SEISMIC VULNERABILITY OF BUILDINGS IN PHUENTSHOLING THROMDE

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Abstract

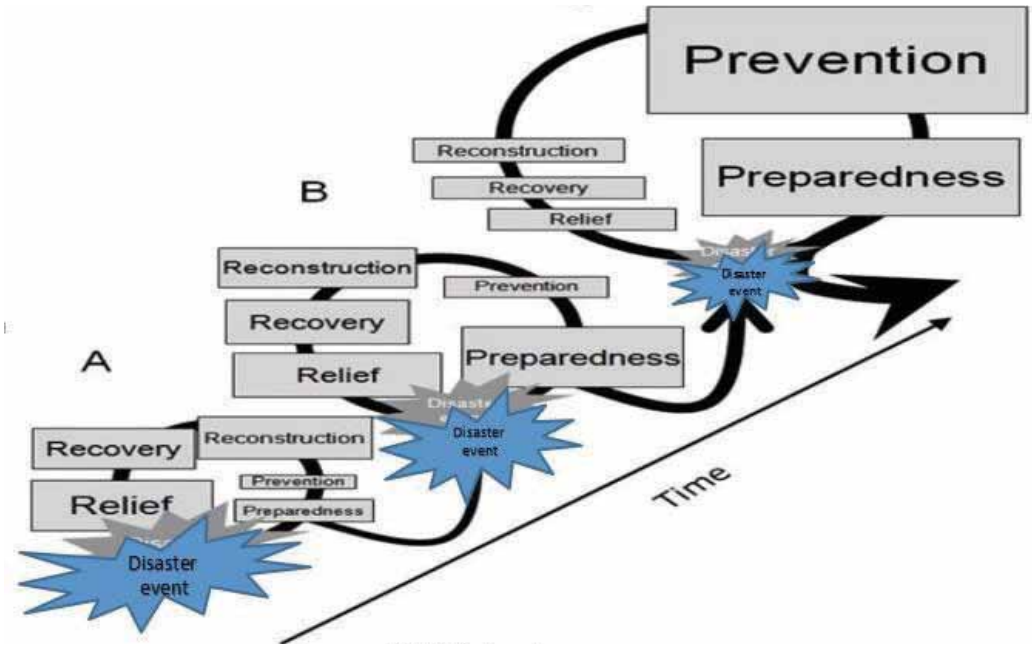
This study focuses on seismic vulnerability assessment of buildings in Phuentsholing Thromde using HAZUS-MH methodology. HAZUS-MH is a software developed by FEMA, the official Federal Emergency Management Agency in the USA for loss estimation and risk assessment of hazards namely earthquake, flood and cyclone. This research considers its earthquake hazard application for assessing buildings at risk. The study is mainly divided into three parts as ward wise statistical sampling of buildings for core area of Phuentsholing Thromde, damage assessment of buildings and risk mapping considering various intensities.

Further, with the help of field survey data and household data, carried out for a total of 50 buildings, the values are extrapolated and then used to find the direct and indirect economic losses and cumulative damage probability of buildings in terms of no, slight, moderate, extensive and complete damage using the SeisVARA-Intensity (Seismic Vulnerability And Risk Assessment of Housing).However, the results obtained may be considered accurate to only a certain limited extent as the analysis demands presence of full inventory of buildings stock and also the missing parameter of landslide and liquefaction susceptibility.

Introduction

Most of the lives and property had been lost due to unpredictable and uncontrollable disaster called earthquake. It is one of the most severe forms of natural disaster which results in the loss of lives and money. There are various ways of preparing for earthquake disaster by capacity building, building of earthquake resistant structures, and preparing the emergency reposes. One of most appropriate method to quantify the venerability of seismic activity is by risk assessment and loss estimation to reduce the loss in terms of social, economic and environmental (Westen n.d). For quantifying these losses, various loss estimation methologies and software such as RADIUS, TELES, and HAZUS-MH are used. HAZUS-MH is the software developed by FEMA, the official Federal Emergency Management Agency in the USA, which can be appropriately used for risk assessment and loss estimation for different building stock and emergency facilities for earthquake, flood and cyclone. (Motiram, Earthquake Risk Assessment, Loss Estimation and Vulnerability Mapping for Dehredun City, 2014)

As described in the management process figures, more emphasis is given to the preparedness phase so that the losses incurred during the disaster is reduced and disaster risk can be easily handled. This study aims to contribute in a small way towards developing a sustainable and resilient society in Phuentsholing.



