approach to a more proactive, holistic and integrated approach of strengthening disaster mitigation, preparedness and response. NDMA acknowledged that initiatives be taken up that are not only significant and far-reaching, but they also highlighted the need for a holistic and integrated risk reduction strategy. On the basis of these deliberations, the NDMA and IIIT Hyderabad together have developed an Earthquake Disaster Risk Index (EDRI), to forecast the relative risk within a city and across cities based on three important factors i.e., topographical condition (known as Hazard), total number of people and buildings spread in the topography (known as Exposure) and the present condition of the buildings (known as Vulnerability). This forecast of risk within a city projects the overall damage or loss that city may experience in expected earthquakes in future and the necessary precautions to be taken.

Need for Estimating Risk in India

In the last 2-3 decades, India has experienced many earthquakes that have caused significant loss of life as well as property. The key observations in those severely affected areas were the lack of awareness in people about the earthquake and its consequences, and absence of a mechanism to ensure earthquake resistant buildings. A large part of these losses are directly because of housing typologies in practice in the country. For example, the 2001 M7.7 Bhuj (Gujarat, India) earthquake caused about 13,000 deaths, whereas relatively smaller size 1993 M6.4 Killari (Maharastra, India) earthquake caused about 8,000 deaths; this colossal loss of life is attributed directly to the collapse of houses.

Rapid urbanization of Indian cities in last few decades has put large pressure on the housing industry to speed up the development. This fast pace of construction with limited and non-holistic planning has led to unregulated development of low-to-medium rise buildings in Tier II cities and medium-to-high rise building in Tier I cities, causing serious threat to life and property during disasters. There are ongoing endeavours in the form of frequent revision of design codes, capacity building of architects, engineers and other stakeholders of the construction industry, developing disaster awareness, towards achieving reduction in loss of life and economic losses during future events. An important step towards this is to assess periodically the earthquake risk in cities in India, which will help mitigate negative consequences, prepare and respond to the next event. Earthquake Disaster Risk Index of cities in Seismic Zones IV and V is an attempt to estimate the earthquake risk of the country to help reduce the social and economic consequences due to an earthquake. In particular, it will help provide a quantitative feel of the impending risk involved, and its consequences, and guide government agencies for prioritizing disaster preparedness and response measures in the more vulnerable cities.

Thus, it is critical to estimate Earthquake Disaster Risk of cities and use the same to guide disaster risk mitigation and preparedness efforts.

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.

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 sub-factors 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 were 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.

Outcome

The present built environment in all the 50 cities were studied to estimate risk of each city, and are placed in three categories (namely Low, Medium and High) risk as shown in the table below:

S.No.	Town	State	Hazard	Exposure	Vulnerability	EDRI
1	Itanagar	Arunachal Pradesh	High	Low	Medium	Medium

S.No.	Town	State	Hazard	Exposure	Vulnerability	EDRI
2	Guwahati	Assam	High	Low	Medium	Medium
3	Dispur	Assam	High	Medium	Medium	Medium
4	Port Blair	A&N Islands	High	Low	Medium	Medium
5	Darbhanga	Bihar	High	Medium	High	Medium
6	Bhuj	Gujarat	High	Low	Low	Low
7	Mandi	Himachal Pradesh	Medium	Low	High	Medium
8	Srinagar	Jammu & Kashmir	High	Medium	Medium	High
9	Imphal	Manipur	High	Medium	Medium	Medium
10	Shillong	Meghalaya	High	Medium	Medium	Medium
11	Aizawl	Mizoram	High	High	High	High
12	Kohima	Nagaland	High	Medium	Medium	Medium
13	Agartala	Tripura	High	Medium	Medium	Medium
14	Chamoli	Uttarakhand	HighLow	Medium	Medium	
15	Pithoragarh	Uttarakhand	High	Medium	High	High
16	Patna	Bihar	Medium	Medium	High	Medium
17	Bhagalpur	Bihar	High	Medium	Medium	High
18	JamnagarGujarat	Medium	Medium	Medium	Medium	
19	Faridabad	Haryana	Medium	Medium	Medium	Medium
20	Gurgaon	Haryana	Medium	Medium	Medium	Medium
21	Panipat	Haryana	High	Medium	Medium	High
22	Panchakula	Haryana	Medium	Medium	Medium	Medium
23	Shimla	Himachal Pradesh	Medium	Medium	High	High
24	Solan	Himachal Pradesh	Medium	High	Medium	High
25	Jammu	Jammu & Kashmir	High	Medium	Medium	Medium
26	Ratnagiri	Maharashtra	Medium	Medium	Medium	High
27	Amritsar	Punjab	Medium	Medium	Medium	Low
28	Jalandhar	Punjab	Medium	Medium	Medium	Medium
29	Ludhiana	Punjab	Medium	Medium	Low	Low
30	Alwar	Rajasthan	Medium	Medium	Low	Medium
31	Gangtok	Sikkim	Medium	High	Medium	High
32	Ghaziabad	Uttar Pradesh	High	High	Low	Medium
33	Gautam Budh Nagar	Uttar Pradesh	Medium	Medium	Medium	Medium

S.No.	Town	State	Hazard	Exposure	Vulnerability	EDRI
34	Meerut	Uttar Pradesh	Medium	Medium	Medium	Medium
35	Bareily	Uttar Pradesh	Medium	Medium	Low	Medium
36	Mathura	Uttar Pradesh	High	Medium	Medium	Medium
37	Moradabad	Uttar Pradesh	Medium	Medium	Medium	High
38	Dehradun	Uttarakhand	Medium	Low	Medium	Low
39	Uttarkashi	Uttrakhand	High	Low	High	High
40	Nainital	Uttarkhand	High	Medium	High	High
41	Chandigarh	UT	Medium	Medium	Medium	Medium
42	Darjeeling	West Bengal	Medium	Medium	Medium	Medium
43	Siliguri	West Bengal	Medium	Medium	Medium	Low
44	Vijayawada	Andhra Pradesh	Medium	High	Medium	High
45	Ahmedabad	Gujarat	Medium	Low	Medium	Medium
46	Mumbai	Maharashtra	Medium	High	Medium	Medium
47	Pune	Maharashtra	Medium	High	Medium	Medium
48	Chennai	Tamil Nadu	Medium	Low	High	Medium
49	Kolkata	West Bengal	Medium	Medium	Medium	Medium
50	Delhi	NCT of Delhi	Medium	Medium	Medium	Medium

As cities were selected from the higher seismic zones, no city has low hazard level. Cities with hilly terrain have low exposure, whereas cities with flat terrain and high populations have high exposure. The vulnerability of each city depends only on the construction typology adopted, of the 50 cities, the vulnerability of built environment is low in only 5 cities, medium in 36 cities and high for 9 cities. The final result of the EDRI shows that, of the 50 cities, only 7 cities have low level risk, whereas 30 cities medium level risk and 13 cities high level risk. This scenario is alarming and needs immediate attention.

Note: Results presented above are based on the sample survey conducted and are based on the data supplied by the city officials. Hence, more accurate risk index can be calculated if sample size is more and also spread out uniformly throughout the city/town.

The Way Forward…

Earthquake Disaster Risk Index obtained is based on the preliminary screening of different housing typologies of selected cities. It further requires a detailed structural evaluation by seismic design professionals for highly vulnerable buildings so that suitable retrofitting measures can be adopted by the policy makers. Other remaining cities lying in zone IV & V shall be targeted in the similar manner. As the screening conducted was on a macro level, so highlighting the hotspot area which are lacking in adequate structural parameter and need utmost attention can be figured out. Further, Extensive field study has to be carried out to get a realistic picture and this can be achieved by inclusion of the local body at the cities itself like city official, local colleges which can aid in task and can help in developing and maintaining the inventory at the city level itself.

In order to better understand the potential risk, an inventory of the surveyed buildings has to be developed such that it can be utilized in case of future event and which in turn help in planning and implementation of mitigation strategies. An Intercity and Intra city comparison of the similar kind of building typologies can be made to notch out the different parameter considered presently such that it can help coming to conclusion for determining the risk estimation in a much better way and need to realize whether additional parameter is required apart from (a) Siting Issues; (b) Soil and Foundation; (c) Architectural Features; (d) Structural Aspects and (e) Material and Construction Details.

Periodic Evaluation of the EDRI & Technical structural safety audit of the buildings shall have to be planned such that present conditions can be compared from the inventory to have a reality check and to gauge out the pattern of improvement and based on which further appropriate measure shall have to be adopted to reduce the risk factor over the period of time. i.e. from high to moderate, moderate to low. Beside all these a ranking system should be developed so that the construction pattern may be gauged and link with the associated pattern which would help in identifying the trend in the construction and associated policy intervention may be fused accordingly. which can help in identifying the critical building and such that mitigation plan can execute effectively.

The EDRI will be helpful in increasing significant awareness among the people residing in highly seismic vulnerable area on broad perspective. It can be achieved by conducting awareness programme and establishment of demonstration retrofitting unit, teaching risk reduction measures, acquiring lifesaving skill and a way to respond during and after earthquake such that even local people should be prepared and can plan their immediate mitigation strategies in case of mishappening; and able to identify the vulnerable hazardous buildings and can plan for quick repair, restoration, and retrofit the structure to make it function thereby reducing the life and property losses. Stringent actions shall have to be implemented into practices against stakeholder for adopting / following illicit practices or deviating away from the laid down guidelines.

Thus, Estimating Earthquake Disaster Risk Index requires active participation of three principal stakeholders, namely:

(1) **Academia:** It shall (a) identify and document various building typologies; (b) study these typologies in detail and describe ideal building in each typology category; (c) identify penalties for each departure by conducting analytical and/or experimental research and to introduce the new technique in the market that can be adopted by industry ; and (d) train graduate and post graduate students to identify the different kind of distress present in the buildings and make them understand the structural and non-structural deficiency (e) introducing the retrofit course as part of course curriculum (f) train manpower for undertaking design of new constructions and retrofit of existing buildings.

(2) **Industry:** It shall: (a) outlaw unsafe typologies and encourage good typologies within the laid guidelines; (b) propose new technologies; (c) build facilities to undertake full-scale testing; (d) build skills in its artisans; (d) encourage continuing education and research; (e) undertake to build competence in retrofit of unsafe constructions; (f) actively engage in developing standards; and (g) update its fraternity with the latest developments in earthquake safety.

(3) **Government:** It shall ensure that policies and systems (with legal standing) are in place for:

(a) ensuring all future constructions to be earthquake resistant; (b) identify cities whose earthquake risks are high; and (c) Seek peer review of structural safety of new constructions and modifications to existing constructions. (d) Setting up the periodic Technical structural safety Audit to ensure the safety and to understand the present condition of the buildings. (e)Stringent action shall be taken against the stakeholders for deviating away from the guidelines. (f) Establishment of the Demonstration unit to aware people and make them understand the severity of the risk involved.

1 Introduction and Scope of Work

1.1 Scenario of Earthquake Disasters Worldwide

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).

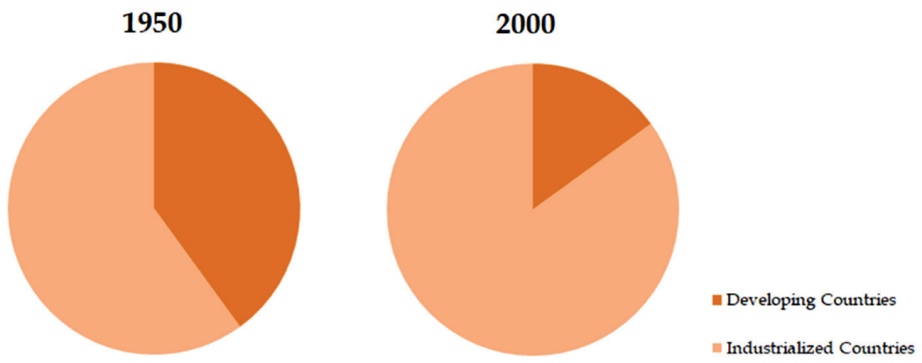


Figure 1.1: Percentage of threat to urban population in industrialized and developing countries (Geohazards International 2001)

1.2 Scenario of Earthquake Disasters in India

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 1.1: 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, 1956	Anjar (in Kutch)	6.1/IX	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	Bhuj (Kutch)	7.7/X	~13,800 deaths. Numerous modern multistorey buildings collapsed. Number of medium and small earth dams severely damaged.

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.

1.3 Impact of Urbanization in India

Indian Administrative structure has classified the liveable localities into several categories based on the geography conditions of a locality and the population density. A hamlet, Village, Panchayat, Town, Municipality, City and Metro Cities etc., are all categorized and fixed a range of the population to live-in. This is to ease the administration process of policy makers. For example, a Town population was fasten between 50,000 and below 1,00,000; In case, more than One Lakh then it should be called as a City; Similarly, if a population ranges more than 10,00,000 – it should be a Metro City. But, during the recent times this range was exceeding than the defined one's. Especially during 80's and 90's period, slowly, people from villages, towns have started migrating to the Urban Cities– this is known as Urbanisation.

This phenomenon is increasing due to the advantages that the urban cities have viz., accessibility to employment opportunities, education, hospital facilities and more importantly, standards of living etc. This resulted into produce more human resources, decent conditions in urban cities. This transformation helped to promote Urban Cities much better than their previous regime resulting into more development. Especially in India, nearly 2/3rd of population is living in rural areas and their major income source is from agriculture sector. At this juncture, majority of academic research was carried out on rural areas and their needs because of the population density. In contrast, due to the urbanization, more industries are established in majority of the Cities. But, the affect of recent low-income reduction rate in agriculture sector, agriculture labour started shifting their profession to industries in Cites.

Because of this shift, nearly 31.6% of the Indian population (377.1 million) is living in urban areas, currently contributing to 63% of GDP of the Nation. Escalating these numbers, it is also estimated by 2030, nearly 40% of population is going to settle down in urban cities that may contribute to 75% of the GDP of the Nation. But, due to this migration, the government's responsibilities are also challenging while meeting the people's desires. For instance, Government's one function is to provide basic facilities such as decent water, sanitation, education, roads, parks and health facilities on priority basis. This resulted governments to concentrate on providing basic amenities in the Cities by giving high priority on setting up sufficient infrastructure.

However, there was very less attention paid on securing this infrastructure and providing safety of the City residents. Especially, the 2004 Tsunami incident exposed policy makers to concentrate on protecting such physical infrastructure. Rigorous research was carried on identifying post incident measures to secure society from natural calamities (e.g., flood, fires, cyclones and earthquakes etc). Globally, much attention was also paid to Disaster Risk Reduction in the forum of UN's Sustainable Development Goals (SDG's) as a major concern. The NDMA's disaster management policy introduced in the year 2009 was another timely step. With this background, this study aims to find the essence of Disaster Mitigation Risks and future of Urban Cities in Indian Context to leverage the risk preparedness.

1.4 Scope of Work

There are ongoing endeavours in the form of frequent revision of design codes, capacity building of architects, engineers & other stakeholders of the construction industry, and developing disaster awareness, towards achieving reduction in loss of life and economic losses (i.e., loss of time, business etc.) during future events. An important step towards this is to assess periodically the earthquake risk of cities in India, which will help mitigate negative consequences, prepare, and respond to the next event.

Preparing the Earthquake Disaster Risk Index of cities in Seismic Zones IV and V is an attempt to estimate the earthquake risk of the country to help reduce the social and economic consequences due to an earthquake. In particular, it will help provide a qualitative feel of the impending risk involved and its consequences, and guide governmental agencies for prioritising disaster preparedness and response measures in the more vulnerable cities.

2 Literature Review and Methodology

2.1 Introduction

In the last 25 years, India has witnessed several moderate earthquakes that caused around 40,000 deaths, largely due to collapse of buildings. One of the main reasons for such large casualties is lack of awareness of earthquake risks and poor construction practices (Table 2.1). The losses could have been reduced, if there was preparedness for the expected disaster. Such preparedness can be initiated by an assessment of earthquake disaster risks. It also helps in enabling the mitigation efforts for future earthquake events. Risk assessment will produce quantitative value that can result in a qualitative sense of severity of problem. To expedite the risk reduction on priority, it is necessary to compare the relative seismic risk levels.

In this project, a pilot study was performed in which the cities were 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.

In general, Risk is integrals of a combination of Hazard, Vulnerability and Exposure. A seismic hazard is a possible level of shaking of a particular site. Exposure describes the size of a city that is subject to the physical demand imposed by the hazard. Vulnerability describes how easily and how severely a city's exposed entities can be affected given a specified level of hazard. On the fly, each of these risks have their own defined parameters and certain weightages for each parameter. EDRI combines all such parameters and weightages in a nonlinear combination to find out the value of risk of a particular city. Using such values, categorization of the cities will become easier.

Attempts were made in the past to develop earthquake vulnerability assessment methodologies and to use them in earthquake risk assessment by considering physical, social, and economical parameters (Davidson 1997). Local, regional, national and international variability was observed in these methodologies. This method is inspired from the Human Development Index (UNDP 1994) which give relative levels of development in various countries. Whereas the proposed methodology rate relative levels of earthquake disaster risk in different cities. The approach adopted to synthesizes the vast amount of information on urban earthquake disaster risk into a simple, easily usable form. Earthquake disaster risk is examined by considering the factors that contribute to it (e.g., frequent earthquakes, vulnerable structures), rather than by directly examining the expected consequences (e.g., deaths, economic loss). The approach gives relative risk since disaster risk was conceived as a continuous, open-ended scale, against traditional bindery classification of Disaster and Not a Disaster. The assessment addresses the full array of factors that contribute to a city's risk without losing sight of the big picture.

Table 2.1: Casualties during past earthquake events

Year	Location	Magnitude	Deaths	Buildings Collapsed
1988	Bihar-Nepal	6.4	1,004	2,50,000
1991	Uttarkashi	6.6	768	42,400
1993	Killari	6.3	8,000	30,000
1997	Jabalpur	6.0	38	8,546
1999	Chamoli	6.8	100	2,595
2001	Bhuj	6.9	13,805	2,31,000
2004	Sumatra	8.9	10,805	Not Available
2005	Kashmir	7.6	~1,500	4,50,000
2006	Sikkim	5.3	2	Not Available
2011	Sikkim	6.9	110	Not Available
2016	Manipur	6.7	~10	Not Available

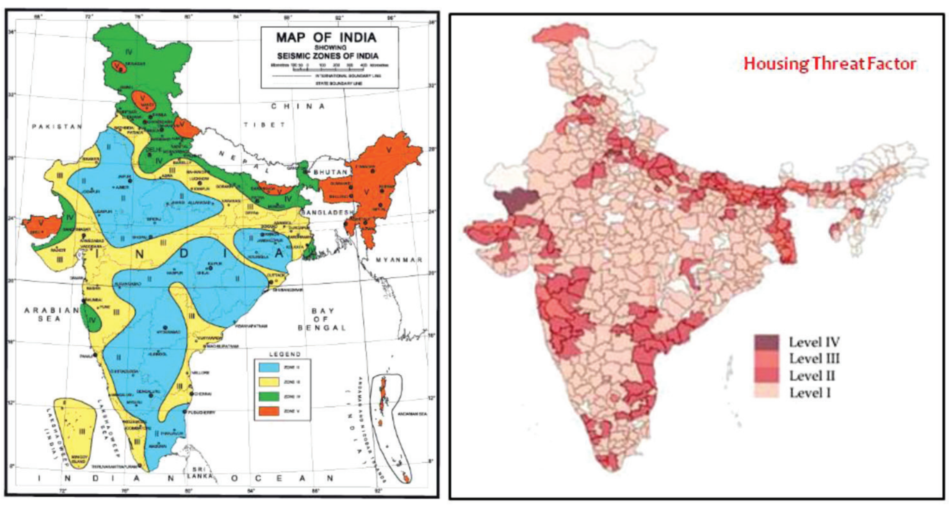
Source: (Seeber, et al. 1993); (S. K. Jain, C. V. Murty and N. N. Chandak, et al. 1994); (S. K. Jain, C. V. Murty and J. N. Arlekar, et al. 1997); (S. Jain, et al. 1999); (Jain, Lettis, et al. 2001); (S. K. Jain, C. V. Murty and D. C. Rai, et al. 2005); (Rai and Murty 2005); (C. V. Murty 2007); (Murty, Sheth and Rai 2011); (C. V. Murty, et al. 2012); (Ramancharla and Murty 2014); (Mahajan, et al. 2012); (Chenna and Ramancharla 2016); (Gahalaut and Kundu 2016).

