EARTHQUAKE VULNERABILITY IN HIGH POPULATION DENSITY AREA: AN EXPERIENCE OF HALDWANI-KATHGODAM MUNICIPAL CORPORATION, INDIA

Kritika Bora* Ravindra K. Pande**
Department of Geography, D.S.B. Campus, Kumaun University, Nainital

Abstract
Vulnerability is a subject of great concern. Be it natural or manmade hazard, society is at the stake of losing its property and life in both events. This work will include the assessment of built-up environment against earthquake using Rapid Visual Screening process. The study region consists of a high population density. This is one of the highly clustered areas of this region. The acceptance of modern technique in the construction practices is still lacking in our society. The boost in the urbanization has resulted in haphazard construction of multistory concrete houses. In a developing country like India growth of urban centers is tremendous and also combined with unplanned growth of cities. Similar is the case with the urban trend in Uttarakhand. Negligence to the skilled construction practices due to enormous concentration of population has led to a boom in unsafe infrastructure. Lack of space and continuous migration from hills has resulted in multistory construction. This area of Shiwalik foothills lies in zone IV under seismic zonation of India, therefore poses seismic vulnerability. This database can also estimate the risk that the area poses. Keeping in view the loss estimation and life loss happened during an earthquake event it is becoming common to carry out this kind of research work to assess vulnerability of buildings. This practice is still not well accepted in the developing nations. Assessing vulnerability of physical infrastructure will help in disaster mitigation and management before earthquake strikes.

Keywords: *Vulnerability, Rapid Visual Screening, Disaster Mitigation*

Introduction

Himalayan mountain range is most recent in its origin and lies from west to east with a length of 2300 kms in North India. Being recent in origin, the events of earthquakes are very common here to see. In the past few decades India has witnessed some of the most devastating seismic events for both life and property. As a newly formed state, Uttarakhand has witnessed rapid growth in urban areas. The result of rapid growth of urban areas has led to unplanned growth of towns and cities. Negligence to the skilled construction practices due to enormous demand by the high concentration of population has led to a boom in unsafe infrastructure. The shift from timber laded construction to reinforced concrete construction has resulted into total absence of traditional architectural design and knowledge in construction practices.

Earthquakes have devastating impacts upon human life and property. So far there has been no scientific technology evolved to predict earthquakes, therefore mitigating seismic losses is the only means available to reduce the losses due to an earthquake. The unsafe built up environment can cause destruction to life and property, therefore it is important to assess the vulnerability of buildings and take mitigative measures for improving the seismic performance of the structures. There is an urgent need to assess the seismic vulnerability of buildings in urban areas which seems to be an essential component of a comprehensive earthquake disaster risk management policy. Keeping in view the loss estimation and life loss happened during an earthquake event it is becoming common to carry out this kind of research work to assess vulnerability of buildings. This practice is still not well accepted in

the developing nations that confront huge population and urban crowd due to migration. It has become a necessity to assess our physical structures and critical infrastructures as they serve as lifelines.