Source: DMP, Dehradhun

Figure 1: Disaster management process

Problem Statement

Bhutan Seismic Hazard Zonation map depicts Phuentsholing in a high seismic hazard zone where no precise evaluation model for earthquake risk and damage assessment has been made for buildings in the region. As adopting risk models adopted in other countries can minimize the devastating effect of an earthquake, there is a need to develop and find out the seismic vulnerability of the buildings in Phuentsholing. Moreover, there are many old buildings in the region, which were constructed before 1998 (i.e. before implementation of building codes in constructions).

Research Objectives

Main objectives: This Project aims to estimate loss for Buildings after earthquakes and generate seismic vulnerability mapping for earthquakes. This map will help

planners to plan the essential facilities such as hospitals, Fire Brigade stations, Government and Institutional Buildings with improved resistance and structures with reduced vulnerability. It can also be used to identify vulnerable areas and mitigation measures for rescue operations against earthquakes.

Expected Outcome

The final vulnerability and risk map generated for Phuentsholing Thromde from the analysis will help to identify the various areas at risk. Government planners and private construction firms could utilize the map generated to come up with infrastructures such as bridges, hospitals, and institutes which will have better resistance to failure from seismic activities in identified vulnerable areas by proper mitigation or avoiding vulnerability wherever possible. This will help the Phuentsholing Thromde avoid losses that will be incurred due to failure of infrastructure from seismic activities.

Previous Related Work

Introduction

Phuentsholing is located in the southern part of Bhutan, in the Himalayan region. The Himalayan region lies in the active fault zone where it is subjected to frequent earthquakes. This imposes a huge threat to most countries in the region. Phuentsholing is a very important place for Bhutan, being the commercial hub and a border area connecting to India. It is the gateway for many other districts like Gelephu, Sarpang ,Samtse, SamdrupJongkhar , Thimphu and Pemagatshel. The city consists of many important features such as schools, monasteries, cooperate office and hospitals. Being the Dungkhag center and commercial hub, there is increase in the population in the city. With the growth of industries in and around the vicinity of the city, there is an increase in the growth of infrastructure development. Construction of various types of houses and buildings are on the rise.

Earthquake History

In accordance to the Seismic Hazard map of Bhutan, Phuentsholing city falls under zone four which is at great risk during earthquakes. A major earthquake of magnitude 6.1 occurred in Narang, in the eastern part of Bhutan taking the lives of 10 people and damaging schools and monasteries. Bhutan has experienced many earthquakes of which most of the epicenters were located in neighboring countries. The detected earthquakes were not equally distributed across the country. Most events were along a line connecting Phuentsholing with Samtse and reaching Gangtok (Sikkim).

Geographical Location

Phuentsholing is located between 260 51'0" N and 89023'0" E latitude and Longitude 26°51.0984 N and 89°23 18 E. It is located at an altitude of 293m above sea level and is located between Jaigaon, West Bengal and Rinchending. The total population of the city is 20,537 (2005).

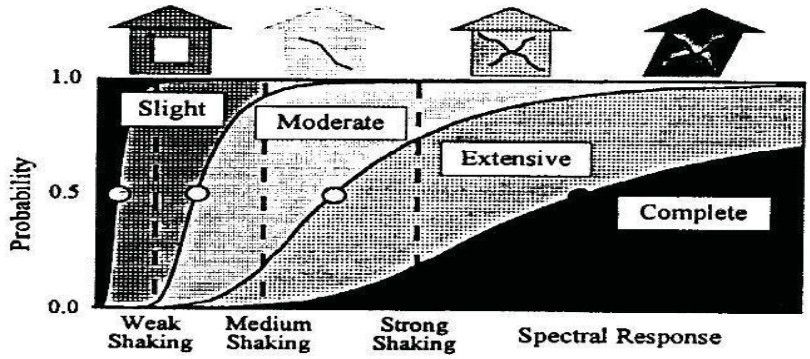
HAZUS - MH Methodology

HAZUS-MH is a nationally applicable standardized methodology that contains models for estimating potential losses from earthquakes, floods, and hurricanes (FEMA, HAZUS MH 2.0 User Manual, 2011). HAZUS is a risk assessment software developed by the Department of Homeland Security, Federal Emergency Management Agency (FEMA) in 1997.It uses ArcGIS as a supporting GIS software for usage.