2.2 Review of existing Risk Assessment methods

Earthquake hazard zonation map of India was first published in 1962 by Bureau of Indian Standards (BIS) and was revised from time to time, based on the findings after major earthquakes took place in the country; the version published in the year 2016 is the very recent one. According to that map, 56% of Indian Geographical area is prone to moderate-to-severe earthquake shaking (Figure 2.1 (a)).

On the other hand, the first institutional attempt to map the earthquake vulnerability of built environment in India was made by the Building Materials and Technology Promotion Council (BMTPC) in the year 2012, based on the types of material used in the construction of roofs and walls. However, it is difficult to compare the seismic risk of different cities in the absence of quantitative mechanism to measure the risk. Quantification of risk through a Risk Index provides the opportunity to compare the risk of cities under threats and prepare them to respond better when an event occurs and demonstrate the resilience to face the future events. Despite that there was no study attempted to estimate the earthquake risk of the cities in Seismic Zones III, IV and V.

The first significant effort of developing the risk index was initiated is USA, where apart from physical risk, the effect of social fragility and resilience of the society also were considered in defining the overall risk (Davidson 1997). It was developed for comparisons of relative risk of different cities, but not for comparing the risk of urban fabrics within a city. Various methodologies have been developed to define the disaster risk index incorporated with vulnerability analysis at different levels internationally [e.g., (IDNDR 1999); (FEMA-NIBS 1999); (Cardona 2001); (Kundak 2004); (Birkmann 2007); (Amini-Hosseini, et al. 2009); (Duzgun, et al. 2011)]. This includes earthquake risk assessment considering the physical urban environment (buildings and infrastructure systems) of select cities from select regions of Asia, Europe, the Middle East, Africa, and Latin America [(IDNDR 1999)]. Further, socio economic aspects of urban earthquake risk, buildings, lifelines, transportation and infrastructure has been incorporated by Federal Emergency Management and Agency (FEMA) in developing a software, Hazard of United States (HAZUS) [(FEMA-NIBS 1999)]. However, the methodology suggested by HAZUS is complicated for urban earthquake risk assessment approach, and its application is limited to the American physical and social conditions. Several initiatives in Europe to develop earthquake risk assessment and loss estimation methodologies across the Euro Mediterranean region are underway. Usually, the final products of their studies are software packages for assessing the seismic risk and earthquake losses.



(a) **(b)**

Figure 2.1: (a) Seismic Hazard Map [(IS 1893(Part 1) 2016)], and (b) Housing Threat Factor [(Ramancharla and Murty 2014)]

A holistic model is developed the seismic risk analysis of urban centres considering both 'hard' and 'soft' risk variables [(Cardona 2001)]. This model takes into account physical risk, exposure and socio-economic characteristics of the different units of the city and their disaster coping capacity or degree of resilience. Relative Seismic Risk Index (RSRi) method applied in the Tehran city of Iran is another holistic seismic risk assessment approach proposed for urban areas. The proposed approach estimates the risk indicator associated with each parameter as a product of vulnerability factor and hazard factor. The risk indicator/weights for each parameter were arrived on validating with damages in past earthquakes in Indian context. Further, total relative seismic risk index is evaluated using the weighted combination of risk indicators. Other methods such as Disaster Risk Index (DRI) developed by UNDP and World Bank's study were used for mapping the natural disaster risk of countries [(Cardona 2001)].

From the above studies, it was learnt that the methods developed elsewhere in the world are finetuned to their respective built environments and social status of the country in focus, these methods cannot be directly applied in the Indian context. Thus, there is a need to develop an earthquake risk index specifically for Indian cities located in Seismic Zones III, IV and V. As an initial attempt in India, a Housing Threat Factor (HTF) was developed (Figure 2.1 (b)) considering the earthquake hazard and housing density at the district level.

HTF was developed with the aim of prioritizing the districts of the country for earthquake risk mitigation projects in the housing sector [(Ramancharla and Murty 2014)]. However, a framework with a holistic view of understanding the earthquake risk is required with vulnerability included.

2.3 Objectives and Advantages of EDRI

The objectives in development of EDRI are

[1] To provide a systematic way to compare the overall earthquake disaster risks across a large number of cities and regions in India;

[2] To create awareness on seismic zones that are under low seismic hazard regions yet poses seismic risk threats and the influencing parameters

[3] To sensitize policy makers for taking appropriate actions towards reducing the earthquake risks

[4] To identify the gaps in the existing seismic risk assessment methods, thereby select specific parameters for building a model that has features of interim assessment and easy replication channel for better management

[5] To prioritize the cities and regions based on the severity of risk for implementing mitigation programs using EDRI model.

The advantages of estimating EDRI are the following

[1] Comparison of overall earthquake risk for relative allocation of available limited mitigation resources and efforts;

[2] EDRI will enunciate the factors that are responsible for the risks vis., expected magnitude of ground shaking, large number of vulnerable structures, and city's current economic situation;

[3] EDRI will also help the national and state governments to identify the higher risk cities and regions on a priority basis to mitigate the expected risks

[4] Towards the end, this study will help the executive authorities for preparing the Master Plan for city development.

2.4 Methodology

Disaster risk requires a multi-disciplinary assessment viz., architecture, building conditions, soil type, geographical conditions, engineering etc. Apart from expected physical damages, there are a set of parameters that lead to second order effects which are to be considered such as conditions related to social fragility and lack of resilience which are required to be considered in the assessment. Therefore, as a first step, a method is proposed that considers mitigating aspects in this study followed by a step-wise procedure for evaluating EDRI.

2.4.1 Earthquake Disaster Risk Index of Building ($EDRI_b$)

Earthquake risk is represented as the product of the prevalent earthquake hazard (H) of the area, the number of persons exposed to the earthquake hazard (E), and the known vulnerability (V) of the houses in that area, as:

$$Risk = H \times V \times E \qquad (2.1)$$

Each of these components of risk has its own characteristics, which can be spatial (e.g., hazard), thematic (e.g., vulnerability of houses) and temporal (e.g., exposure).

2.4.1.1 Seismic Hazard of Building (H_b)

Earthquake Hazard the potential threat of occurrence of a damaging earthquake, within the design life of the house in a given area. The hazard due to an earthquake can be reflected by expected intensity of ground shaking (quantified by PGA, PGV and PGD, soil liquefaction, surface fault rupture and slope instability). Rational understanding of the seismic hazard of the different areas is critical to a meaningful risk assessment exercise.

Hazard is generally estimated as a combination of Seismic Zone Factor (Z), Soil Type (Sta) and Spectral Shape (Sa) (Figure 2.2); the value of hazard estimated consistent with IS 1893 (1), using the above procedure, ranges from 0.2 to 1.5. Further, if buildings are located in regions susceptible to liquefaction, landslide or rock fall or fire hazard, the building is declared as one with 100% risk; no further calculations are done.

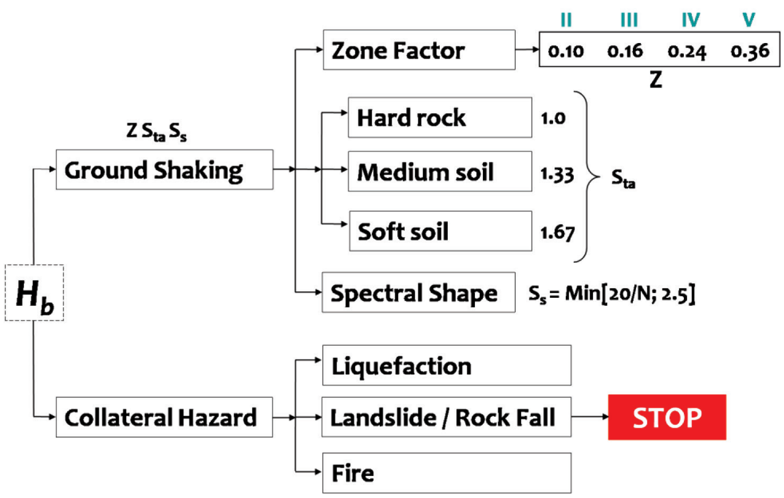


Figure 2.2: Flowchart for Hazard Estimation of a Building

2.4.1.2 Exposure (E_b)

Exposure is assessed as:

$$IE_b = I \times FAR \qquad (2.2)$$

where I is Importance Factor of the building and FAR the Floor Area Ratio. Importance Factor I is 1 for ordinary residential buildings, 1.25 for offices and 1.5 for important buildings (like hospitals), as per IS1893 (1) (Figure 2.3). Floor area ratio is specified in Municipal bye-laws. Usually, it is estimated as the ratio of sum of carpet area in all the floors, and the total plot area. The value of Eb of buildings ranges from 1.33 to 4.0.

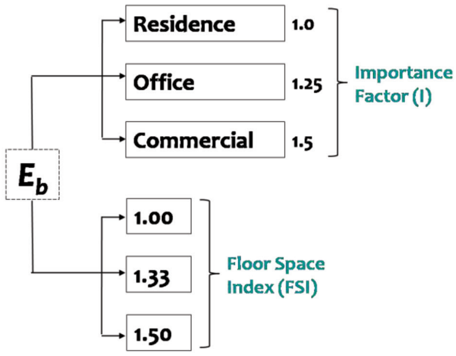


Figure 2.3: Flowchart for Exposure Estimation of a Building (values of Importance Factor I recommended in IS1893 (1) are given in brackets)

2.4.1.3 Vulnerability (V_b)

Earthquake vulnerability of a building is the amount of expected damage induced to it by the expected intensity of earthquake shaking. It can be quantified in terms of Life Threatening Factors (LTF) and Economic Loss Inducing Factors (ELIF).

(a) Life-Threatening Factors (LTF)

A condition that jeopardizes life declares that the house is unsafe. Two types of life-threatening factors are considered, namely (i) those related to the structure of the house, and (ii) those related to the contents and utilities of the house; hereinafter, these two sets of factors are referred to as Life Threatening House Structure Factors L(S) and Life Threatening House Contents & Utilities Factors L(C). Life threatening factors can be quantified in terms of: (i) site, (ii) form, and (iii) strength. If any of these factors are present in the buildings, then that building is declared as one with as 100% risk.

(b) Economic Loss Inducing Factors (ELIF)

An ideal house of the typology in focus. A departure from the ideal condition, which is described may not cause the house to collapse or cause life-threatening conditions in the house, but may attract huge economic burden (loss of time, business etc by occupant values) of retrofitting the house to make it earthquake-resistant. Two types of economic loss-inducing factors are considered; hereinafter, these factors will be referred to as Economic Loss Inducing House Structure Factors E(S) and Economic Loss Inducing House Contents and Utilities Factors E(C). These factors include items drawn from the clauses of the relevant Indian Standards, which are required to be adopted in the construction of a house of the relevant housing typology. The above can be quantified as the algebraic sum of: (i) siting issues (5%), (ii) soil & foundation conditions (5%), (iii) architecture features (50%), (iv) structural aspects (20%), and (v) construction details (20%). The above percentage varies with building type, and over time upon gaining experience of risk assessment. These percentages can be assigned for different building typologies by using Delphi Method, wherein experienced engineers sit together and suggest relative weight in first round, and upon discussion on mean and standard deviation of their proposed value with the overall average, they propose revised percentages if convinced. Vulnerability estimated will be between zero (for a resistant building) and 100% (for a fully vulnerable building) (Figure 2.4).

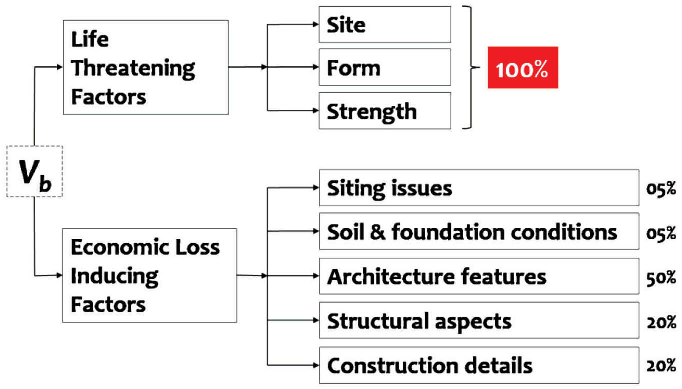


Figure 2.4: Flowchart for Vulnerability Estimation of a Building (values of Economic Loss Inducing Factors are given alongside the flowchart [(Murty, Raghukanth, et al. 2012)]

2.4.1.4 Earthquake Disaster Risk Index of a Building

Finally, EDRIb of a building is estimated as:

$$Risk = H_b \times V_b \times E_b \tag{2.3}$$

Substituting the minimum and maximum values of hazard, exposure and vulnerability in Eq. (2.3), the EDRIb value ranges from 0 to 9.

$$EDRI_b = \begin{bmatrix}0.2\\1.5\end{bmatrix} \times \begin{bmatrix}0\\1\end{bmatrix} \times \begin{bmatrix}1.33\\6.0\end{bmatrix} = \begin{bmatrix}0\\9\end{bmatrix}$$

2.4.1.5 Earthquake Disaster Risk Index of a Town

EDRI for a town or city is estimated by considering EDRI of fully vulnerable buildings and partially vulnerable buildings, as:

$$EDRI_{Town} = \frac{N_1 R_{b1} + N_2 R_{b2} + .. + N_T R_{bT}}{N_1 + N_2 + .. + N_T}\text{, and} \tag{2.4}$$

$$(EDRI_{Town})_{Stop} = \frac{(N_1)_{Stop} + (N_2)_{Stop} + .. + (N_T)_{Stop}}{N_1 + N_2 + .. + N_T}\,. \tag{2.5}$$

where $EDRI_{Town}$ is the Earthquake Disaster Risk Index of Town, N1 the number of buildings of typology 1, Rb1 the summation of risks of buildings of typology 1, (EDRITown)Stop the Earthquake Disaster Risk Index of Town having 100% risk and (N1)Stop the number of buildings of typology 1 having 100% risk.

3 Data Collection in 50 Cities and Towns

3.1 Introduction

As per the Census of India, the towns in the country are categorized based on population into three classes, namely (i) semi-urban centers, having population in the range 10,000-99,999, (ii) urban centers, having population in the range 1,00,000-9,99,999, (iii) metro Cities, having population more than 10,00,000. In this study, 50 cities were selected based on the population density and high Housing Threat Factor (Chapter 2), cities identified by Government of India to develop as Smart Cities, and those in the seismically active regions in India, i.e., Seismic Zones IV and V. These, 50 cities include: (i) cities in Seismic Zones IV and V, (ii) state capitals, (iii) metro cities (Tables 3.1, 3.2 and 3.3).

Apart from these 50 cities, one district Bareilly District in Uttar Pradesh, was selected for study. In the 50 cities, the area of interest was within the municipal boundaries only, but in the Bareilly District, the survey was done in the City, in all the Tehsils of the Bareilly District (Table 3.4) and few villages in each Tehsil (Table 3.5). The task of collection of necessary information from the 50 cities and one district, within the limited time and with available limited manpower, was overcome by carrying out the tasks with the separate teams in only selected 24 cities of the 50 cities, and in the Bareilly district (Annex A: Table A.1). Rapid Visual Survey (RVS) was performed in those cities between January 2017 and November 2017.

Table 3.1: Selected Cities Located in Seismic Zone V

S. No.	City/Town	State/Union Territory
1	Itanagar	Arunachal Pradesh
2	Guwahati	Assam
3	Dispur	Assam
4	Port Blair	Andaman &Nicobar Islands
5	Darbhanga	Bihar
6	Bhuj	Gujarat
7	Mandi	Himachal Pradesh
8	Srinagar	Jammu and Kashmir
9	Imphal	Manipur
10	Shillong	Meghalaya
11	Aizwal	Mizoram
12	Kohima	Nagaland
13	Agartala	Tripura
14	Chamoli	Uttarakhand
15	Pithoragarh	Uttarakhand

Table 3.2: Selected Cities Located in Seismic Zone IV

S. No.	City/Town	State/ Union Territory
16	Patna	Bihar
17	Bhagalpur	Bihar
18	Jamnagar	Gujarat
19	Faridabad	Haryana
20	Gurgaon	Haryana
21	Panipat	Haryana
22	Panchkula	Haryana
23	Shimla	Himachal Pradesh
24	Solan	Himachal Pradesh
25	Jammu	Jammu and Kashmir
26	Ratnagiri	Maharashtra
27	Amritsar	Punjab
28	Jalandhar	Punjab
29	Ludhiana	Punjab
30	Alwar	Rajasthan
31	Gangtok	Sikkim
32	Ghaziabad	Uttar Pradesh
33	GautamBudh Nagar	Uttar Pradesh
34	Meerut	Uttar Pradesh
35	Bareilly	Uttar Pradesh
36	Mathura	Uttar Pradesh
37	Moradabad	Uttar Pradesh
38	Dehradun	Uttarakhand
39	Uttarkashi	Uttarakhand
40	Nainital	Uttarakhand
41	Chandigarh	Union Territory
42	Darjeeling	West Bengal
43	Siliguri	West Bengal

Table 3.3: Selected Metro Cities

S. No.	City/Town	State/UT	Seismic Zone
44	Delhi	Delhi	IV
45	Vijayawada	Andhra Pradesh	III
46	Ahmedabad	Gujarat	III
47	Mumbai	Maharashtra	III
48	Pune	Maharashtra	III
49	Chennai	Tamil Nadu	III
50	Kolkata	West Bengal	III

Table 3.4: Tehsils in Bareilly District (Uttar Pradesh)

S. No.	Tehsil	District	Seismic Zone
1	Bareilly (Sadar)	Bareilly (Uttar Pradesh)	IV
2	Aaonla		
3	Baheri		
4	Faridpur		
5	Meerganj		
6	Nawabganj		

Table 3.5: Villages visited in each Tehsil of Bareilly District (Uttar Pradesh)

S. No.	Village	Tehsil
1	Devchara	Aaonla
2	Bhamora	
3	Ramnagla	
4	Sendha	
5	Motipura	
6	BehtaJanu	
7	Shivpuri	
8	Balliya	
9	Ramnagar	
10	Richa	Baheri
11	Kesar Sugar Mill	
12	Girdharpur	
13	Sharif Nagar	
14	Shergarh	
15	Bhindolia	Faridpur
16	Zed Sabdalpur	
17	Pachoni	
18	PurvFatehgang	
19	Bilpur	
20	Tisva	
21	Dunka	Meerganj
22	Jaferpur	
23	Saijna	
24	Sindhouli	
25	Id Jagir	
26	Richhola Kifayatullah	Nawabganj
27	Hardua Kifayatullah	
28	Hafizganj	

3.2 City/Town Housing Information

The level of risk in a city depend not only on the vulnerability of individual building typologies in that city, but also on factors such as topography of city, soil conditions, seismic hazard, population, possibilities of collateral hazards (e.g., liquefaction of soil, landslides and fire), use of buildings (e.g., residential, office and commercial uses), and FAR or FSI (i.e., floor area ratio or floor space index). In addition, quality of construction alone does not ensure safety of a building. For example, if all the design guidelines are properly followed for the construction of a G+5 storey RC framed building, but built on a very loose soil strata or on a vulnerable hill slope, is safe under normal loading conditions and clearly unsafe under severe earthquake shaking. This is because, during earthquake shaking, loose soil may undergo liquefaction, resulting in severe damage and even collapse of building. Further, landslides may occur in a vulnerable hill slope during earthquake shaking and the buildings may collapse into the valley.