Study Area

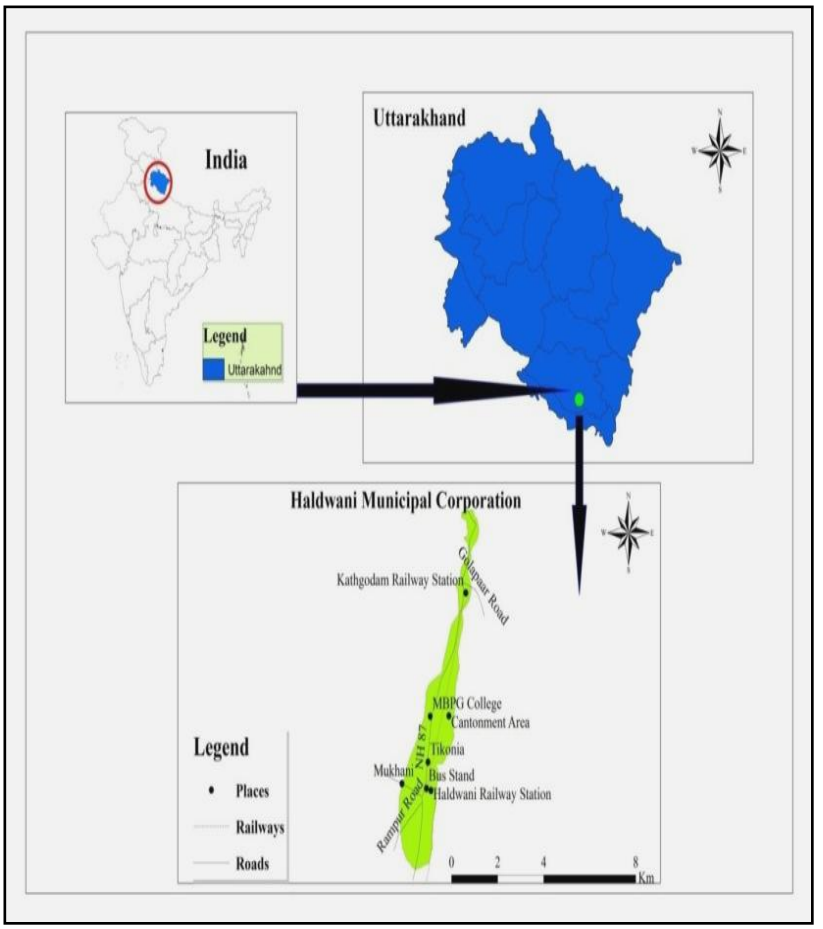

Figure 1. Location of Study area.

The study region i.e., Haldwani-Kathgodam Municipal Corporation is located between 29°11' to 29°17' north latitude and 79°32' to 79°31' east longitude in the district Nainital of Uttarakhand state of India. It is a twin township including Haldwani towards the south and Kathgodam towards north. The city covers an area of 10.62 square kilometers with a population of 156,080 according to the 2011 Census of India. The Municipal Corporation of Haldwani-Kathgodam is divided into 25 Municipal wards. Apart from the Haldwani-Kathgodam Municipal Corporation area the urban agglomeration includes eleven city outgrowths, namely Damua Dhunga Bandobasti, Byura, Bamori Talli Bandobasti, Amrawati Colony, Shakti Vihar, Bhatt Colony, Manpur Uttar, Haripur Sukha, Gaujajali Uttar, Kusumkhera, Bithoria No. 1, Korta, Bamori Malli and Bamori Talli Kham).Two census towns,

Mukhani and Haldwani Talli, are also being included in Municipal Corporation of Haldwani-Kathgodam.

Geomorphic Setup

The Municipal Corporation of Haldwani-Kathgodam and its environs is located on a typical Himalayan geomorphic landscape known as piedmont or alluvial fan. The Himalayan Frontal Fault separates Bhabhar region from Siwalik. This part is made up of porous and rocky soils that are washed out from uphill. There are fans of colluviums and fluvial debris towards the south of Siwalik. This piedmont belt is known as Bhabhar. This formation mainly consists of cobble, boulders, pebbles, gravel, sand and silt with intervening clay layers. The lithological constituents are of heterogeneous nature viz., basic, acid and intermediate along with epiclastics and metamorphiclasts.

Methodology

The theoretical framework of the data collection has been designed as per third edition, FEMA-154 data collection form designed for seismic zone 4 of high damage seismic risk zone, followed by an extensive field work covering the highly populated zone of the study area. Using FEMA data collection form for the assessment of buildings, door to door purposive sampling survey was conducted considering the three types of buildings, i.e. houses in Good Condition, Livable and Dilapidate. Later the maps for the population density and respective Earthquake Vulnerability have been created in ArcGis 10.4.