What is HAZUS- MH?

1) It provides a platform for risk assessment for various hazards.
2) It calculates direct and indirect losses and suggests mitigation measures.
3) Identifies and visualizes hazards and vulnerabilities.

This model requires an exhaustive data like general building stock, occupancy type, utilities for database creation. General building stock inventory is formed by using census tract characteristics as the unit for grouping of buildings. Also the methodology helps to find damage probabilities under various ground shaking conditions as shown in Figure 2.1 Building types in HAZUS are basically classified into five frames such as unreinforced concrete frame, reinforced concrete frame, concrete frame, steel frame and wood frame (B.Gulati, 2006).



Source: (Motiram,2014)

Figure 2.1: Example fragility curves for different types of damages

Phuentsholing Building Types

The construction of RC buildings had begun as early as 1970s in Bhutan (Dorji, 2009). Today, RC structures have replaced almost all the traditional structures such as adobe and stone masonry buildings in the urban areas. Most of the RC buildings in Phuentsholing are three to seven storey tall and are mostly rectangular in plan. The ground floor is mainly used for commercial purposes while top floors are used as residential units. In this study, three typical residential RC buildings are considered. They represent the most common RC buildings in Phuentsholing. There are typical 5,4,3,2 storey RC buildings, which were designed and built after the adoption of Indian seismic code in 1997. Six storey RC buildings are very common in the central area of Phuentsholing where population of the city is concentrated. Three storey RC buildings were was also designed and built after the adoption of Indian seismic code and there are even three storey RC buildings built prior to 1997 when no seismic provisions had been incorporated (Kinzang Thinley, 2014).

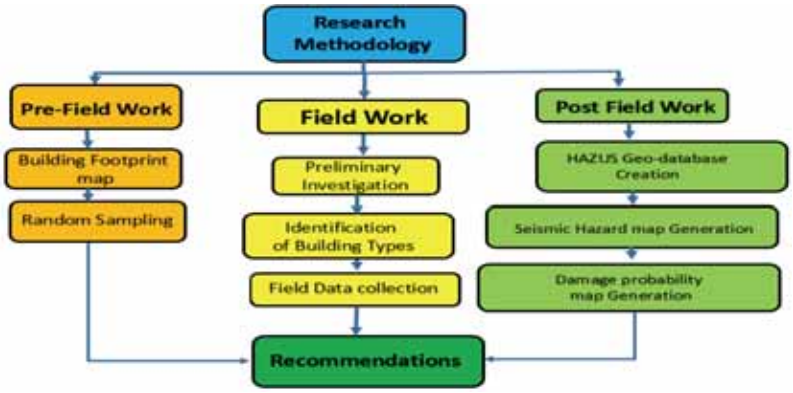
Classification of existing construction is done in three classes. These are a) adobe and random rubble masonry, b) masonry wall construction using rectangular units and c) framed structures. The above mentioned classes are further classified based on roof type and stories. Six different roof types are identified. Some classified building types can be compared with already existing building types in HAZUS except adobe and rubble masonry.

Previous Related Work

Many research and studies have been carried out using the HAZUS-MH methodology for different areas prioritizing the seismic proneness. In Bhutan, the department of Engineering Adaptation and Risk Reduction under Ministry of Works and Human Settlement has also developed seismic vulnerability assessment guidelines with CNR- GNDT ITALIAN method. Likewise, a PHD student from Curtin University has also researched on "Seismic Performance of Reinforced Concrete and Building in Bhutan". This project also incorporates all aspects of seismic vulnerability assessment by using this methodology considering only five ward out of many wards in Phuentsholing area owing to the difficulty of obtaining various parameters. This Project aims to generate seismic vulnerability mapping for earthquake risk assessment and loss estimation analysis for Buildings. This map would also help planners to plan the essential facilities like hospitals, Fire Bridgade stations, Government and Institutional Buildings with improved resistance and structures with reduced vulnerability. It can also be used to identify vulnerable areas and mitigation measures for rescue operations against earthquakes.