Due to the difficulty of collecting information on each building in a city, it was decided that at least 50 representative buildings are surveyed. In the process, in 36 cities, the size of sample buildings is between 60 to 100 buildings, and in remaining cities, it is more than 100. Further, after evaluating the risk index using the sample surveyed buildings in each city, the risk index of all buildings is obtained by extrapolating the risk in each typology of the total number of buildings in that typology.

3.3 Data Collection Format

The data collection was carried out personally by visiting 24 cities. Further, two sets of information were collected, namely building information and city information (Table 3.6). The parameters involved are dependent on geology, site conditions, overall built environment, and building typologies present in the building. The Nodal Officers of each city (identified by local governments) provided the data online; the online google form was developed by IIIT Hyderabad. The link of the online google form along with the soft copy of the form was sent through an eMails to the District Collectors and the concerned Nodal Officers of all 50 cities. And, the type of data collected during the field visits is the same as required in the online form.

Table 3.6: Methods followed for Data Collection of 50 Cities

Data Collection of 50 Cities			
IIIT Hyderabad (for 24 Cities)		Nodal Officer (for 26 Cities)	
City information collected by personally visiting the Municipal Office and discussing with the concerned Officers	Building information collected by RVS and photographs of buildings taken in person in different areas of the city	City information provided through online form with help of different persons in the Municipal Office	Building photographs in different wards of city collected by Nodal Officers team and provided online

The risk at individual building level requires visual inspection and estimate based on its functionality, which together form the Rapid Visual Survey (RVS). The RVS has predefined set of questions regarding the presence or absence of a certain feature in the building, and in general has to be documented in the field manually. But, considering the large time required for survey and field data conversion in a computer for further analysis, it was decided to capture the visual inspection notes in the form of photographs. These photographs of buildings were analysed later for estimating the risk of individual buildings. As a result, the risk calculations and results were documented in a systematic way on the computer. In addition to collecting city information of 10 cities, RVS was performed by IIIT Hyderabad on few sample buildings first, and photographs captured of many buildings later in different parts of city. Similarly, in the remaining 40 cities also, the building photographs were collected from different wards of city. A sample google survey form duly filled is attached in Annexure B.

3.4 EDRI

The next step was the estimation of the risk of individual building, and the risk of city. IIIT Hyderabad prepared a procedure to estimate the risk of city based upon the risk of individual buildings in the city (Chapter 2). The procedure for risk estimation of individual building involves a set of questions, which needs answers only in the form of 'Yes' or 'No'. The questions are selected in such a way that they address all three components of risk i.e., hazard, exposure and vulnerability of building, and all five broad domains related to the vulnerability of building, namely site issues, soil and foundation condition, architectural features, structural aspects and construction details. At the beginning, each building typology is given a score of 100 and each question is given a negative penalty. The questions are prepared in such a way that it asks whether the building has any of those parameters related to the three components, which will affect negatively the building performance or behaviour, during an earthquake. Building earns penalties for the questions whose answers are YES and no penalties for those whose answers are NO. Proper and detailed inspection of each photograph of a building is required to understand the building's functionality, before answering these questions. Building typology with maximum questions answered as 'yes' gets the least total score. The total score is a quantitative value. Then, the risk of all the surveyed buildings is estimated. Finally, the typology-wise score collected over sample buildings (at least 50) is extrapolated to all buildings in the city of that typology. Thus, the final EDRI of city is estimated considering all buildings in the city. A sample calculation is presented in Table 3.7. The breakup of EDRI score is presented in Table 3.8, with a score of more than 0.4 being an alarming number.

Table 3.7: Sample Calculation of EDRI of all Surveyed Buildings and EDRI of Pithoragarh City

Housing Typology	EDRI Calculation of Surveyed Buildings				EDRI Calculation from Census		
	Number of Buildings	$\sum R_{i,RC}$	EDRI Vulnerable	EDRI	Number of Buildings	Sum Risk (T)	EDRI of Town
Reinforced Concrete Building	279	181.54	0.65	0.65	6,565	4,272	0.65
Brick Masonry building with Concrete Roof	43	30.96	0.72		3,282	2,363	
Brick Masonry building with Other Roof	26	12.56	0.48		1,641	793	
Stone Masonry building	0	0.00	0.00		0.00	0.00	
Other	0	0.00	0.00		0.00	0.00	

Table 3.8: Comparison of Final Score and Level of Risk/Damage of Building

Score	Level of Risk/Damage
0.0 – 0.2	No Damage
0.2 – 0.4	Slight Damage
0.4 – 0.6	Moderate Damage
0.6 – 0.8	Severe Damage
0.8 – 1.0	Collapse

3.4.1 EDRI of a City

The risk index of overall city was estimated as shown below:

$$R_{RCC} = \frac{\Sigma R_{i,RC}}{N_{RC}} \quad (3.1)$$

$$EDRI_{Sample Buildings} = \frac{N_1 R_{b1} + N_2 R_{b2} + .. + N_T R_{bT}}{N_1 + N_2 + .. + N_T} \quad (3.2)$$

$$EDRI_{City} = \frac{N_{1T} R_{B1} + N_{2T} R_{B2} + .. + N_{nT} R_{BT}}{N_{Total}} \quad (3.3)$$

$$\text{Sum Risk}_{City(RC)} = \frac{N_{1T}}{N_1} \times \text{Sum of EDRI of Buildings Surveyed} \quad (3.4)$$

where, R_{RC} is EDRI of all reinforced concrete buildings, $\Sigma R_{i,RC}$ the summation of EDRI of individual reinforced concrete buildings, Rb1 the summation of risk of buildings of Typology 1, N_1 the total number of surveyed buildings of Typology 1, N_{1T} the total number of buildings of Typology 1 in city, R_{B1} the summation of risk of all buildings of Typology 1 in city, N_{Total} the total number of buildings in city (including all typologies), $EDRI_{SampleBuilding}$ the Earthquake Disaster Risk Index of the sample buildings surveyed and $EDRI_{Town}$ the Earthquake Disaster Risk Index of the overall city.

Similarly, the risk indexes of all the 50 cities were estimated as shown in Annex B: Table B.1. But, the level of damage in a city cannot be projected from there of a single building, but can be done by projecting thereof a typology. This is because in the large building stock of a single typology, there are varying levels of damage in a city, owing to different geology, soil conditions and construction quality. Every single building in any group of buildings in any city may have a different score, but this study considers the values averaged for all buildings of a single typology.

In general, EDRI of a particular city, indicates levels of damage ranging from No Damage state to Collapse state. This distribution varies between cities; some cities have more buildings with slight or no damage, while some other have more buildings with severe to collapse damage state. Thus, EDRI of a city is estimated quantitatively. Therefore, a simple and quantitative approach is proposed by assigning a percentage to the risk; risk of 0% is safe, and 100% is unsafe. Percentages of the EDRI values in the said 50 cities and metro cities are estimated and presented in Annex

B: Tables B.1, B.2, B.3, and B.4. Buildings with risk close to 100% may experience huge losses to life and property, in the event of expected earthquakes. In the above tables, RC represents the Reinforced Concrete Buildings, BM_CR the Brick Masonry Buildings with concrete roof, and BM_OR the Brick Masonry Buildings with other roof materials. The accuracy of estimation of risk of a city increases as the size of the sample buildings surveyed increases.

3.4.2 EDRI of a Circle/Ward within a City

The EDRI of circle or ward in a city is attempted, because the same typology of a building within a city may not be equally vulnerable earthquakes. For instance, if the risk of a city is 85%, it can be assumed that large number of buildings in this city is expected to reach a damage state between severe and collapse. Thus, the vulnerable area can be divided into small groups (circles or wards) which is more convenient for authorities to take necessary steps to reduce the vulnerability of buildings in that area. Also, this will speed up the disaster response of the city. Conceptually, the method of risk estimation is the same for a city and a small area within the city; the risk can be estimated, if the necessary census data of a particular small area in the city is available, similar to the estimation of risk of a city. Because the data for each number of wards in each city and town are provided by the Census of India, the risk (in percentage) is estimated of all the wards in a city. But, building information of wards/circles was available in only a few cities, namely Pithoragarh, Agartala, and Gangtok; thus, EDRI values of these Cities are presented in Annex B: Table B.4, B.5 and B.6.

4 Data Analysis and Results

4.1 Introduction

The factors are identified, which contribute to risk of the individual house, and thereby risk of city as a whole. The focus of the study is to determine a trend of risk factor on cumulative EDRI score of housing typology, and its effect on the risk of town. The factors contributing to risk of a building in each city are different and depending on the percentage of each factor, the risk varies.

4.2 Major Factors Contributing to Risk

The factors contributing to risk are identified separately for the three typologies of buildings, namely the Reinforced Concrete (RC) moment resisting frame (MRF) buildings, Brick Masonry (BM) buildings with concrete roof, and BM buildings with roof other than RC. These factors are discussed separately for the said three building typologies in Seismic Zone V and Zone IV cities.

4.2.1 RC MRF Buildings in Cities in Seismic Zone V

The common economic loss inducing factors observed in RC MRF buildings of five cities in Seismic Zone V are presented in Annex C: Table C.1. These factors pertain to three categories, namely (i) structural aspects; (ii) architectural features of the building, and (c) soil and foundation conditions of building location. Further, the percentages of buildings with the identified deficiency are also presented.

The most common Economic Loss Inducing Factors observed in RC MRF buildings in Zone V cities are presented in Annex C: Table C.2. Ten cities have the risk of incurring damages due to lack of separation of staircase from the house. The architectural and structural features of large window opening were found to be common in six cities. This was followed by unsymmetrical placement of staircase in plan area and staircase not integrally built in to building frame in five and four cities respectively. Other factors (like insufficient gap between house, house touching each other and large area of door openings) were found in four cities.

4.2.2 BM Buildings with Concrete Roof in Cities in Seismic Zone V

The common Economic Loss Inducing Factors observed in the BM buildings with RC roof in Seismic Zone V are presented in Annex C: Table C.3. These factors pertain to three categories, namely (i) structural aspects, (ii) architectural features of the building, and (c) soil and foundation conditions of building location. Further, the percentages of buildings with the identified deficiency are presented. But conclusion was not drawn from all the cities because of insufficient or no data available for a building typology under consideration from that city. “Not Applicable” indicates no data for analysis, because building data is less than 50 from that city. The total number of buildings in such cases is mentioned in the bracket.

The most common Economic Loss Inducing Factors observed in BM buildings with concrete roof in Zone V cities are presented in Annex C: Table C.4. Absence of band at lintel and sill level were the most common architectural and structural deficiencies found in about nine cities in Zone V. Houses constructed touching each other, unsymmetrical staircase location with respect to plan and staircase not adequately separated from house, were common among the factors contributing to risk.

4.2.3 BM Buildings with Other Types of Roof in Cities Located in Seismic Zone V

The common Economic Loss Inducing Factors observed in the BM buildings with roofs other than concrete in cities in Seismic Zone V are presented in Annex C: Table C.5. These factors pertain to two categories, namely (i) structural aspects, and (ii) architectural features of the building. But, it is difficult to draw any similarities as a particular type of building belonging to one city are either absent or very few in other cities. Further, the percentages of buildings with the identified deficiency are presented.

4.2.4 RC MRF Buildings in Cities in Seismic Zone IV

The common Economic Loss Inducing Factors observed in the BM buildings with RC roof in cities in Seismic Zone IV are presented in Annex C: Table C.6. These factors pertain to three categories, namely (i) structural aspects; (ii) architectural features of the building, and (c) soil and foundation conditions of building location. Architectural Features found to contribute to risk more common than structural aspects. Further, the percentages of buildings with the identified deficiency are presented.

The most common Economic Loss Inducing Factors observed in RC MRF buildings in Zone IV cities are presented in Annex C: Table C.7. 22 cities have the risk of incurring damages due to window openings covering large area. The architectural and structural features of large and heavy projections were another major parameter is common in 11 cities. Rare single are windows are close to corner and staircase are not separated from house.

4.2.5 BM Buildings with Concrete Roof in Cities in Seismic Zone IV

The common Economic Loss Inducing Factors observed in the BM buildings with RC roof in cities in Seismic Zone IV are presented in Annex C: Table C.8. These factors pertain to three categories, namely (i) structural aspects, (ii) architectural features of the building, and (c) soil and foundation conditions of building location. Further, the percentages of buildings with the identified deficiency are presented. But, conclusion was not drawn from all the cities because of insufficient or no data available for a building typology under consideration from cities. “Not Applicable” indicates no data for analysis, because building data is less than 50 from that city. The total number of buildings in such cases is mentioned in the bracket.

The most common Economic Loss Inducing Factors observed in BM buildings with concrete roof in cities in Seismic Zone IV are presented in Annex C: Table C.9. Absence of RC band at lintel and sill level were the most common architectural and structural deficiency found in 11 cities in Seismic Zone IV. This observation is similar to that in cities in Seismic Zone V. Staircase not separated from house, houses touching each other and large projection/overhangs are other common factors contributing to risk, in half of the cities where sufficient building data is available.

4.2.6 BM buildings with Other Types of Roof in Cities in Seismic Zone IV

BM buildings with other types of roof are common in Seismic Zone IV regions with heavy rainfall or snow fall, but sufficient data of such buildings is not available to draw any conclusion on the level of risk except in the Bareilly city (Annex C: Table C.11).

4.3 Cities with similar challenges

The present built environment in all the 50 cities were studied to calculate risk of each city. Further all the cities were divided into three main categories to understand the qualitative risk level of each city. Separate group of cities with High and Medium risk level were formed and further sub-groups were made in order to identify cities with similar challenges. The names of cities based on stated classifications are tabulated below Table 4.1.

Table 4.1: Sub-groups of cities with High and Medium risk level

Group ID	Classification	Cities
G1A	High EDRI - High Hazard	Aizwal, Pithoragarh, Srinagar, Uttarkashi, Nainital, Bhagalpur, and Panipat
G1B	Medium EDRI - High Hazard	Darbhanga, Ghaziabad, Itanagar, Guwahati, Dispur, Port Blair, Imphal, Shillong, Kohima, Agartala, Chamoli, Jammu, and Mathura
G2A	High EDRI - High Exposure	Aizwal, Solan, Gangtok, and Vijayawada
G2B	Medium EDRI - High Exposure	Ghaziabad, Pune, and Mumbai
G3A	High EDRI - High Vulnerability	Shimla, Aizwal, Pithoragarh, Nainital, and Uttarkashi
G3B	Medium EDRI - High Vulnerability	Darbhanga, Patna, Mandi, and Chennai

Among 50 cities, 13 cities were found to have High risk, 30 cities have Medium risk and remaining 7 cities with Low risk level. Hazard is estimated as a combination of Seismic Zone Factor, Soil Type and Spectral Shape. It was observed that among 13 cities with High risk level, 7 cities have High hazard level. Aizwal, Pithoragarh, and Srinagar lies in zone V which leads to higher hazard level. The cities like Uttarkashi, Nainital, Bhagalpur, and Panipat even though lies in seismic zone IV, however, they still make into this sub-group of high hazard level. Aizwal, Pithoragarh, Uttarkashi, and Nainital are located in hilly terrain compared to Srinagar, Bhagalpur, and Panipat which are located in relatively flat terrain. Soft soil in Bhagalpur and good number of low to mid-rise buildings surveyed in Panipat city is contributing to high hazard level. Among 30 cities with medium risk, 13 cities can be grouped together based on their high hazard level. Among these 13 cities 10 cities lies in seismic zone V which obviously led them for higher level of hazard. Geographically 7 cities among these 13 are located in hilly region.

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.

5 Major Observations

The major findings of the earthquake risk assessment exercise are summarized here. The risk of cities in seismic Zone V and IV are discussed separately, and similarities are identified. This is expected to help take crucial decisions in identifying techniques of retrofitting the buildings located in such regions; improving local construction techniques and adhering to Indian Standard Code of Practice, regularizing construction on hilly regions will bring down the seismic risk of these cities.

5.1. Cities in Seismic Zone V

From all the selected cities in seismic zone V, cities with high percentage of risk are listed in Table 5.1. Aizwal city in Mizoram is observed to have maximum risk; more than 90% of buildings are either built on hill slopes or located on sites vulnerable to falling debris from the hill tops (Figure 5.1a). 35% of these buildings are located very close to an adjacent and seemingly unsafe building/construction, whose collapse can damage the building easily. Pithoragarh, Shillong and Kohima have more or less similar conditions as that of Aizwal. These cities are situated in hilly areas, which have steep to extremely steep sloped terrains. Srinagar is situated at the foot hills.

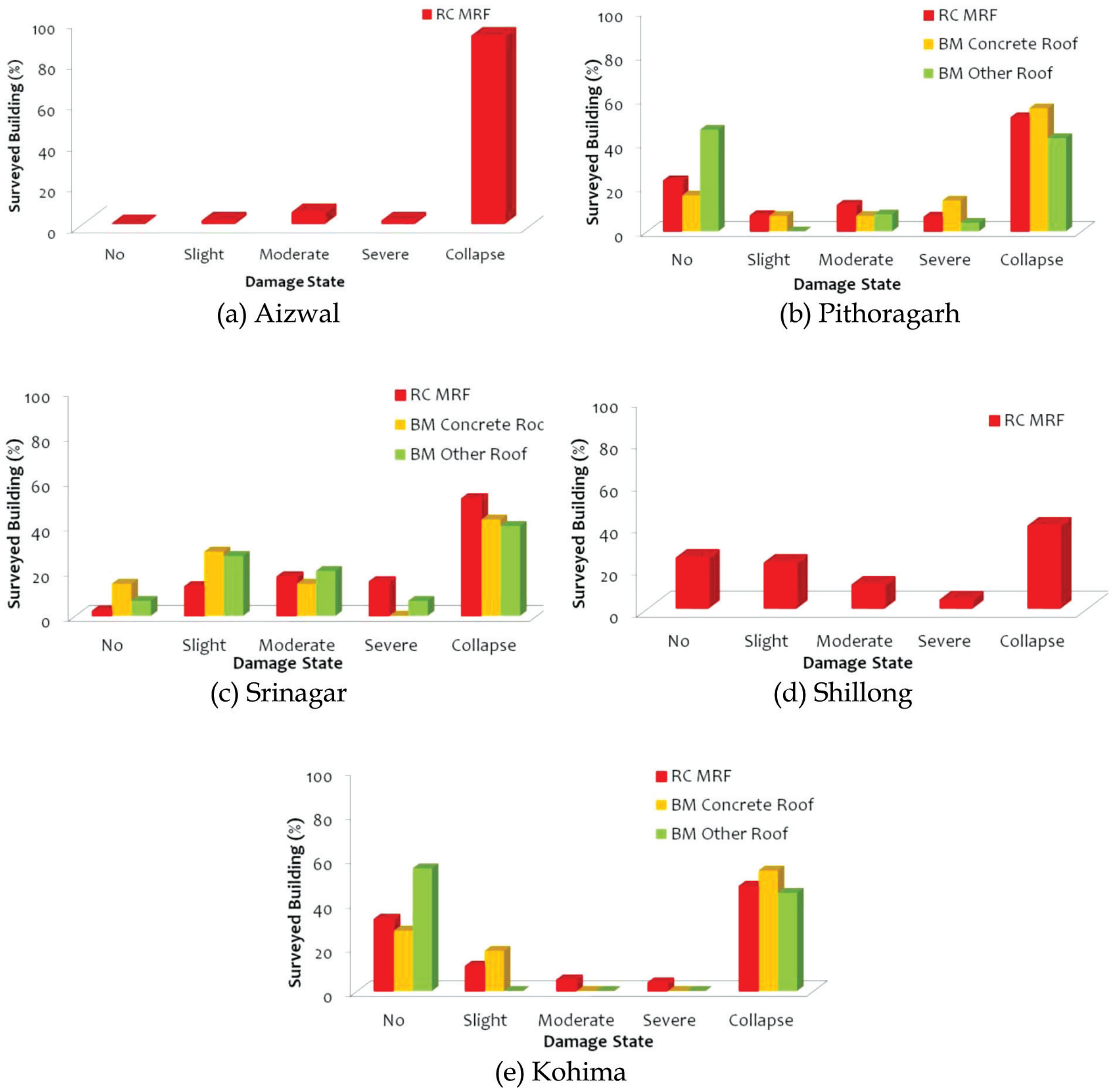
Pithoragarh city has around 20% reinforced concrete buildings as well as brick masonry with concrete roof buildings falling in no damage category; around 50% of brick masonry with other roof buildings are in the same damage category. Whereas the City has nearly 50-60% reinforced concrete buildings, brick masonry concrete roof buildings and brick masonry other roof buildings are in the category of collapse damage state. Even though brick masonry buildings and reinforced concrete buildings are of same percentage the number of sample buildings is different of these typologies (Figure 5.1b).