Areas with high population density have been taken for study, which includes 11 wards namely Gandhi Nagar, Tankapur Road, Banbhool pura L. No. 8-13, Nayi Basti Kidwai Nagar, Banbhool Pura L. No. 1-7, Railway Bazaar, Indra Nagar East, Rajendra Nagar, Indra Nagar West, Banbhool Pura L. No. 14-16, Banbhool Pura L. No. 17-20.

Determining Vulnerability

For assessing the vulnerability of the buildings there are various parameters used in RVS data collection form and these are the following: Age of the building. Height of the building. Occupancy of the building. Adjacency and pounding. Irregularities in the building. These vulnerability parameters have been carefully covered during the field study and data was registered in RVS data collection form.

Figure 2: Damage Probability based on RVS Scoring

RVS Score	Damage Potential
$S < 0.3$	High probability of Grade 5 damage; Very high probability of Grade 4 damage
$0.3 < S < 0.7$	High probability of Grade 4 damage; Very high probability of Grade 3 damage
$0.7 < S < 2.0$	High probability of Grade 3 damage; Very high probability of Grade 2 damage
$2.0 < S < 3.0$	High probability of Grade 2 damage; Very high probability of Grade 1 damage
$S > 3.0$	Probability of Grade 1 damage

Result and Discussion

The study region of Haldwani-Kathgodam Municipal Corporation has very high density of population. The selected ward has an area of less than a square kilometer but with high clusteration of built-up. This region being the oldest inhabited area of the city has very old to old construction with maximum adjacency and pounding. The concept of individual housing

is missing in this area unlike the rest of the Municipal Corporation. Lack of space has also led to vertical growth of this region. This makes the area more vulnerable towards seismic activities. Seismic Vulnerability of of this region is highly dependent on the high density of population of this region.

Figure 3. Classification of nature of Damage to buildings.

Grade 3: Substantial to heavy damage (moderate structural damage, heavy non-structural damage) Large and extensive cracks in most walls. Roof tiles detach. Chimneys fracture at the roof line; failure of individual non-structural elements (partitions, gable walls etc.).	**Grade 3: Substantial to heavy damage (moderate structural damage, heavy non-structural damage)** Cracks in columns and beam-column joints of frames at the base and at joints of coupled walls. Spalling of concrete cover, buckling of reinforced bars. Large cracks in partition and infill walls, failure of individual infill panels.
Grade 4: Very heavy damage (heavy structural damage, very heavy non-structural damage) Serious failure of walls (gaps in walls); partial structural failure of roofs and floors.	**Grade 4: Very heavy damage (heavy structural damage, very heavy non-structural damage)** Large cracks in structural elements with compression failure of concrete and fracture of rebars; bond failure of beam reinforcing bars; tilting of columns. Collapse of a few columns or of a single upper floor.
Grade 5: Destruction (very heavy structural damage) Total or near total collapse of the building.	**Grade 5: Destruction (very heavy structural damage)** Collapse of ground floor parts (e.g. wings) of the building.