The research methodology is divided into three stages i.e., pre field work, field work

and post field work. These three stages are further divided into steps for achieving the goals as shown in figure 2.2.



Source: (Motiram,2014)
Figure 2.2: HAZUS Methodology

Sampling, HAZUS geo-database creation, building damage probability and risk map generation are some of the key steps of the research methodology. The main part of the research lies in the creation of seismic hazard map and damage assessment for the development of final risk.

Pre Field Work

Building Footprint Map

Building footprint map for 5 wards is generated in Phuentsholing city. These 5 wards are selected according to the building foot print map of Phuentsholing Thromde and building types are covered during actual field survey. Around 200 numbers of building blocks have been digitized for 5 wards using ArcGIS software. The figure shows the building footprint map for selected wards with ward numbers.

Source: Phuentsholing Thromde, 2016
Figure 2.3: Core Area, Phuentsholing Thromde

Random Sampling

As the area is large and buildings are also high in number, random statistical sampling method has been adopted for the collection of samples with the intention that the sample points have a good spread over the complete ward. 50 sample points from each ward has been selected and survey has been done for the building type at particular point.

Field Work

Identification of Building Types

Extensive filed work was carried out in three stages. Firstly, a preliminary survey of 2 days in October 2016 was carried out for selecting the wards to be digitized so that a good variety of building types with different ages is recorded. Then the main field work was carried out for 3 days in November 2016 for 50 numbers of buildings across Phuentsholing core area after random sampling. Along with collection of GPS points, a photograph of each and every building type was taken for reference. Classification is based on the type of building construction and number of floors. One more important factor is the type of roof of building. All the wards are a mixture of residential, commercial, and institutional with 5 types of building i.e., RC1M, RC2L, RC2M and MH described in detail in Table 2-2 and short description in table 4-1. Some of the typical examples of building types seen in Phuentsholing core area with its satellite image are given in the figure below:

Table3.1: Short Description of 5 building types

Building Type	Description
RC1L	Reinforced Concrete category 1 with Low-rise (1-3)
RC1M	Reinforced Concrete category 1 with Mid-rise(4-7)
RC2L	Reinforced Concrete category 2 with Low-rise(1-3)
RC2M	Reinforced Concrete category 2 with Mid-rise (4-7)
MH	Manufacture Home

Figure 3.1: Building type RC1M of ward No. 2 on ground (Source: Google Earth 2017)

Figure 3.2:Building type RC1M of ward no. 2 on GEOEYE image (Source: Google Earth 2017)

Figure 3.3:Building type RC2L of ward No. 3 on ground (Kinley P. b., 2017)

Figure 3.4: Building type RC2L of ward No. 3 on GEOEYE image (Source: Google Earth 2017)

Figure 3.5: Building type RC2L of ward No.3 on ground (Source: Google Earth 2017)

Figure 3.6: Building type RC2L of ward No. 3 on GEOEYE image (Source: Google Earth 2017)

Figure 3.7:Building type RC2L of ward No. 4 on ground (Source: Google Earth 2017)

Figure 3.8: Building type RC2L of ward No. 4 on GEOEYE image (Source: Google Earth 2017)

Field Data Collection

Building samples from 5 selected wards of Phuentsholing core area is surveyed to collect all the information necessary for the analysis and results. The result is further used for exploration. Apart from this, other field data like visual characteristics of building like age of building, its utility and building appearance are recorded for reference. For validation of distribution of buildings over surveyed samples, an extensive detailed field survey is carried out for ward number 4 having a total of 20 buildings. This household data is used for extrapolating the total number of houses in the city across different wards.

Concluding Remarks

A disaster resilient nation is one in which its communities, through mitigation and pre- disaster preparedness, develop adaptive capacity and recover quickly when major disaster occurs. The result from this research will help in preparing the community for seismic activities and will also help indicate the places that are the most vulnerable whereby either such places are avoided for engineering works or extra precautions are taken to make the Phuentsholing Thromde more earthquake resilient.

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Authors' Profile

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