In Srinagar City, 50% of reinforced concrete buildings and nearly 40% of brick masonry other roof buildings are in the category of collapse. Split roof and pitched roof are the main common factors contributing to the high risk of reinforced concrete buildings.

Table 5.1: Five cities in seismic Zone V cities with highest EDRI

S.No.	City	State/UT	EDRI City (%)
1	Aizwal	Mizoram	96
2	Pithoragarh	Uttarakhand	65
3	Srinagar	J & K	62
4	Shillong	Meghalaya	56
5	Kohima	Nagaland	54

Srinagar city has small number of brick masonry concrete roof sample buildings. Therefore, it is not possible to conclude the overall behaviour of those buildings (Figure 5.1c). As in Aizwal, Shillong City has a small sample building data of RC sample building. Shillong has nearly 21% buildings with slight damage state, 11% buildings with moderate damage and 5% buildings with severe damage. In contrast, it has nearly 40% buildings falling in category of collapse condition. Shillong city is situated in the hilly areas so apart from the buildings constructed on hill slopes, large and heavy overhangs, irregular plan and complex overall shape are some of the factors affecting the buildings behaviour (Figure 5.1d).



(a) Aizwal (b) Pithoragarh

(c) Srinagar (d) Shillong

(e) Kohima

Figure 5.1: Possible Damage States of different building typologies in the cities in seismic Zone V with highest EDRI

Kohima city has few reinforced concrete sample buildings with moderate and severe damage state, but has 45% buildings in collapse condition, because these buildings are constructed on hill slopes. From the available data of brick masonry other roof building, the estimate shows that

56% buildings are likely to be in no damage state and remaining 44% in complete collapse state. But, the total number of brick masonry buildings is so small that it is not possible to conclude anything about the current condition of these buildings in the city, unless a detailed investigation is done. Apart from the buildings built on hill slopes, there are no structural features, but there are few architectural factors that are likely to contribute 8% of moderate damage and 4% of severe damage state of the buildings in Kohima city (Figure 5.1e).

Buildings located on unstable slopes, houses constructed close to each other, presence of overhang or large projection area in a building to get maximum benefit of usable space, and large opening for windows, are the most common factors observed in the cities with highest risk (Table 5.1).

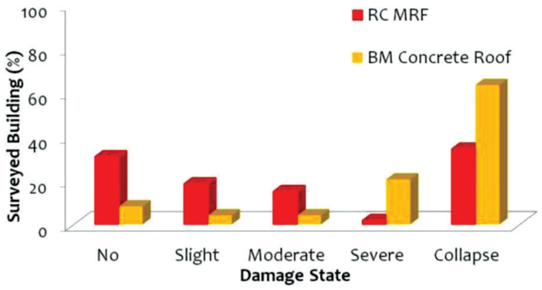
5.2 Cities in seismic Zone IV

Shimla (the capital of Himachal Pradesh) is observed to have highest risk of 83% of all cities in seismic Zone IV. Shimla is the second most vulnerable city compared to the cities considered for risk assessment, irrespective of their seismic zone. Cities located on hilly regions are most vulnerable compared to cities located in flat terrains (Table 5.2) The factors contributing to risk in hilly regions in cities are same as those in cities in seismic Zone V.

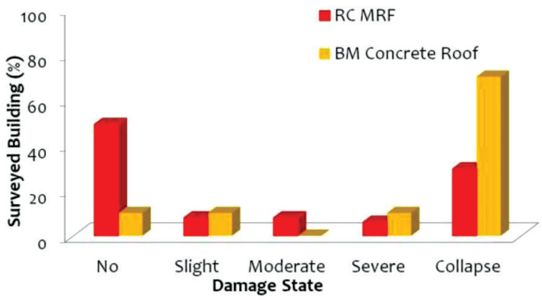
Table 5.2: Top ten cities in seismic Zone IV with highest EDRI

S. No.	City	State/UT	EDRI City (%)
1	Shimla	Himachal Pradesh	81
2	Panipat	Haryana	78
3	Ratnagiri	Maharashtra	69
4	Gangtok	Sikkim	68
5	Moradabad	Uttar Pradesh	67
6	Nainital	Uttarakhand	65
7	Bhagalpur	Bihar	62
8	Solan	Himachal Pradesh	62
9	Uttarkashi	Uttarakhand	62
10	Patna	Bihar	52

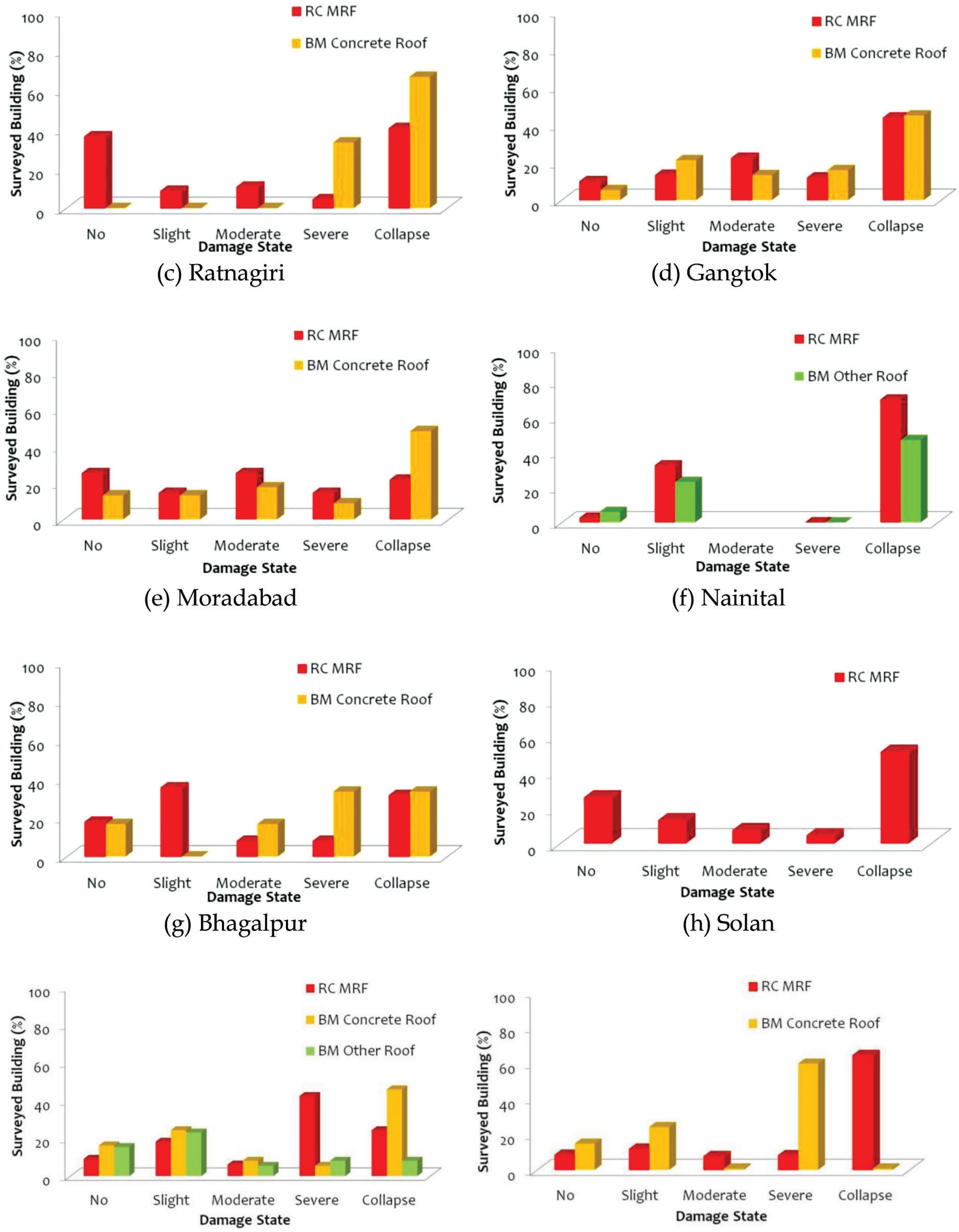
Shimla has 34% reinforced concrete sample buildings and 63% brick masonry buildings with concrete roof buildings, which are either located on hill slopes or built almost touching or located close to an adjacent seemingly unsafe building, whose collapse can damage such buildings. Hence, all these buildings fall under collapse category.



(a) Shimla



(b) Panipat



(c) Ratnagiri (d) Gangtok

(e) Moradabad (f) Nainital

(g) Bhagalpur (h) Solan

(i) Uttarkashi (j) Patna

Figure 5.2: Possible Damage States of building typologies in the cities in seismic Zone IV cities with highest EDRI

The damage distribution in reinforced concrete buildings is found to be skew towards no damage state i.e., more buildings fall under no damage state. About 26% of brick masonry buildings with concrete roof fall under collapse state. But, overall damage distribution of such buildings is skew towards higher damage category, i.e., percentage of buildings falling under no damage state is less compared to those falling under higher states of damage. This is because majority of these buildings have large door and window openings provided near corner. Due to local climate, these buildings have pitched roof, which adds to the risk in such buildings during earthquake shaking (Figure 5.2a).

Panipat has nearly 30% of reinforced concrete sample buildings falling under collapse category, because and there as on being more than half of the buildings have open ground storey that are not designed for earthquake resistance. It was also observed that around 45% buildings are expected to have minimum damage i.e., (no damage state). In the other three damage categories the percentage of buildings varies from 5 to 8%. The number of brick masonry buildings, with other roof is only 7%. Hence, it is not possible to comment on damage pattern of such buildings (Figure 5.2b).

Ratnagiri has 40% of reinforced concrete sample buildings coming in collapse category, because most buildings have open ground storeys and are not designed for earthquake shaking. Also, they buildings touching or located close to an adjacent seemingly unsafe building/construction. Also many buildings are in no damage condition. In the remaining three damage categories, the percentage of buildings varies from 4-10%. Numbers of brick masonry building with RC roof are only three in number. Hence it is not possible to comment on the expected damage pattern of such buildings (Figure 5.2c).

Gangtok city has normal distribution of damage between no damage to severe damage category for both reinforced concrete buildings and brick masonry buildings with concrete roof. The buildings of both typologies are expected to sustain slight damage, 13% and 21% respectively. But the percentage of reinforced concrete buildings in collapse state is 43%, because most buildings in the city are constructed on sloping ground by excavating some part of the hill; owners keep finding more space in the front portion and extending the building in the front in this newly available space, making the building vertically irregular. In addition, open ground storey, heavy overhangs, heavy roof tops, and irregular plan shapes are common in buildings in the city that makes them seismically more vulnerable (Figure 5.2d).

Reinforced concrete buildings in Moradabad city are skewed towards no damage but have about 21% buildings expected to be in collapsed state. Whereas 48% of brick masonry buildings with concrete roof building are expected to be in collapse state in the city, the remaining 52% of buildings come under the four damage states with highest 17% of buildings in the moderate category (Figure 5.2e).

Most buildings in Nainital city are constructed on hill slope. Due to this geographical condition and local construction practices, buildings with large amount of window openings and openings (door or windows) located near corner are common. Such factors make nearly 32% of reinforced concrete and 23% of brick masonry buildings with other roof come under collapse category. Other buildings are constructed on flat ground or sufficiently away from slope and hence are in no or slight damage state (Figure 5.2f).

In Bhagalpur City reinforced concrete buildings have similar trend as their counterparts in Moradabad city with nearly 30% buildings in collapse state and the remaining skewed towards slight damage state. The percentage of reinforced concrete buildings in the no damage state is only 17%. Commenting on damage pattern of brick masonry building with concrete roof is difficult because due total number of sample buildings is just 12 (Figure 5.2g).

Reinforced concrete buildings in Solan city are skewed towards no damage state and have about 50% buildings in collapse state. In other damage categories, the highest number of buildings is about 25% in no damage state, and reduces to 4.2% in severe category. Other typologies were not part of the sample buildings, and hence, no comment is made on damage pattern in masonry buildings (Figure 5.2h).

In Uttarkashi, large number of brick masonry buildings is likely to collapse. Analysis of various factors responsible for high vulnerability of the brick masonry buildings, suggests that the structural aspects (like absence of provision of horizontal bands at different levels) are the major cause for the damage of such buildings. In RC buildings, the major risk factors contributing to 66% risk of severe damage to collapse state are large window opening and its location near the corner, unsymmetrical location of column and non-separation of staircase from main structure. Damage state of 13 sample buildings of brick masonry with other roof category, indicate similar damage of all five-damage state (Figure 5.2i).

In Patna City, of all buildings surveyed, the percentage of reinforced concrete buildings in category of collapse state is very high (64%), that of brick masonry buildings with concrete roof in severe damage state is also high (60%) (Figure 5.2j). During field visit, it was observed that most reinforced concrete buildings privately constructed do not have earthquake resistant features. For example, out of 359 surveyed reinforced concrete buildings, nearly 40% buildings are touching or located close to an adjacent building, whose collapse can cause damage, and nearly 15% buildings have open ground storey. Of the brick masonry buildings surveyed, nearly 50% have door and window openings in walls at the corners, which can cause severe damage to the building in future.

6 Way Forward

Earthquake Disaster Risk Index obtained is based on the preliminary screening of different housing typologies of selected cities. It further requires a detailed structural evaluation by seismic design professionals for highly vulnerable buildings so that suitable retrofitting measures can be adopted by the policy makers. Other remaining cities lying in zone IV & V need to be targeted in the similar manner. As the screening conducted was on a macro level, so highlighting the hotspot area which are lacking in adequate structural parameter and need utmost attention can be figured out. Further, Extensive field study has to be carried out to get a realistic picture and this can be achieved by inclusion of the local bodies like city officials, local colleges which can aid in task and can help in developing and maintaining the inventory at the city level itself.

In order to better understand the potential risk, an inventory of the surveyed buildings is to be developed such that it can be utilized in case of future events and which in turn help in planning and implementation of mitigation strategies. An Intercity and Intra city comparison of the similar kind of building typologies can be made to notch out the different parameter considered presently such that it can help coming to conclusion for determining the risk estimation in a better way and to assess whether additional parameters are required apart from (a) Siting Issues; (b) Soil and Foundation; (c) Architectural Features; (d) Structural Aspects and (e) Material and Construction Details.

Periodic Evaluation of the EDRI & Technical structural safety audit of the buildings shall have to be planned such that present conditions can be compared from the inventory to have a reality check and to gauge out the pattern of improvement and based on which further appropriate measure shall have to be adopted to reduce the risk factor over the period of time. i.e. from high to moderate, moderate to low. Beside all these a ranking system may be developed so that the construction pattern may be gauged and link with the associated pattern which would help in identifying the trend in the construction and associated policy intervention may be fused accordingly.

The EDRI will be helpful in increasing significant awareness among the people residing in highly seismic vulnerable area. It can be achieved by conducting awareness programme and establishment of demonstration retrofitting units, teaching risk reduction measures, acquiring lifesaving skills and a way to respond during and after earthquakes such that local people should be prepared and can plan their immediate mitigation strategies in case of mishappening; and are able to identify the vulnerable hazardous buildings and can plan for quick repair, restoration, and retrofit the structures. Stringent actions shall have to be put in place on violation of codes or deviating away from the laid down guidelines.

Thus, Estimating Earthquake Disaster Risk Index requires active participation of three principal stakeholders, namely:

(1) Academia:

It shall (a) identify and document various building typologies; (b) study these typologies in detail and describe ideal building in each typology category; (c) identify penalties for each departure by conducting analytical and/or experimental research and to introduce the new technique in the market that can be adopted by industry ; and (d)train graduate and post graduate students to identify the different kind of distress present in the buildings and make them understand the structural and non-structural deficiency (e) introducing the retrofit course as part of course curriculum (f) train manpower for undertaking design of new constructions and retrofit of existing buildings.

(2) Industry:

It shall: (a) outlaw unsafe typologies and encourage good typologies within the laid guidelines; (b) propose new technologies; (c) build facilities to undertake full-scale testing; (d) build skills in its artisans; (d) encourage continuing education and research; (e) undertake to build competence in retrofit of unsafe constructions; (f) actively engage in developing standards; and (g) update its fraternity with the latest developments in earthquake safety.

(3) Government:

It shall ensure that policies and systems (with legal standing) are in place for: (a) ensuring all future constructions to be earthquake resistant; (b) identify cities whose earthquake risks are high; and (c) Seek peer review of structural safety of new constructions and modifications to existing constructions. (d) Setting up the periodic Technical structural safety Audit to ensure the safety and to understand the present condition of the buildings. (e)Stringent action shall be taken against the stakeholders for deviating away from the guidelines. (f) Establishment of the Demonstration unit to aware people and make them understand the severity of the risk involved.