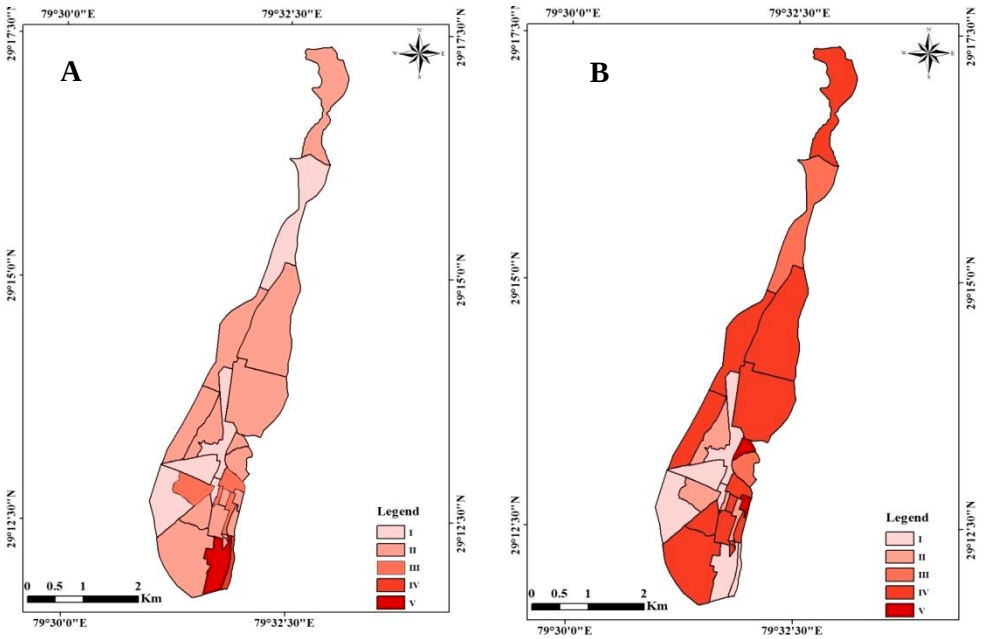

Figure 5. Distribution of Building Vulnerability. A. Very High Vulnerability B. High Vulnerability

The entire building stock has been classified into five categories and further sub divided into five sub categories based on the percentage of buildings stock falling in main category, where V shows highest percentage and I shows least percentage.

Table 1: Ward Wise Vulnerability Scenario of Buildings (in Percentage).

Ward Name	**(S<0.3)**	**(0.3<S<0.7)**
Gandhi Nagar	1.92	4.8
Tanakpur Road	2.13	5.68
Banbhool Pura LNo 8-13	1.6	4
Nayi Basti Kidwai Nagar	3.2	12.8
Banbhoolpura LNo1-7	1.8	3
Railway Bazaar	3	5.4
Indra Nagar East	16.74	1.86
Rajendra Nagar	3.06	21.42
Indra Nagar West	59.5	1.7
Banbhool Pura LNo 14-16	4.96	3.72
Banbhool Pura LNo 17-20	2.2	5.5

Recommendation & Conclusion

There is an absolute need of making people aware and conscious about the consequences of earthquake hazard. The authorities must be motivated to implement and monitor the existing building by-laws and town planning. A massive drive for capacity building in area of urban seismic disaster management must be taken up by the corporation authorities. The effective and efficient linkages between the administration, community and stakeholders. Resource database of the city related to emergency services, medical facilities, ambulances, fire brigades, community centers, schools, free open space, transport connectivity and trained medical and emergency operational staff. Transport route and their traffic carrying capacity. Evacuation plan for the city. Capacity and effectiveness of non-governmental organizations (NGOs) and volunteer organization. Professionals like seismologists, engineers, architects, social scientists and community should be involved in the decision making. Time to time mock drills should be under taken in schools, government and other offices.

With the rapid growth of population and resultant migration the population from hilly region is now shifting to Haldwani-Kathgodam urban center and consequently the culture of multi storey buildings, unplanned construction and loss to traditional knowledge is taking place. Situation with regard to seismic safety is observed to be the worst and the studies undertaken in the region suggests that seismic vulnerability of the region is on the rise. Moreover people are not aware of the concept of earthquake resistant construction and have been following the age old building trend with minor input of engineering. There has been immense loss of life and property in past few years due to earthquakes and assessment of seismic safety becomes a preparedness measure if followed on larger scale. The study area registers a complex built up scenario. The buildings represent various categories of different parameters considered to be very significant to assess vulnerability of civil structures. The analysis reveals that the study area represent five categories of vulnerability ranging from very high to very low. Interestingly the distribution of vulnerability is very closely associated

with the growth of Municipal Corporation, viz., even the new buildings in newly developed areas are falling in highly vulnerable category. It indicates that there is absolute absence of building by-laws being followed by their residents and being monitored by the corporation authorities.

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