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Annexure A

Field Visits Conducted

Table A.1 Cities selected for field visit as part of the project

S. No.	*City /Town*	*State/Union Territory*	*Seismic Zone*	*Date of Visit*	*Team Members*
1.	Uttarkashi	Uttarakhand	IV	16-17 April 2017	R. Pradeep Kumar
2.	Bhuj	Gujarat	V	23-25 March 2017	R. Pradeep Kumar, Velani Pulkit D, Manoj Reddy
3.	Amritsar	Punjab	IV	27-29 May 2017	Velani Pulkit D
4.	Pithoragarh	Uttarakhand	IV	28-30 May 2017	Aniket Bhalkikar, Manoj Reddy
5.	Bareilly	Uttar Pradesh	IV	11-16 June 2017	Velani Pulkit D, Aniket Bhalkikar, Manoj Reddy, P. V. S. Neelima, E. Keerthana
6.	Mandi	Himachal Pradesh	V	17-19 June 2017	Velani Pulkit D
7.	Agartala	Tripura	V	17-19 June 2017	Aniket Bhalkikar
8.	Chandigarh	Union Territory	IV	15-17 August 2017	Velani Pulkit D, Aniket Bhalkikar
9.	Gangtok	Sikkim	IV	8-10 November 2017	Aniket Bhalkikar, Mangesh Shendkar
10.	Port Blair	Andaman Nicobar Islands	V	20-22 November 2017	Velani Pulkit D, Pammi Vyas
11.	Gurgaon	Hariyana	IV	9-11 July 2018	R. Pradeep Kumar, P. V. S. Neelima, Niharika Talyan, E. Keerthana
12.	Meerut	Uttar Pradesh	IV	9-11 July 2018	R. Pradeep Kumar, Aniket Bhalkikar, Velani Pulkit D, Pammi Vyas
13.	Guwahati	Assam	V	20 November 2018	P. V. S. Neelima, Pammi Vyas, Niharika Talyan
14.	Faridabad	Haryana	IV	20-22 November 2018	Aniket Bhalkikar, Velani Pulkit D
15.	Itanagar	Arunachal Pradesh	V	21-22 November 2018	P. V. S. Neelima, Pammi Vyas,

S. No.	City /Town	State/Union Territory	Seismic Zone	Date of Visit	Team Members
					Niharika Talyan
16.	Dispur	Assam	V	23-24 November 2018	P. V. S. Neelima, Pammi Vyas, Niharika Talyan
17.	Patna	Bihar	IV	23-24 November 2018	Aniket Bhalkikar
18.	Mathura	Uttar Pradesh	IV	23-24 November 2018	Velani Pulkit D
19.	Darbhanga	Bihar	V	25-26 November 2018	Aniket Bhalkikar
20.	Jammu	Jammu and Kashmir	IV	25-26 November 2018	Velani Pulkit D
21.	Dehradun	Uttarakhand	IV	26-27 November 2018	P. V. S. Neelima, Pammi Vyas
22.	Imphal	Manipur	V	28-29 November 2018	Aniket Bhalkikar, Velani Pulkit D
23.	Chamoli	Uttarakhand	V	28-29 November 2018	P. V. S. Neelima, Pammi Vyas
24.	Mumbai	Maharashtra	III	4-5 December 2018	Himachandan Dasari

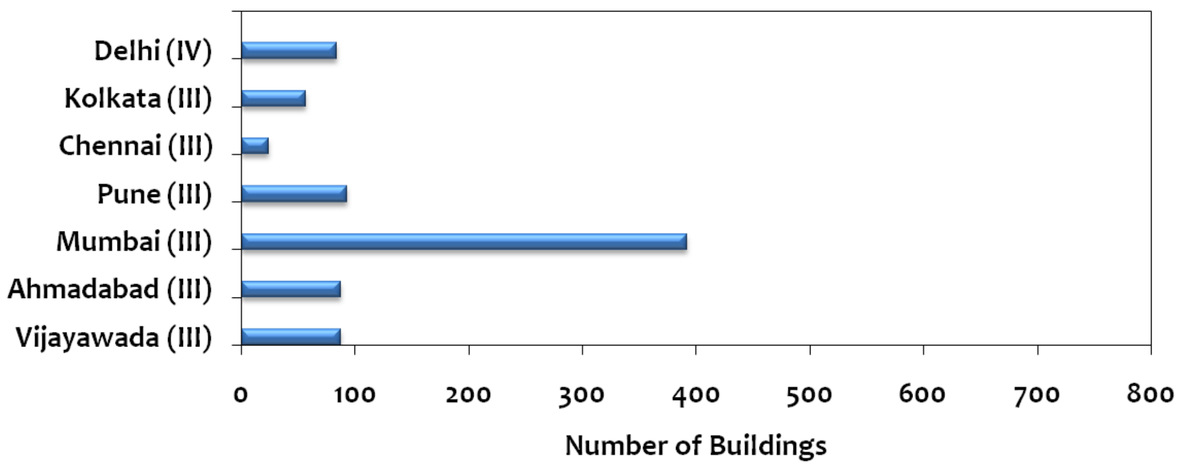

Figure A.1 Number of Buildings surveyed in metro cities

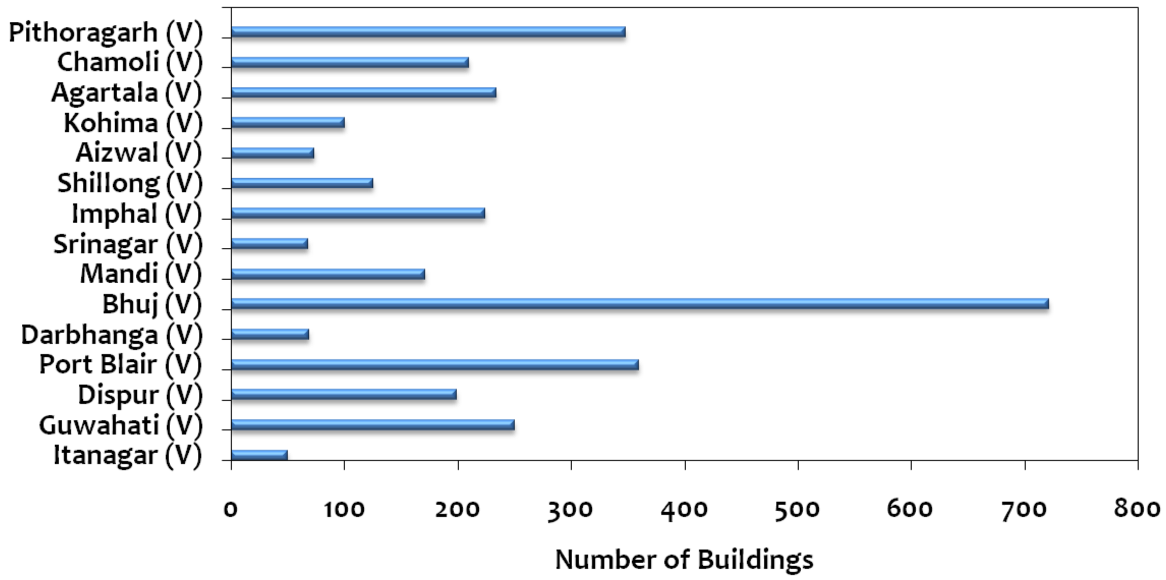

Figure A.2 Number of buildings surveyed in seismic zone V cities

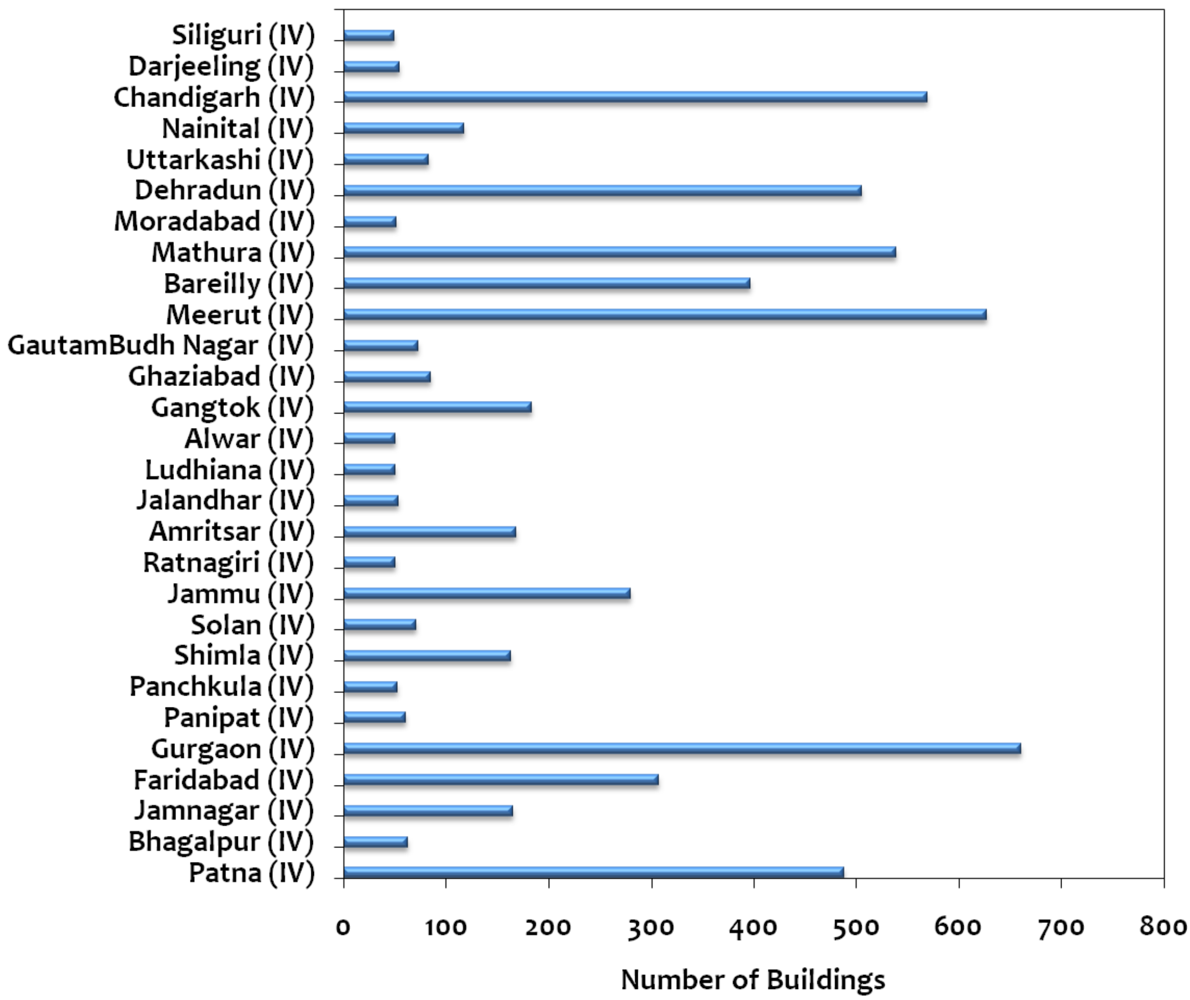

Figure A.3 Number of buildings in seismic zone IV cities

Annexure B

EDRI of 50 Cities

Table B.1 EDRI of cities in seismic zone V

S. No.	City	State or UT	Type	Number of buildings	Risk	EDRI	Sample Data		Census Data	
							EDRI CITY	Risk (%)	EDRI CITY	Risk (%)
1	Itanagar	Arunachal Pradesh	RC	62	30.51	0.49	0.45	45	0.46	46
			BM_CR	22	10.55	0.48				
			BM_OR	44	17.03	0.39				
2	Guwahati	Assam	RC	164	95.69	0.58	0.52	52	0.46	46 31*
			BM_CR	38	14.68	0.39				
			BM_OR	48	20.97	0.44				
3	Dispur	Assam	RC	181	92.19	0.51	0.50	50	0.48	48 28*
			BM_CR	18	4.54	0.25				
			BM_OR	0	0.00	0.00				
4	Port Blair	A & N Islands	RC	360	123.8	0.34	0.34	34	0.34	34
			BM_CR	0	0.00	0.00				
			BM_OR	0	0.00	0.00				
5	Darbhanga	Bihar	RC	221	162.5	0.74	0.66	66	0.43	43 32*
			BM_CR	127	67.3	0.53				
			BM_OR	2	0.60	0.28				
6	Bhuj	Gujarat	RC	580	111.2	0.19	0.18	18	0.17	17
			BM_CR	142	18.30	0.13				
			BM_OR	0	0.00	0.00				
7	Mandi	Himachal Pradesh	RC	54	42.61	0.79	0.56	56	0.46	46
			BM_CR	117	52.75	0.45				
			BM_OR	0	0.00	0.00				
8	Srinagar	J & K	RC	46	34.62	0.75	0.71	71	0.62	62
			BM_CR	7	4.14	0.59				
			BM_OR	15	9.23	0.62				
9	Imphal	Manipur	RC	452	109.4	0.24	0.25	25	0.32	32 37*
			BM_CR	31	10.99	0.35				
			BM_OR	27	8.38	0.31				
10	Shillong	Meghalaya	RC	125	69.52	0.56	0.56	56	0.56	56
			BM_CR	0	0.00	0.00				
			BM_OR	0	0.00	0.00				
11	Aizwal	Mizoram	RC	73	69.93	0.96	0.96	96	0.96	96
			BM_CR	0	0.00	0.00				
			BM_OR	0	0.00	0.00				
12	Kohima	Nagaland	RC	80	46.46	0.58	0.57	57	0.54	54
			BM_CR	11	6.93	0.63				

S. No.	City	State or UT	Type	Number of buildings	Risk	EDRI	Sample Data		Census Data	
							EDRI CITY	Risk (%)	EDRI CITY	Risk (%)
			BM_OR	9	4.02	0.45				
13	Agartala	Tripura	RC	187	85.85	0.46	0.45	45	0.43	43
			BM_CR	41	15.87	0.39				
			BM_OR	6	2.90	0.48				
14	Chamoli	Uttarakhand	RC	180	97.95	0.54	0.53	53	0.46	46 27*
			BM_CR	30	12.12	0.46				
			BM_OR	0	0.00	0.00				
15	Pithoragar h	Uttarakhand	RC	279	181.5	0.65	0.65	65	0.65	65
			BM_CR	43	30.96	0.72				
			BM_OR	26	12.56	0.48				
Note: * Indicates old score.										

Table B.2 EDRI cities in seismic zone IV

Sl. No.	City	State or UT	Type	Number of buildings	Risk	EDRI	Sample Data		Census Data	
							EDRI CITY	Risk (%)	EDRI CITY	Risk (%)
1	Patna	Bihar	RC	359	277.5	0.77	0.70	70	0.52	52 34*
			BM_CR	129	64.6	0.5				
			BM_OR	0	0.00	0.00				
2	Bhagalpur	Bihar	RC	51	27.55	0.54	0.56	56	0.62	62
			BM_CR	12	7.5	0.62				
			BM_OR	0	0.00	0.00				
3	Jamnagar	Gujarat	RC	123	44.74	0.36	0.34	34	0.29	29 17*
			BM_CR	42	11.95	0.28				
			BM_OR	0	0.00	0.00				
4	Faridabad	Haryana	RC	141	82.29	0.58	0.52	52	0.47	47 37*
			BM_CR	166	76.61	0.46				
			BM_OR	0	0.00	0.00				
5	Gurgaon	Haryana	RC	292	196.4	0.67	0.56	56	0.49	49 31*
			BM_CR	369	174.0	0.47				
			BM_OR	0	0.00	0.00				
6	Panipat	Haryana	RC	51	21.85	0.43	0.49	49	0.78	78
			BM_CR	10	7.92	0.79				
			BM_OR	0	0.00	0.00				
7	Panchkula	Haryana	RC	49	26.23	0.54	0.53	53	0.43	43
			BM_CR	3	1.29	0.43				
			BM_OR	0	0.00	0.00				
8	Shimla	Himachal Pradesh	RC	114	58.44	0.51	0.60	60	0.81	81
			BM_CR	49	40.12	0.82				

Sl. No.	City	State or UT	Type	Number of buildings	Risk	EDRI	Sample Data		Census Data	
							EDRI CITY	Risk (%)	EDRI CITY	Risk (%)
			BM_OR	0	0.00	0.00				
9	Solan	Himachal Pradesh	RC	71	44.36	0.62	0.62	62	0.62	62
			BM_CR	0	0.00	0.00				
			BM_OR	0	0.00	0.00				
10	Jammu	J & K	RC	119	40.5	0.34	0.35	35	0.35	35 37*
			BM_CR	161	56.2	0.35				
			BM_OR	0	0.00	0.00				
11	Ratnagiri	Maharashtra	RC	47	25.24	0.54	0.56	56	0.69	69
			BM_CR	3	2.65	0.88				
			BM_OR	0	0.00	0.00				
12	Amritsar	Punjab	RC	105	38.55	0.37	0.30	30	0.22	22
			BM_CR	63	12.67	0.2				
			BM_OR	0	0.00	0.00				
13	Jalandhar	Punjab	RC	38	23.02	0.61	0.54	54	0.4	40
			BM_CR	16	5.95	0.37				
			BM_OR	0	0.00	0.00				
14	Ludhiana	Punjab	RC	39	12.37	0.32	0.29	29	0.22	22
			BM_CR	11	2.28	0.21				
			BM_OR	0	0.00	0.00				
15	Alwar	Rajasthan	RC	28	8.22	0.29	0.37	37	0.46	46
			BM_CR	22	10.18	0.46				
			BM_OR	0	0.00	0.00				
16	Gangtok	Sikkim	RC	145	97.34	0.67	0.67	67	0.68	68
			BM_CR	38	25.91	0.68				
			BM_OR	0	0.00	0.00				
17	Ghaziabad	Uttar Pradesh	RC	85	43.69	0.51	0.51	51	0.51	51
			BM_CR	0	0.00	0.00				
			BM_OR	0	0.00	0.00				
18	Gautam Budh Nagar	Uttar Pradesh	RC	58	30.83	0.53	0.52	52	0.46	46
			BM_CR	15	6.78	0.45				
			BM_OR	0	0.00	0.00				
19	Meerut	Uttar Pradesh	RC	326	154.0	0.47	0.47	47	0.47	47 18*
			BM_CR	296	138.2	0.47				
			BM_OR	5	0.40	0.09				
20	Bareilly	Uttar Pradesh	RC	137	69.95	0.51	0.35	35	0.45	45
			BM_CR	224	50.87	0.23				
			BM_OR	36	19.66	0.55				
21	Mathura	Uttar Pradesh	RC	187	66.00	0.35	0.37	37	0.38	38 35*
			BM_CR	352	135.3	0.38				
			BM_OR	0	0.00	0.00				
22	Moradaba	Uttar	RC	28	13.7	0.49	0.57	57	0.67	67

Sl. No.	City	State or UT	Type	Number of buildings	Risk	EDRI	Sample Data EDRI CITY	Sample Data Risk (%)	Census Data EDRI CITY	Census Data Risk (%)
	d	Pradesh	BM_CR	23	15.52	0.67				
			BM_OR	0	0.00	0.00				
23	Dehradun	Uttarakhand	RC	193	28.36	0.15	0.25	25	0.25	25 20*
			BM_CR	308	53.47	0.17				
			BM_OR	4	0.74	0.19				
24	Uttarkashi	Uttarakhand	RC	33	21.31	0.65	0.62	62	0.62	62
			BM_CR	37	23.17	0.63				
			BM_OR	13	7.12	0.55				
25	Nainital	Uttarakhand	RC	70	42.82	0.61	0.63	63	0.65	65
			BM_CR	0	0.00	0.00				
			BM_OR	47	30.71	0.65				
26	Chandigar h	U.T	RC	187	73.63	0.39	0.32	32	0.3	30
			BM_CR	382	110.9	0.29				
			BM_OR	0	0.00	0.00				
27	Darjeeling	West Bengal	RC	32	12.7	0.40	0.33	33	0.35	35
			BM_CR	15	3.55	0.24				
			BM_OR	8	1.99	0.25				
28	Siliguri	West Bengal	RC	38	9.16	0.24	0.24	24	0.24	24
			BM_CR	11	2.61	0.24				
			BM_OR	0	0.00	0.00				
Note: * Indicates old score.										

Table B.3 EDRI of Metro Cities

Sl. No.	City	State or UT	Type	Number of buildings	Risk	EDRI	Sample Data EDRI CITY	Sample Data Risk (%)	Census Data EDRI CITY	Census Data Risk (%)
1	Vijayawada	Andhra Pradesh	RC	81	49.49	0.61	0.61	61	0.65	65
			BM_CR	6	3.97	0.66				
			BM_OR	0	0.00	0.00				
2	Ahmedabad	Gujarat	RC	68	36.51	0.54	0.52	52	0.47	47
			BM_CR	19	8.75	0.46				
			BM_OR	0	0.00	0.00				
3	Mumbai	Maharashtra	RC	347	210.3	0.61	0.57	57	0.41	41

Sl. No.	City	State or UT	Type	Number of buildings	Risk	EDRI	Sample Data		Census Data	
							EDRI CITY	Risk (%)	EDRI CITY	Risk (%)
			BM_CR	45	12.1	0.27				
			BM_OR	0	0.00	0.00				
4	Pune	Maharashtra	RC	65	31.97	0.49	0.54	54	0.58	58
			BM_CR	28	18.23	0.65				
			BM_OR	0	0.00	0.00				
5	Chennai	Tamil Nadu	RC	63	46.50	0.74	0.72	72	0.53	53
			BM_CR	1	0.37	0.37				
			BM_OR	3	1.69	0.56				
6	Kolkata	West Bengal	RC	43	25.53	0.59	0.58	58	0.54	54
			BM_CR	13	6.93	0.53				
			BM_OR	0	0.00	0.00				
7	Delhi	Delhi	RC	62	12.97	0.21	0.21	21	0.22	22
			BM_CR	22	4.96	0.23				
			BM_OR	0	0.00	0.00				
Note: * Indicates old score.										

Table B.4 EDRI of all wards in Pithoragarh city (Uttarakhand)

Ward Number	Ward	Census Population	Census Household	Number of Buildings	Type	Number of Buildings	Risk	EDRI Surveyed	EDRI Ward	Risk (%)
1	Bhatkot	4,207	1,028	18	RC	17	10.84	0.64	0.69	**69**
					BM_CR	0	0.00	0.00		
					BM_OR	1	1.60	1.60		
2	Vin Jackni	3,775	945	31	RC	29	23.94	0.83	0.84	**84**
					BM_CR	0	0.00	0.00		
					BM_OR	2	2.00	1.00		
3	Kumound	3,817	1,016	51	RC	46	36.19	0.79	0.79	**79**
					BM_CR	4	3.96	0.99		
					BM_OR	1	0.12	0.12		
4	Cinema	2,581	591	38	RC	26	24.87	0.96	0.96	**96**

Ward *Number*	*Ward*	*Census Population*	*Census Household*	*Number of Buildings*	*Type*	*Number of Buildings*	*Risk*	*EDRI* *Surveyed*	*EDRI Ward*	*Risk (%)*
					BM_CR	12	11.78	0.98		
					BM_OR	0	0.00	0.00		
5	Pandgav	3,435	831	24	RC	24	11.88	0.50	0.50	**50**
					BM_CR	0	0.00	0.00		
					BM_OR	0	0.00	0.00		
6	Bhajeti	4,801	1,193	2	RC	1	0.17	0.17	0.13	**13**
					BM_CR	0	0.00	0.00		
					BM_OR	1	0.09	0.09		
7	Cimalgier	4,031	998	18	RC	13	5.55	0.43	0.42	**42**
					BM_CR	5	2.06	0.41		
					BM_OR	0	0.00	0.00		
8	Khadkot	3,939	996	21	RC	17	2.95	0.17	0.25	**25**
					BM_CR	2	0.24	0.12		
					BM_OR	2	2.00	1.00		
9	Cerapundi	1,772	397	16	RC	11	8.90	0.81	0.83	**83**
					BM_CR	2	1.59	0.80		
					BM_OR	3	2.77	0.92		
10	Luntyunda	1,981	449	21	RC	16	7.16	0.45	0.49	**49**
					BM_CR	2	1.22	0.61		
					BM_OR	3	1.99	0.66		
11	Shivalaya	3,509	909	24	RC	20	11.32	0.57	0.55	**55**
					BM_CR	4	1.76	0.44		
					BM_OR	0	0.00	0.00		
12	Tildookri	4,985	1,303	16	RC	11	10.78	0.98	0.97	**97**
					BM_CR	5	4.78	0.96		
					BM_OR	0	0.00	0.00		
13	Naya Bazar	3,895	975	21	RC	18	16.27	0.90	0.91	**91**
					BM_CR	3	2.74	0.91		
					BM_OR	0	0.00	0.00		
14	Takana	4,592	1,142	22	RC	9	1.61	0.18	0.17	**17**
					BM_CR	2	0.03	0.02		
					BM_OR	11	2.174	0.20		
15	Chandra Bhag	4,724	1,263	25	RC	21	15.62	0.74	0.69	**69**
					BM_CR	2	0.80	0.40		
					BM_OR	2	0.89	0.45		
									Average	**61.30**

Table B.5 EDRI of all wards in Gangtok city (Sikkim)

Ward *Number*	*Ward*	*Census Population*	*Census Household*	*Number of Buildings*	*Type*	*Number of Buildings*	*Risk*	*EDRI* *Surveyed*	*EDRI Ward*	*Risk (%)*
1	Upper Burtuk	9,957	2,282	10	RC	5	2.43	0.49	0.59	**59**
					BM_CR	5	3.43	0.69		
					BM_OR	0	0.00	0.00		
2	Lower Burtuk	5,873	1,363	19	RC	10	6.19	0.62	0.59	**59**
					BM_CR	9	4.99	0.55		
					BM_OR	0	0.00	0.00		
3	Lower Siche	7,979	1,997	18	RC	10	6.32	0.63	0.65	**65**
					BM_CR	8	5.4	0.68		
					BM_OR	0	0.00	0.00		
5	Upper Siche	6,177	1,448	10	RC	10	4.79	0.48	0.48	**48**
					BM_CR	0	0.00	0.00		
					BM_OR	0	0.00	0.00		
6	Chandmari	6,723	1,687	10	RC	10	9.09	0.91	0.91	**91**
					BM_CR	0	0.00	0.00		
					BM_OR	0	0.00	0.00		
7	Development Area	3,987	990	10	RC	10	6.06	0.61	0.61	**61**
					BM_CR	0	0.00	0.00		
					BM_OR	0	0.00	0.00		
8	Diesel Power House	8,212	2,008	14	RC	10	5.86	0.59	0.56	**56**
					BM_CR	4	1.95	0.49		
					BM_OR	0	0.00	0.00		
9	Arthang	4,032	809	10	RC	10	5.46	0.55	0.55	**55**
					BM_CR	0	0.00	0.00		
					BM_OR	0	0.00	0.00		
10	Lower M.G. Road	2,664	547	10	RC	10	5.42	0.54	0.54	**54**
					BM_CR	0	0.00	0.00		
					BM_OR	0	0.00	0.00		
11	Upper M.G. Road	3,266	765	10	RC	10	6.83	0.68	0.68	**68**
					BM_CR	0	0.00	0.00		
					BM_OR	0	0.00	0.00		
13	Deorali	6,938	1,753	10	RC	10	6.74	0.67	0.67	**67**
					BM_CR	0	0.00	0.00		
					BM_OR	0	0.00	0.00		
14	Daragoan	9,325	2,290	10	RC	10	7.65	0.77	0.77	**77**
					BM_CR	0	0.00	0.00		
					BM_OR	0	0.00	0.00		
15	Tadong	4,520	1,047	16	RC	10	10.0	1.0	0.88	**88**

Ward *Number*	*Ward*	*Census Population*	*Census Household*	*Number of Buildings*	*Type*	*Number of Buildings*	*Risk*	*EDRI* *Surveyed*	*EDRI Ward*	*Risk (%)*
					BM_CR	6	4.15	0.69		
					BM_OR	0	0.00	0.00		
17	Syari	11,028	2,343	16	RC	20	14.52	0.73	0.79	**79**
					BM_CR	6	6.00	1.00		
					BM_OR	0	0.00	0.00		
									Average	**54**

Table B.6 EDRI of all wards in Port Blair City (Andaman and Nicobar Islands)

Ward *Number*	*Census Population*	*Census Household*	*Number of Buildings*	*Type*	*Number of Buildings*	*Risk*	*EDRI* *Surveyed*	*EDRI Ward*	*Risk (%)*
1	6,580	1,534	20	RC	20	9.44	0.47	0.47	**47**
				BM CR	0	0	0.00		
				BM OR	0	0	0.00		
2	6,437	1,501	20	RC	20	5.66	0.33	0.28	**28**
				BM CR	0	0	0.00		
				BM OR	0	0	0.00		
3	5,805	1,354	20	RC	20	7.09	0.35	0.35	**35**
				BM CR	0	0	0.00		
				BM OR	0	0	0.00		
4	5,805	1,354	20	RC	20	4.97	0.25	0.25	**25**
				BM CR	0	0	0.00		
				BM OR	0	0	0.00		
5	6,330	1,476	20	RC	20	7.31	0.37	0.37	**37**
				BM CR	0	0	0.00		
				BM OR	0	0	0.00		
6	5,714	1,332	20	RC	20	5.28	0.26	0.26	**26**
				BM CR	0	0	0.00		
				BM OR	0	0	0.00		
7	5,736	1,338	20	RC	20	5.75	0.29	0.29	**29**
				BM CR	0	0	0.00		
				BM OR	0	0	0.00		
8	5,416	1,263	20	RC	20	13.93	0.70	0.70	**70**
				BM CR	0	0	0.00		
				BM OR	0	0	0.00		
9	6,721	1,567	20	RC	20	12.75	0.64	0.64	**64**
				BM CR	0	0	0.00		
				BM OR	0	0	0.00		
11	5,476	1,277	20	RC	20	9.42	0.47	0.47	**47**
				BM CR	0	0	0.00		

Ward *Number*	*Census Population*	*Census Household*	*Number of Buildings*	*Type*	*Number of Buildings*	*Risk*	*EDRI* *Surveyed*	*EDRI Ward*	*Risk (%)*
				BM OR	0	0	0.00		
12	5,206	1,214	20	RC	20	5.5	0.28	0.28	**28**
				BM CR	0	0	0.00		
				BM OR	0	0	0.00		
13	5,297	1,235	20	RC	20	5.87	0.29	0.29	**29**
				BM CR	0	0	0.00		
				BM OR	0	0	0.00		
14	6,575	1,533	20	RC	20	5.59	0.28	0.28	**28**
				BM CR	0	0	0.00		
				BM OR	0	0	0.00		
15	5,978	1,394	20	RC	20	4.09	0.24	0.20	**20**
				BM CR	0	0	0.00		
				BM OR	0	0	0.00		
16	6,277	1,464	20	RC	20	3.64	0.18	0.18	**18**
				BM CR	0	0	0.00		
				BM OR	0	0	0.00		
17	5,880	1,371	20	RC	20	3.94	0.20	0.20	**20**
				BM CR	0	0	0.00		
				BM OR	0	0	0.00		
18	5,698	1,329	10	RC	10	4.02	0.45	0.40	**40**
				BM CR	0	0	0.00		
				BM OR	0	0	0.00		
19	6,135	1,431	10	RC	10	4.46	0.17	0.45	**45**
				BM CR	0	0	0.00		
				BM OR	0	0	0.00		
23	5,308	1,238	10	RC	10	1.70	0.34	0.17	**17**
				BM CR	0	0	0.00		
				BM OR	0	0	0.00		
24	5,727	1,335	10	RC	10	3.44	0.39	0.34	**34**
				BM CR	0	0	0.00		
				BM OR	0	0	0.00		
								Average	**29**

Annexure C

Major Contributing Factors to Risk

Table C.1 Economic Loss Inducing Factors in RC MRF buildings in cities in Seismic Zone V

S. No.	*City*	*Economic Loss Inducing Factors*	*Buildings (%)*	*Category*
1	Itanagar	Staircase at Unsymmetrical location	80.65	Structural
		Both top and bottom of staircase integrally built into building frame	77.42	Structural
		Staircase not adequately separated from house	75.81	Structural
		Unsymmetrical staircase location with respect to plan	70.97	Architectural
		Large projections or overhangs	46.77	Architectural
		Large and heavy projections and overhangs	40.32	Architectural
2	Guwahati	Both top and bottom of staircase integrally built into building frame	93.29	Structural
		Staircase not adequately separated from house	93.29	Structural
		Frames have symmetric lateral stiffness along one plan direction	55.49	Structural
		Rare single window close to corners	40.85	Architectural
		Unsymmetrical staircase location with respect to plan	36.59	Architectural
3	Dispur	Large area of window openings	72.38	Architectural
		Staircase not adequately separated from house	61.88	Structural
		Large storey heights	36.23	Architectural
		Large area of door openings	59.67	Architectural
		Large projections or overhangs	49.72	Architectural
		Heavier top	46.41	Architectural
4	Port Blair	Pitched roof/floor slab	33.89	Structural
		Large projections or overhangs	28.06	Architectural
		Large area of door openings	23.33	Architectural
		Complex overall shape with re-entrant corners	21.11	Architectural
		Grid of parallel planar frames only along one plan direction	16.11	Structural
5	Darbhanga	Staircase not adequately separated from house	84.16	Structural
		Both top and bottom of staircase integrally built into building frame	83.26	Architectural
		Unsymmetrical staircase location	73.76	Structural

S. No.	City	Economic Loss Inducing Factors	Buildings (%)	Category
		Houses have insufficient gap between them	66.06	Architectural
		Large projections or overhangs	64.25	Architectural
6	Bhuj	Unsymmetrical staircase location with respect to plan	65.34	Architectural
		Unsymmetrical location of staircase	72.76	Structural
		Rare single window close to corners	69.14	Architectural
		Frames have symmetric lateral stiffness along one plan direction	68.10	Structural
		Houses touch each other	67.76	Architectural
7	Mandi	Roof/floor slab with large size openings, especially located along the edge of the slab	51.85	Structural
		Staircase not adequately separated from house	44.44	Structural
		Houses have insufficient gap between them	27.78	Architectural
		Large projections or overhangs	24.07	Architectural
		Differences in storey heights	24.07	Architectural
		Heavy roof/floor slab	24.07	Structural
8	Srinagar	Staircase not adequately separated from house	100.00	Structural
		No grid of parallel planar frames along both plan directions	95.65	Structural
		Split roof/floor slab	69.57	Structural
		Split roof	65.22	Architectural
		Pitched roof/floor slab	63.04	Structural
		Large projections or overhangs	54.35	Architectural
9	Imphal	Staircase at unsymmetrical location	70.27	Structural
		Staircase not adequately separated from house	65.95	Structural
		Both top and bottom of staircase integrally built into building frame	65.41	Structural
		Houses touch each other	63.24	Architectural
		Large area of window openings	46.49	Architectural
		Large area of door openings	44.32	Architectural
10	Shillong	Large projections or overhangs	53.60	Architectural
		Large and heavy projections and overhangs	53.60	Architectural
		Irregular orientation of rooms	52.00	Architectural
		Rare single window close to corners	46.40	Architectural
		Complex overall shape with re-entrant corners	45.60	Architectural
11	Aizwal	Staircase not adequately separated from house	100.00	Structural
		Houses touch each other	47.95	Architectural

S. No.	City	Economic Loss Inducing Factors	Buildings (%)	Category
		Houses have insufficient gap between them	47.95	Architectural
		About half of openings close to corners	43.84	Architectural
		Large area of window openings	43.84	Architectural
12	Kohima	Soft soil	100.00	Soil & Foundation Condition
		About half of openings close to corners	33.75	Architectural
		Houses touch each other	33.75	Architectural
		Houses have insufficient gap between them	33.75	Architectural
		Window openings covering large area	23.75	Architectural
13	Agartala	High water table	79.14	Soil & Foundation Condition
		Parapet or objects on roof not secured to structural system	56.15	Architectural
		Narrow Staircase	45.99	Architectural
		Staircase built integrally with both top and bottom into the frame	74.87	Structural
		Staircase not adequately separated from house	63.64	Structural
14	Chamoli	Building built on sloped ground with access at two or more levels	44.44	Structural
		Frames don't have symmetric lateral stiffness along any plan direction	41.11	Structural
		Frames don't have symmetric lateral strength along any plan direction	40.00	Structural
		Large area of door openings	37.78	Architectural
		Large area of window openings	26.11	Architectural
		Large projections or overhangs	23.89	Architectural
15	Pithoragarh	No/insufficient anchorage of reinforcement from columns to foundation	52.33	Structural
		Door openings cover large area	50.54	Architectural
		Window openings cover large area	48.39	Architectural
		Staircase not adequately separated from house	47.67	Structural
		Differences in storey heights	44.09	Architectural

Table C.2 Most common Economic Loss Inducing Factors in RC MRF buildings in cities in Seismic Zone V

S. No	*Economic Loss Inducing Factors*	*Number of Cities*
1	Staircase not adequately separated from house	10
2	Large area of window openings	6
3	Unsymmetrical staircase location with respect to plan	5
4	Both top and bottom of staircase integrally built into building frame	4
5	Houses have insufficient gap between them	4
6	Houses touch each other	4
7	Large area of door openings	4

Table C.3 Economic Loss Inducing Factors in BM buildings with concrete roof in cities in Seismic Zone V

S. No.	*City Name*	*Economic Loss Inducing Factors*	*Buildings (%)*	*Category/Remark*
1	Itanagar	No lintel band	100	Structural
		No sill band	100	Structural
		No roof band with flat roof	63.64	Structural
		Unsymmetrical staircase location with respect to plan	59.09	Architectural
		Staircase at unsymmetrical location	54.55	Structural
		Building built on sloped ground with access to house at two/three levels	54.55	Sitting Issues
2	Guwahati	Staircase not adequately separated from house	97.35	Structural
		Both top and bottom of staircase integrally built into building frame	94.74	Structural
		Walls unsymmetrical in one direction	86.84	Structural
		Unsymmetrical staircase location with respect to plan	76.32	Architectural
		Staircase at unsymmetrical location	71.05	Structural
3	Dispur	No sill band	56.67	Structural
		Large openings in walls	56.67	Architectural
		No lintel band	53.33	Structural
		No roof band with flat roof	50.00	Structural
		Large door openings	50.00	Architectural
		Large projections/overhangs	46.67	Architectural
4	Port Blair	-	-	Not Applicable
5	Darbhanga	No sill band	18.90	Structural
		No lintel band	15.75	Architectural
		Large door openings	11.02	Structural
		Rare single window close to corners	8.60	Structural

S. No.	*City Name*	*Economic Loss Inducing Factors*	*Buildings (%)*	*Category/Remark*
		Complex overall shape including those with re-entrant corners	7.09	Architectural
6	Bhuj	No lintel band	95.77	Structural
		No sill band	95.77	Structural
		Window openings covering large area	69.72	Architectural
		Houses touch each other	45.77	Architectural
		Unsymmetrical staircase location with respect to plan	38.73	Architectural
7	Mandi	About half of openings close to corners	41.03	Architectural
		Staircase not adequately separated from house	23.93	Structural
		Complex overall shape including those with re-entrant corners	21.37	Architectural
		Houses touch each other	17.09	Architectural
		No lintel band	11.11	Structural
8	Srinagar	-	-	Insufficient data
9	Imphal	No sill band	96.00	Structural
		No lintel band	88.00	Structural
		No roof band with flat roof	88.00	Structural
		Both top and bottom of staircase integrally built into building frame	76.00	Structural
		Staircase not adequately separated from house	76.00	Structural
		Complex overall shape including those with re-entrant corners	76.00	Architectural
10	Shillong	-	-	Not Applicable
11	Aizwal	-	-	Not Applicable
12	Kohima	-	-	Insufficient data
13	Agartala	Large openings in walls	73.17	Structural
		Window openings covering large area	68.29	Architectural
		No sill band	68.29	Structural
		High water table	65.85	Soil & Foundation Condition
		No lintel band	65.85	Structural
14	Chamoli	No roof band with flat roof	90.00	Structural
		No lintel band	90.00	Structural
		No sill band	90.00	Structural
		No Plinth band	90.00	Structural
		Building built on sloped ground with access to house at two/three levels	63.33	Sitting Issues

S. No.	*City Name*	*Economic Loss Inducing Factors*	*Buildings (%)*	*Category/Remark*
		Large area of door openings	60.00	Architectural
15	Pithoragarh	Differences in storey heights	58.14	Architectural
		Houses touch each other	60.47	Architectural
		No roof band with flat roof	65.12	Structural
		No lintel band	67.44	Structural
		No sill band	67.44	Structural

Table C.4 Most common Economic Loss Inducing Factors among the BM buildings with concrete roof in cities in Seismic Zone V

S. No	*Economic Loss Inducing Factors*	*Number of Cities*
1	No lintel band	9
2	No sill band	9
3	Houses touch each other	3
4	Staircase not adequately separated from house	3
5	Unsymmetrical staircase location with respect to plan	3

Table C.5 Economic Loss Inducing Factors in BM buildings with other type of roof in cities located in Seismic Zone V

Sl. No.	*City Name*	*Economic Loss Inducing Factors*	*Buildings (%)*	*Category/Remark*
1	Itanagar	No sill band	69.35	Structural
		Split roof	69.35	Structural
		No lintel band	66.13	Structural
		The building connected to sloped ground, and no gap between building and natural slope	54.84	Sitting Issues
		Houses touch each other	33.87	Architectural
2	Guwahati	Walls unsymmetrical in one direction	100.00	Structural
		Houses touch each other	91.67	Architectural
		Houses have small gap between them	66.67	Architectural
		Adhoc procedures of construction	62.50	Construction workmanship
		Split roof	56.25	Structural
3	Dispur	-	-	Not Applicable
4	Port Blair	-	-	Not Applicable
5	Darbhanga	-		Insufficient data
6	Bhuj	-		Not Applicable

Sl. No.	*City Name*	*Economic Loss Inducing Factors*	*Buildings (%)*	*Category/Remark*
7	Mandi	-		Not Applicable
8	Srinagar	Pitched roof	100.00	Structural
		Staircase not adequately separated from house	100.00	Structural
		Split roof	86.67	Architectural
		Split roof	80.00	Structural
		Houses touch each other	60.00	Architectural
9	Imphal	No sill band	100.00	Structural
		No lintel band	100.00	Structural
		Tiled roof or roof with separate planks	100.00	Structural
		Unsymmetrically located and integrally built staircase	78.57	Structural
		Staircase not adequately separated from house	78.57	Structural
		Unsymmetrical staircase location with respect to plan	78.57	Architectural
10	Shillong	-		Not Applicable
11	Aizwal	-		Not Applicable
12	Kohima	-		Insufficient data
13	Agartala	-		Insufficient data
14	Chamoli	-		Insufficient data
15	Pithoragarh	Door openings covering large area	46.15	Architectural
		Window openings covering large area	30.77	Architectural
		About half of openings close to corners	23.08	Architectural
		Split roof	23.08	Structural
		Differences in storey heights	19.23	Architectural
		Almost all openings close to corners	19.23	Architectural
		Houses touch each other	19.23	Architectural

Table C.6 Economic Loss Inducing Factors for RC MRF buildings in cities in Seismic Zone IV

Sl. No.	*City Name*	*Economic Loss Inducing Factor*	*Buildings (%)*	*Category*
1	Patna	Staircase not adequately separated from house	89.69	Structural
		Both top and bottom of staircase integrally built into building frame	86.07	Structural
		Irregular orientation of rooms	71.59	Architectural
		Large projection and overhangs	69.92	Architectural
		Houses have insufficient gap between them	66.57	Architectural
2	Bhagalpur	Window openings covering large area	56.86	Architectural

Sl. No.	*City Name*	*Economic Loss Inducing Factor*	*Buildings (%)*	*Category*
		Soft soil	52.94	Soil & Foundation Condition
		Door openings covering large area	27.45	Architectural
		Frames have symmetric lateral strength along one plan direction	27.45	Structural
		Heavier top	23.53	Architectural
3	Jamnagar	Staircase not adequately separated from house	67.48	Structural
		Window openings covering large area	58.54	Architectural
		Large room sizes	47.97	Architectural
		Large area of door openings	38.21	Architectural
		Differences in storey heights	36.59	Architectural
4	Faridabad	Soft soil	100.00	Soil & Foundation Condition
		Large area of window openings	57.45	Architectural
		Staircase Both top and bottom integrally built into building frame	30.50	Structural
		Staircase not adequately separated from house	30.50	Structural
		Rare single window close to corners	29.79	Architectural
		Large area of door openings	28.40	Architectural
5	Gurgaon	Large area of window openings	70.00	Architectural
		Complex overall shape with reentrant corners	58.22	Architectural
		Large projections or overhangs	54.45	Architectural
		No grid of parallel planar frames along both plan directions	53.42	Structural
		About half of openings close to corners	50.68	Architectural
		Complex overall shape with reentrant corners	71.43	Architectural
		Large and heavy projections and overhangs	71.43	Architectural
6	Panipat	Soft soil	52.94	Soil & Foundation Condition
		Window openings covering large area	43.14	Architectural
		Large room sizes	27.45	Architectural
		Door openings covering large area	25.49	Architectural
		Rare single window close to corners	23.53	Architectural
7	Panchkula	No grid of parallel planar frames along both plan directions	59.18	Structural

Sl. No.	City Name	Economic Loss Inducing Factor	Buildings (%)	Category
		Large projections or overhangs	48.98	Architectural
		Large and heavy projections and overhangs	46.94	Architectural
		Split roof/floor slab	46.94	Structural
		Complex overall shape with re-entrant corners	44.90	Architectural
8	Shimla	Parapet or objects on roof not secured to structural system	92.98	Architectural
		Differences in storey heights	47.37	Architectural
		Houses touch each other	39.47	Architectural
		Houses have insufficient gap between them	39.47	Architectural
		Split roof	29.82	Architectural
		Split floor slab/floor slab	29.82	Structural
9	Solan	Large room sizes	39.44	Architectural
		Window openings covering large area	36.62	Architectural
		Building built on sloped ground with access at two or more levels	29.58	Siting Issue
		Parapet or objects on roof not anchored to the structural system	23.94	Architectural
		Heavy roof/floor slab	12.68	Structural
10	Jammu	Soft soil	47.50	Soil & Foundation Condition
		Staircase not adequately separated from house	99.05	Structural
		Large area of window openings	63.03	Architectural
		Unsymmetrical location	57.98	Structural
		Rare single window close to corners	40.00	Architectural
11	Ratnagiri	About half of openings close to corners	40.43	Architectural
		Large and heavy projections and overhangs	36.17	Architectural
		Differences in storey heights	34.04	Architectural
		Houses have insufficient gap between them	34.04	Architectural
		Tall storey heights	31.91	Architectural
12	Amritsar	Staircase not adequately separated from house	99.05	Structural
		Large room sizes	46.67	Architectural
		Window openings covering large area	46.67	Architectural
		Unsymmetrical location	40.95	Structural
		Frames have symmetric lateral stiffness along one plan direction	38.10	Structural
13	Jalandhar	Large and heavy projections and	47.37	Architectural

Sl. No.	*City Name*	*Economic Loss Inducing Factor*	*Buildings (%)*	*Category*
		overhangs		
		Window openings covering large area	44.74	Architectural
		Large projections or overhangs	39.47	Architectural;
		Split roof/floor slab	39.47	Structural
		Split roof	36.84	Architectural
14	Ludhiana	Staircase built integrally with both top and bottom into the frame	84.21	Structural
		Window openings covering large area	76.32	Architectural
		Unsymmetrical staircase location with respect to plan	63.16	Architectural
		Unsymmetrical location of staircase	60.53	Structural
		Large projections or overhangs	57.89	Architectural
15	Alwar	Complex overall shape with re-entrant corners	21.43	Architectural
		Large projections or overhangs	21.43	Architectural
		Rare single window close to corners	39.29	Architectural
		Window openings covering large area	21.43	Architectural
		Frames don't have symmetric lateral stiffness along any plan direction	42.86	Structural
		Large and heavy projections and overhangs	25.00	Architectural
16	Gangtok	Staircase not adequately separated from house	59.31	Structural
		Large area of window openings	51.03	Architecture
		Unsymmetrical location of staircase	40.00	Structural
		Unsymmetrical staircase location with respect to plan	37.93	Architecture
		Large projections or overhangs	31.03	Architecture
17	Ghaziabad	Soft soil	100.00	Soil & Foundation Condition
		Window openings covering large area	51.76	Architectural
		Large room sizes	35.29	Architectural
		Large storey heights	27.06	Architectural
		Door openings covering large area	25.88	Architectural
18	Gautam Budh Nagar	Window openings covering large area	72.41	Architectural
		Split roof/floor slab	67.24	Structural
		Large projections or overhangs	65.52	Architectural
		Split roof	62.07	Architectural
		Large and heavy projections and overhangs	58.62	Architectural
19	Meerut	Staircase not adequately separated from house	74.00	Structural

Sl. No.	*City Name*	*Economic Loss Inducing Factor*	*Buildings (%)*	*Category*
		High water table	57.06	Soil & Foundation Condition
		Large area of window openings	56.44	Architectural
		Both top and bottom integrally built into building frame	54.00	Structural
		Not secured to the structural system	40.00	Architectural
20	Bareilly	Large area of window openings	51.82	Architectural
		Rare single window close to corners	49.64	Architectural
		Split roof	43.80	Architectural
		Split roof/floor slab	42.34	Architectural
		Houses touch each other	36.50	Architectural
21	Mathura	Soft soil	98.93	Soil & Foundation Condition
		Parapet or objects on roof not secured to structural system	95.72	Architectural
		Staircase not adequately separated from house	79.68	Structural
		Frames have symmetric lateral stiffness along one plan direction	67.38	Structural
		Large area of window openings	52.94	Architectural
22	Moradabad	Heavier top	67.86	Architectural
		Heavy roof/floor slab	64.29	Structural
		Window openings covering large area	53.57	Architectural
		Split roof/floor slab	53.57	Structural Aspects
		Large projections or overhangs	50.00	Architectural
23	Dehradun	Irregular orientation of rooms	17.62	Architectural
		Rare single window close to corners	17.10	Architectural
		Unsymmetrical staircase location with respect to plan	10.88	Architectural
		Unsymmetrical location	10.36	Structural
		Staircase not adequately separated from house	10.36	Structural
24	Uttarkashi	Window openings covering large area	24.24	Architectural
		Unsymmetrical staircase location with respect to plan	21.21	Architectural
		Rare single window close to corners	21.21	Architectural
		Unsymmetrical location	15.15	Structural
		Open ground storey not designed to resist earthquake shaking	12.12	Architectural
		Staircase not adequately separated from house	12.12	Structural

Sl. No.	*City Name*	*Economic Loss Inducing Factor*	*Buildings (%)*	*Category*
25	Nainital	Soft soil	100.00	Soil & Foundation Condition
		Window openings covering large area	37.14	Architectural
		About half of openings close to corners	21.43	Architectural
		Frames don't have symmetric lateral stiffness along any plan direction	17.14	Structural
		Complex overall shape with reentrant corners	14.29	Architectural
		Houses touch each other	14.29	Architectural
26	Chandigarh	Large area of window openings	100.00	Architecture
		Almost all openings close to corners	99.38	Architecture
		Large area of door openings	91.93	Architecture
		Large and heavy projections and overhangs	87.58	Architecture
		Houses touch each other	62.73	Architecture
27	Darjeeling	No grid of parallel planar frames along both plan directions	100.00	Structural
		Staircase not adequately separated from house	100.00	Structural
		Split roof	81.25	Architectural
		Split roof/floor slab	81.25	Structural
		Large projections or overhangs	56.25	Architectural
28	Siliguri	Staircase built integrally with both top and bottom into the frame	71.05	Structural
		Window openings covering large area	65.79	Architectural
		Complex overall shape with reentrant corners	50.00	Architectural
		About half of openings close to corners	42.11	Architectural
		Irregular orientation of rooms	36.84	Architectural
		Rare single window close to corners	36.84	Architectural

Table C.7 Most common Economic Loss Inducing Factor among the RC MRF buildings in cities in Seismic Zone IV cities

Sl. No	*Economic Loss Inducing Factor*	*Number of Cities*
1	Window openings covering large area	22
2	Large projections or overhangs	11
3	Staircase not adequately separated from house	10
4	Rare single window close to corners	07

Table C.8 Economic Loss inducing factors in BM buildings with RC roof in cities in Seismic Zone IV

Sl. No.	*City Name*	*Economic Loss Inducing Factors*	*Building (%)*	*Category/Remark*
1	Patna	Staircase not adequately separated from house	91.47	Structural
		No sill band	88.37	Structural
		Both top and bottom of staircase integrally built into building frame	86.82	Structural
		Unsymmetrically located staircase	82.95	Structural
		Irregular orientation of rooms	75.97	Architectural
2	Bhagalpur			Insufficient data
3	Jamnagar	No lintel band	30.95	Structural
		No sill band	30.95	Structural
		Staircase not adequately separated from house	23.81	Architectural
		Unsymmetrical staircase location with respect to plan	16.67	Architectural
4	Faridabad	Both top and bottom of staircase integrally built into building frame	94.58	Structural
		Walls unsymmetrical in one direction	93.98	Structural
		No sill band	93.98	Structural
		Unsymmetrical staircase location with respect to plan	89.76	Architectural
		Unsymmetrical location	87.35	Structural
5	Gurgaon	Houses touch each other	95.18	Architectural
		Houses have small gap between them	89.16	Architectural
		Large projections/overhangs	85.91	Architectural
		Staircase not adequately separated from house	81.84	Architectural
		Staircase Unsymmetrical location	71.27	Architectural
6	Panipat	-	-	Insufficient data
7	Panchkula	-	-	Insufficient data
8	Shimla	Door and window openings in walls at the corner	73.47	Architectural
		About half of openings close to corners	73.47	Architectural
		Pitched roof	40.82	Structural
		House has large unanchored projections and overhangs	38.78	Architectural
		Heavier top	38.78	Architectural
9	Solan			Not Applicable
10	Jammu	Soft soil	85.71	Soil & Foundation Condition
		No sill band	85.09	Structural

Sl. No.	*City Name*	*Economic Loss Inducing Factors*	*Building (%)*	*Category/Remark*
		No lintel band	84.47	Structural
		Staircase not adequately separated from house	78.26	Structural
		Unsymmetrical location	69.57	Structural
11	Ratnagiri	-	-	Insufficient data
12	Amritsar	Staircase not adequately separated from house	100.00	Structural
		Soft soil	30.16	Architectural
		No sill band	98.41	Architectural
		No lintel band	98.41	Architectural
		Houses touch each other	23.81	Architectural
13	Jalandhar	No lintel band	81.25	Structural
		Window openings covering large area	37.50	Architectural
		Large projections/overhangs	43.75	Architectural
		Indirect or limited load paths	37.50	Structural
		Complex overall shape including those with openings at corners	43.75	Architecture Features
14	Ludhiana			Insufficient data
15	Alwar	No sill band	100.00	Structural
		No lintel band	100.00	Structural
		Window openings covering large area	72.73	Architectural
		Large projections/overhangs	68.18	Architectural
		Large and heavy projections and overhangs (Not available in book)	68.18	Architectural
16	Gangtok	No lintel band	81.58	Structural
		No sill band	81.58	Structural
		Large window openings	52.63	Architecture
		No roof band with pitched roof	44.74	Structural
17	Ghaziabad			Not Applicable
18	Gautam Budh Nagar	No sill band	100.00	Structural
		No lintel band	100.00	Structural
		Heavy roof	60.00	Structural
		Rare single window close to corners	73.33	Architectural
		Complex overall shape including those with openings at corners	60.00	Architectural
19	Meerut	No lintel band	89.50	Structural
		No sill band	89.19	Structural
		Houses touch each other	71.96	Architectural
		Staircase not adequately separated from house	62.50	Structural
		Unsymmetrically located and integrally built staircase	46.28	Structural

Sl. No.	*City Name*	*Economic Loss Inducing Factors*	*Building (%)*	*Category/Remark*
20	Bareilly	No lintel band	70.54	Structural
		Rare single window close to corners	66.07	Architectural
		Large openings in walls	45.54	Structural
		Large window openings	33.04	Architectural
		No sill band	30.36	Structural
21	Mathura	Soft soil	100.00	Soil & Foundation Condition
		No lintel band	99.15	Structural
		No sill band	98.30	Structural
		Houses touch each other	90.34	Architectural
		Staircase not adequately separated from house	85.23	Structural
22	Moradabad	No lintel band	60.87	Structural
		Window openings covering large area	47.83	Architectural
		Large projections/overhangs	47.83	Architectural
		Large openings in walls	43.48	Structural
		About half of openings close to corners	43.48	Architectural
23	Dehradun	Irregular orientation of rooms	43.83	Architectural
		Rare single window close to corners	43.51	Architectural
		Large door openings	37.66	Architectural
		No lintel band	31.17	Structural
		Houses touch each other	30.19	Architectural
24	Uttarkashi	No sill band	75.68	Structural
		No lintel band	72.97	Structural
		No Plinth band	59.46	Structural
		No roof band with flat roof	35.14	Structural
		No roof band with pitched roof	27.03	Structural
25	Nainital	-	-	Not Applicable
26	Chandigarh	Large window openings	100.00	Architecture
		Large openings in walls	99.40	Structural
		Large projections/overhangs	97.90	Architecture
		Large door openings	93.39	Architecture
		Houses touch each other	87.80	Architecture
27	Darjeeling	Split roof	100.00	Structural
		Staircase not adequately separated from house	86.67	Structural
		Pitched roof	86.67	Structural
		Split roof	86.67	Architectural
		Large projections/overhangs	53.33	Architectural
28	Siliguri	-	-	Insufficient data

Table C.9 Most common Economic Loss Inducing Factor in BM buildings with Concrete Roof in cities in Seismic Zone IV

S. No	*Economic Loss Inducing Factors*	*Number of Cities*
1	No lintel band	11
2	No sill band	10
3	Staircase not adequately separated from house	8
4	Houses touch each other	5
5	Large projections/overhangs	5

Table C.10 Cities with BM buildings with other type of roof in Zone IV

S. No.	*City Name*	*Remark*
1	Patna	Not Applicable
2	Bhagalpur	Not Applicable
3	Jamnagar	Not Applicable
4	Faridabad	Not Applicable
5	Gurgaon	Not Applicable
6	Panipat	Not Applicable
7	Panchkula	Not Applicable
8	Shimla	Not Applicable
9	Solan	Not Applicable
10	Jammu	Not Applicable
11	Ratnagiri	Not Applicable
12	Amritsar	Not Applicable
13	Jalandhar	Not Applicable
14	Ludhiana	Not Applicable
15	Alwar	Not Applicable
16	Gangtok	Not Applicable
17	Ghaziabad	Not Applicable
18	Gautam Budh Nagar	Not Applicable
19	Meerut	Insufficient data
20	Bareilly	Available
21	Mathura	Not Applicable
22	Moradabad	Not Applicable
23	Dehradun	Insufficient data
24	Uttarkashi	Insufficient data
25	Nainital	Insufficient data
26	Chandigarh	Not Applicable
27	Darjeeling	Insufficient data
28	Siliguri	Not Applicable

Table C.11 Economic L**oss** Inducing Factors in BM buildings with RC roof in cities in Seismic Zone IV

S. No.	*City Name*	*Economic Loss Inducing Factors*	*Building (%)*	*Category/Remark*
1	Bareilly	No lintel band	94.44	Structural
		No sill band	94.44	Structural
		Tiled roof or roof with separate planks	75.00	Structural
		No Plinth band	66.67	Structural
		Poor quality of materials	66.67	Construction Materials

Annexure D

Google Survey Form

EDRI City/Town Information Input Form

Overall Information Regarding Earthquake Safety of Built Environment

* Required

1. **Email address** *

For Queries....

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Mr. Aniket Bhalkikar, Research Scholar, EERC, IIIT-Hyderabad (Mob: +91 99850 04656)

City/Town General Information

2. **Name of the City/Town** *

3. **Seismic Zone** *

Check all that apply.

- [ ] Zone II
- [ ] Zone III
- [ ] Zone IV
- [ ] Zone V

4. **Area of City/Town (Square km)** *

5. **Population of City/Town** *

Information about Person Filling the Data

6. **Name** *

7. **Designation** *

8. **Email ID** *

9. **Mobile Number** *

10. **Landline Number**

Contact Details of relevant officers

11. **Name** *

12. **Designation** *

13. **Email ID** *

14. **Mobile Number** *

15. **Landline Number** *

16. **Population Distribution Criteria** *

Mark only one oval.

- Zone
- Circle
- Ward

Geology and Site Information

17. **Soil type at site (%)** *

Percentage distribution of buildings built on different soil condition. e.g. Buildings built on medium soil are 20%

Mark only one oval per row.

	10%	25%	40%	60%	80%
Rock or Hard Soil					
Medium Soil					
Soft Soil					

18. **Site Condition (%)**

Percentage of Buildings with foundation level built on ground types. e.g. 15% and 85% of buildings built on flat ground and sloped ground, respectively.

Mark only one oval per row.

	10%	25%	40%	60%	80%	>80%	None
Flat Ground							
Sloped Ground							
River Bed							
Filled-up Soil							
Others							

19. **Possible Threats (%)** *

Percentage of Buildings experienced or susceptible to threats which may cause damage in structures.

Mark only one oval per row.

	10%	25%	40%	60%	80%	None
Liquefaction of Soil						
Landslide or Rock Fall						
Fire						
Others						

Information about Built Environment

20. **Total Number of Buildings in City/Town (as per 2011 Census)** *

____

21. **Total Number of Buildings constructed after 2011 Census** *

____

22. **Percentage of Buildings: Typologies** *

RC Frame

Stone Masonry

Mud House

Brick Masonry

Bamboo House

Mark only one oval per row.

	0-10%	11-25%	26-40%	41-60%	61-80%	>80%	None
RCC							
Brick Masonry							
Stone Masonry							
Mud Masonry							
Bamboo							
Others							

23. **Percentage of Buildings Classified Based on Purpose/Utility** *

Mark only one oval per row.

	0-10%	11%-20%	21%-40%	41-60%	60-80%	>80%
Residential						
Commercial						
Government/Private Office						
Educational						
Health/						
Industry						
Mixed Use						
Others						

24. **Maximum allowable FAR/FSI** *

Maximum allowable FAR/FSI based on purpose or utility of buildings.

Mark only one oval per row.

	1.33	1.55	1.75	2.0	2.5	4.0	>4.0	None
Residential								
Commercial								
Government/Private Office								
Educational								
Health								
Industry								
Mixed Use								
Others								

25. **Height-wise distribution of building** *

Fill the percentage of buildings in each category. e.g. 1-3 Storey Buildings 60%, etc.

Mark only one oval per row.

	0-5%	6-20%	21-40%	41-60%	61-80%	None
1-3 Storey Buildings						
4-5 Storey Buildings						
6-10 Storey Buildings						
11-15 Storey Buildings						
16-20 Storey Buildings						
>20						

Reinforced Concrete Building Typology

26. **Reinforced Concrete Building Typology Present in City/Town** *

Mark only one oval.

- Yes
- No *Skip to question 39.*

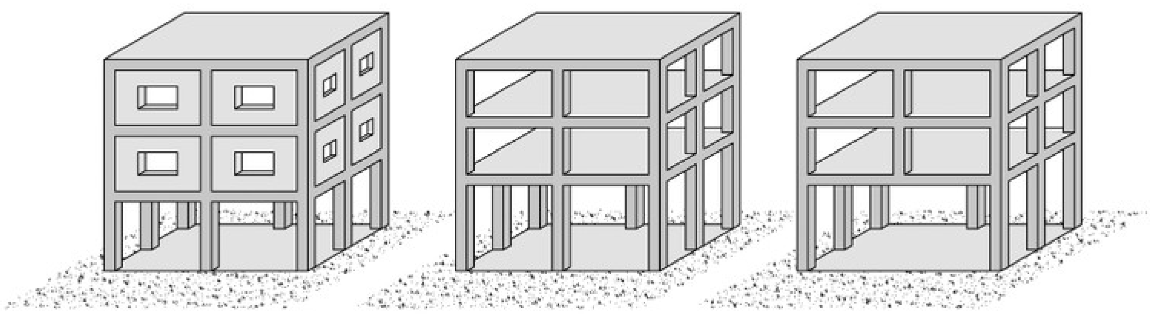
Reinforced Concrete Building Typology

27. **Total Number of RC Building** *

28. **Minimum Number of RC Storeys** *

29. **Maximum Number of RC Storeys** *

Open Ground Storey/ Soft Storey



(a) Stiff and strong upper floors due to masonry infills

(b) The columns in one storey longer than those above

(c) Soft storey caused by discontinuous column

30. **Total Number of Open Ground Storey Buildings**
*

31. **Distribution of Open Ground Storey Buildings in City (%)** *
Mark only one oval per row.

	0-5%	6-10%	11-15%	16-20%	21-30%	31-40%	41-50%	None
<5 Storey								
6-10 Storey								
11-15 Storey								
15-20 Storey								

32. **Wall Material RC Buildings** *
Mark only one oval per row.

	0-10%	10-20%	20-30%	30-40%	40-50%	50-60%	None
Burnt Brick							
Mud/Unburnt Brick							
Concrete							
Stone							
Wooden							
Bamboo							
Grass Thatch							
GI/Metal/Asbestos Sheet							
Plastic Polythene							
Other							

33. **Roof Material RC Buildings** *
Mark only one oval per row.

	0-10%	10-20%	20-30%	30-40%	40-50%	50-60%	None
Burnt Brick							
Mud/Unburnt Brick							
Concrete							
Stone							
Wooden							
Bamboo							
Grass Thatch							
GI/Metal/Asbestos Sheet							
Plastic Polythene							
Other							

34. **Foundation Material RC Buildings** *
Mark only one oval per row.

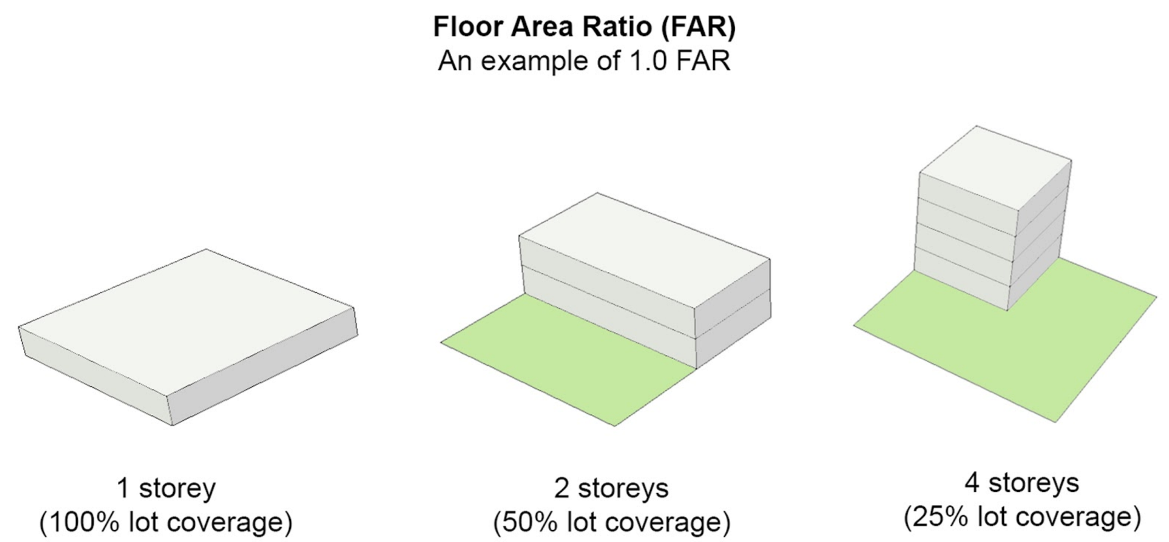
	0-10%	10-20%	20-30%	30-40%	40-50%	50-60%	None
Concrete							
Stone							
Brick							
Bamboo							
Other							

35. **Cost of Construction per square feet (sft) for RC Building as per 2016** *

36. **Special Features that can cause threat to RC Buildings** *
Mark only one oval per row.

	0-10%	11-20%	21-30%	31-40%	41-50%	51-60%	61-70%	None
Chimney								
Balcony								
Water Tank								
Adjoining Unsafe Buildings								
Pounding								
Hoardings								
Roof Top Towers								
Others								

Floor Area Ratio for RC Buildings



37. **Maximum FAR/FSI** *
Percentage of buildings classified based on FAR
Mark only one oval.

- 1.33
- 1.5
- 1.75
- 2
- 2.5
- 4
- >4

38. **Number of RC Buildings permission given after 2011** *
E.g.: Reinforced Concrete: 50000, Brick Masonry: 1500

39. **Any other Information regarding safety of people for RC Buildings**

Brick Masonry (BM) Building Typology

40. **Brick Masonry Typology Present in City/Town** *

Mark only one oval.

- Yes
- No *Skip to question 55.*

Brick Masonry (BM) Building Typology

41. **Total Number of BM Building** *

42. **Minimum Number of BM Storeys** *

43. **Maximum Number of BM Storeys** *

Building Plan Dimensions

44. **Minimum Plan Dimension of BM Building** *

45. **Maximum Plan Dimension of BM Building** *

Masonry Buildings without Bands

46. **Total Number of Masonry Buildings without Horizontal Bands** *

47. **Distribution of Masonry Buildings without Horizontal Bands in City (%)** *

Mark only one oval per row.

	0%-5%	6%-10%	11%-15%	16%-20%	21%-30%	31%-40%	41%-50%	None
1 Storey								
2 Storey								
3 Storey								
4 Storey								
5 Storey								
> 5 Storey								

48. **Wall Material BM Buildings** *
Mark only one oval per row.

	0-5%	6-10%	11-25%	26-40%	41-60%	61-80%	None
Burnt Brick							
Mud/Unburnt Brick							
Other							

49. **Roof Material BM Buildings** *
Mark only one oval per row.

	0-10	10-20%	20-30%	30-40%	40-50%	50-60%	None
Burnt Brick							
Mud/Unburnt Brick							
Concrete							
Stone							
Wooden							
Bamboo							
Grass Thatch							
GI/Metal/Asbestos Sheet							
Plastic Polythene							
Other							

50. **Foundation Material BM Buildings** *
Mark only one oval per row.

	0-10%	10-20%	20-30%	30-40%	40-50%	50-60%	None
Concrete							
Stone							
Brick							
Bamboo							
Other							

51. **Cost of Construction per square feet (sft) for BM Building as per 2016** *

52. **Special Features that can cause threat to BM Buildings** *
Mark only one oval per row.

	0-10%	11-20%	21-30%	31-40%	41-50%	51-60%	61-70%	None
Chimney								
Balcony								
Water Tank								
Adjoining Unsafe Buildings								
Pounding								
Hoardings								
Roof Top Towers								
Others								

53. **Maximum FAR/FSI BM Building** *

Mark only one oval.

- 1.33
- 1.5
- 1.75
- 2
- 2.5
- 4
- >4

54. **Number persons living in BM buildings** *

55. **Any other Information regarding safety of people for BM Buildings**

Stone Masonry (SM) Building Typology

56. **Stone Masonry Typology Present in City/Town** *

Mark only one oval.

- Yes
- No *Skip to question 71.*

Stone Masonry (SM) Building Typology

57. **Minimum Number of SM Storeys** *

58. **Total Number of SM Building** *

59. **Maximum Number of SM Storeys** *

Building Plan Dimensions

60. **Minimum Plan Dimension of SM Building** *

61. **Maximum Plan Dimension of SM Building** *

Stone Masonry Buildings without Bands

62. **Total Number of Stone Masonry Buildings without Horizontal Bands** *

63. **Distribution of Stone Masonry Buildings without Horizontal Bands in City (%)** *
Mark only one oval per row.

	0-5%	6-10%	11-15%	16-20%	21-30%	31-40%	41-50%	None
1 Storey								
2 Storey								
3 Storey								
4 Storey								
5 Storey								
> 5 Storey								

64. **Wall Material SM Buildings** *
Mark only one oval per row.

	0%-10%	10%-20%	20%-30%	30%-40%	40%-50%	50%-60%	None
Burnt Brick							
Mud/Unburnt Brick							
Other							

65. **Roof Material SM Buildings (%)** *
Mark only one oval per row.

	0-10%	10-20%	20-30%	30-40%	40-50%	50-60%	None
Burnt Brick							
Mud/Unburnt Brick							
Concrete							
Stone							
Wooden							
Bamboo							
Grass Thatch							
GI/Metal/Asbestos Sheet							
Plastic Polythene							
Other							

66. **Foundation Material SM Buildings (%)** *
Mark only one oval per row.

	0-10%	10-20%	20-30%	30-40%	40-50%	50-60%	None
Concrete							
Stone							
Brick							
Bamboo							
Other							

67. **Cost of Construction per square feet (sft) for SM Building as per 2016**

68. **Special Features that can cause threat to SM Buildings** *
Mark only one oval per row.

	0-10%	11-20%	21-30%	31-40%	41-50%	51-60%	61-70%	None
Chimney								
Balcony								
Water Tank								
Adjoining Unsafe Buildings								
Pounding								
Hoardings								
Roof Top Towers								
Others								

69. **Maximum FAR/FSI for SM Buildings** *
Mark only one oval.

- 1.33
- 1.5
- 1.75
- 2
- 2.5
- 4
- >4

70. **Number persons living in SM buildings** *

71. **Any other Information regarding safety of people for SM Buildings**

Mud House (MH) Building Typology

72. **MH Typology Present in City/Town** *
Mark only one oval.

- Yes
- No *Skip to question 85.*

Mud House (MH) Building Typology

73. **Total Number of MH Building** *

74. **Minimum Number of MH Storeys** *

75. **Maximum Number of MH Storeys** *

Building Plan Dimensions

76. **Minimum Plan Dimension of MH Building**

77. **Maximum Plan Dimension of MH Building**

78. **Wall Material MH Buildings** *
Mark only one oval per row.

	0-10%	10-20%	20-30%	30-40%	40-50%	50-60%	None
Burnt Brick							
Mud/Unburnt Brick							
Other							

79. **Roof Material MH Buildings** *
Mark only one oval per row.

	0-10%	10-20%	20-30%	30-40%	40-50%	50-60%	None
Burnt Brick							
Mud/Unburnt Brick							
Concrete							
Stone							
Wooden							
Bamboo							
Grass Thatch							
GI/Metal/Asbestos Sheet							
Plastic Polythene							
Other							

80. **Foundation Material MH Buildings** *
Mark only one oval per row.

	0-10%	10-20%	20-30%	30-40%	40-50%	50-60%	None
Concrete							
Stone							
Brick							
Bamboo							
Other							

81. **Cost of Construction per square feet (sft) for MH Building as per 2016** *

82. **Special Features that can cause threat to MH Buildings** *
Mark only one oval per row.

	0-10%	11-25%	26-40%	41-60%	61-80%	None
Chimney						
Balcony						
Water Tank						
Adjoining Unsafe Buildings						
Pounding						
Hoardings						
Roof Top Towers						
Others						

83. **Maximum FAR/FSI for MH Buildings** *
Mark only one oval.

- 1.33
- 1.5
- 1.75
- 2
- 2.5
- 4
- >4

84. **Number persons living in MH buildings** *

85. **Any other Information regarding safety of people for MH Buildings**

Bamboo House (BH) Building Typology

86. **Bamboo House Typology Present in City/Town** *
Mark only one oval.

- Yes
- No *Skip to question 99.*

Bamboo House (BH) Building Typology

87. **Total Number of BH Building** *

88. **Minimum Number of BH Storeys** *

89. **Maximum Number of BH Storeys** *

Building Plan Dimensions

90. **Minimum Plan Dimension of BH Building**

91. **Maximum Plan Dimension of BH Building**

92. **Wall Material BH Buildings** *
Mark only one oval per row.

	0-10%	10-20%	20-30%	30-40%	40-50%	50-60%	None
Burnt Brick							
Mud/Unburnt Brick							
Other							

93. **Roof Material BH Buildings** *
Mark only one oval per row.

	0-10%	10-20%	20-30%	30-40%	40-50%	50-60%	None
Burnt Brick							
Mud/Unburnt Brick							
Concrete							
Stone							
Wooden							
Bamboo							
Grass Thatch							
GI/Metal/Asbestos Sheet							
Plastic Polythene							
Other							

94. **Foundation Material BH Buildings** *
Mark only one oval per row.

	0-10%	10-20%	20-30%	30-40%	40-50%	50-60%	None
Concrete							
Stone							
Brick							
Bamboo							
Other							

95. **Cost of Construction per square feet (sft) for BH Building as per 2016** *

____

96. **Special Features that can cause threat to BH Buildings** *
Mark only one oval per row.

	0-10%	11-25%	26-40%	41-60%	61-80%	None
Chimney						
Balcony						
Water Tank						
Adjoining Unsafe Buildings						
Pounding						
Hoardings						
Roof Top Towers						
Others						

97. **Maximum FAR/FSI for BH Buildings** *
Mark only one oval.

- 1.33
- 1.5
- 1.75
- 2
- 2.5
- 4
- >4

98. **Number persons living in BH buildings** *

99. **Any other Information regarding safety of people for BH Buildings**

Data Uploading

Population and Building Distribution Zone/Circle/Ward Wise

Fill the data as per the information required in excel sheet :

Click below link to download Excel Sheet

http://eerc.iiit.ac.in/EDRI_Input_Data.xlsx

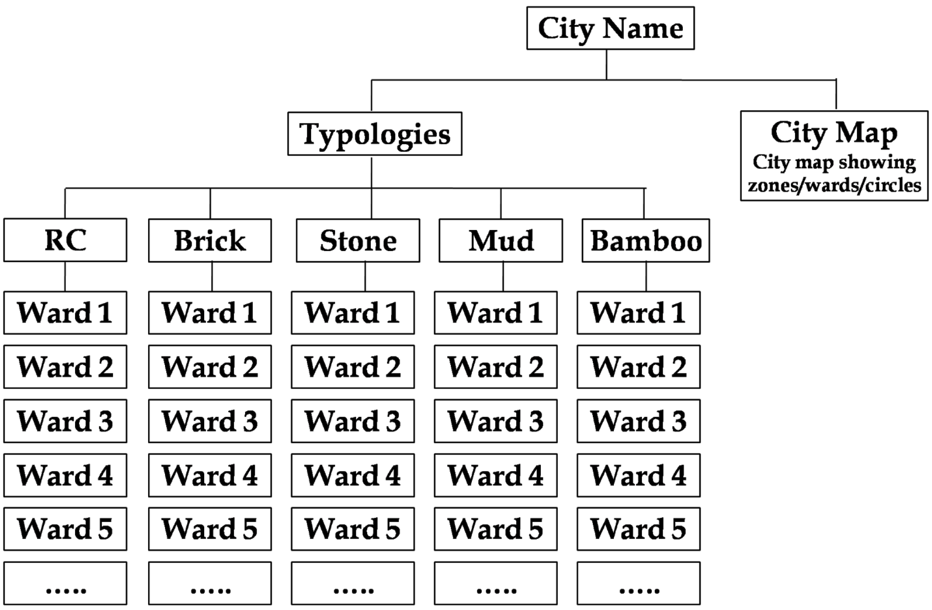
100. **Click below link to upload Excel Sheet** *
https://www.dropbox.com/request/TLf1oSzHjm3gBU9FDsZS
Mark only one oval.

- Uploaded Successfully
- Error in Uploading

Building Images and Ward/Zone/Circle Map

Create folder in following format

Uploading File Structure



101. **Provide link of (Dropbox/Google drive)folder containing building photographs** *
Share the downloadable link below: