ASSESSMENT OF THE SEISMIC VULNERABILITY OF RESIDENTIAL BUILDINGS OF SRINAGAR CITY JAMMU AND KASHMIR

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ABSTRACT

Earthquakes are unique among natural hazards in that they occur without warning. Surveys show that collapsing buildings and structures during an earthquake can cause huge social, economic and human disasters. Earthquakes have occurred regularly over centuries in Kashmir and people have learnt to live with it. The aim of this paper is to assess the structural vulnerability of residential buildings of Srinagar City on the basis of certain selected indicators. The results of the study indicate that the residential buildings in the inner parts of the City are highly vulnerable to earthquakes and immediate measures should be taken to make them safe for the people residing in them.

Keywords: Earthquakes, Structural vulnerability, Indicators

INTRODUCTION

Earthquakes are unique among natural hazards in that they occur without warning (Langenbach 2009). During an earthquake when a structure is shaking, it gets damaged if it is not sufficiently strong and/or flexible (UNESCO and UNDP 2007). Earthquakes have occurred regularly over centuries in Kashmir and people have learnt to live with it (Gobar Times 2006). Soft, loose soils, such as those found in Srinagar tend to amplify the longer period ground motion characteristic of earthquakes which may accentuate building damage. The danger of earthquakes and the soft building ground have had a great influence on the way people traditionally built their houses in Kashmir (Langenbach 2009). The buildings are provided with wooden floors in case of rural constructions whereas reinforced concrete slab floors and roofs are used in the case of urban constructions (Ali and Mohammad 2006; Gupta et al. 2008; Ahmad et al. 2012).

Urban environments are physically characterized by a small scale alignment of buildings, infrastructure and open spaces with their specific types and dimensions (Muck et al. 2012). The dynamic interaction between urban components or subsystems and diverse forms of vulnerability
(Rashed 2003) and the concept of chain of losses and failures (Menoni and Pergalani 1996) proves that vulnerability is an inherently spatial problem (Hashemi and Alesheikh 2012). Damages due to seismic events in the last decades particularly in cities with dense urban fabric have raised the interest of emergency planners in estimating the seismic risk associated with future earthquakes (Kontoes et al. 2012). Surveys show that collapsing buildings and structures during an earthquake can cause huge social, economic and human disasters (Panahi et al. 2013). The seismic vulnerability of a building represents its sensitivity to be damaged by a ground shaking of a given intensity (Giardina et al. 2010). The determination of expected damages or victims occurring during an earthquake requires over all, the evaluation of two factors, i.e. seismicity and vulnerability. The second factor is depending on seismic performance of buildings and many ways have been attempted for its assessment (Angeletti et al. 1988). The vulnerability of buildings is one of the most important parameters for evaluation of earthquake potential damages in urban fabrics (Hosseini et al. 2009). Existing buildings can become seismically deficient since seismic design code requirements are constantly upgraded and there is advancement in engineering knowledge (Chourasia and Agrawal 2007). Vulnerability estimation is a complex process which has to take into account not only the design of building but also the deterioration of the material and damage caused to the building if any (Agrawal and Chourasia 2007). Structural vulnerabilities have arisen in Kashmir in recent decades where traditional practices have been diluted and knowledge and skill have been lost. It is therefore very important to check the earthquake vulnerability of all existing buildings of mixed traditional and modern construction in Kashmir, since all of these are located in Seismic Zones IV or V (UNESCO and UNDP 2007).

DATABASE AND METHODOLOGY

The evaluation of earthquake risks both to individual buildings and for a community as a whole is a complex task (Langenbach 2009). The difficulties faced in the seismic evaluation of a building are manifold (Chourasia and Agrawal 2007). Srinagar is divided into 68 municipal wards as delineated by Srinagar Municipal Corporation (SMC). Intensive field survey was conducted on 300 residential buildings by filling a comprehensive questionnaire. A vulnerability analysis of built environment was attempted with an objective to assess the structural vulnerability of Srinagar city. The methodology followed was based by considering which characteristics of buildings affect their vulnerability. Based on the degree of vulnerability according to various structural parameters (Monzavi et al. 2010; Gheitarani et al. 2013), the integrated vulnerability analysis of the study area was carried out.

INDICATORS SELECTED FOR ASSESSING THE STRUCTURAL VULNERABILITY OF SRINAGAR CITY

Vulnerability of buildings to earthquakes is dependent on a variety of form and functional parameters (Muck et al. 2012). Residential building vulnerability is up to five times larger than either commercial or industrial building vulnerabilities (Cochrane and Schaad 1992). A structure with higher vulnerability is likely to suffer severe damage (UNESCO and UNDP 2007). Cochrane and Schaad (1992) determined vulnerability on the basis of construction material type and building age. The Global Earthquake Model (GEM) initiative (GEM 2012) identified different factors like building height, age, design and construction as main indicators for building stability (Muck et al. 2012). Panahi et al. (2013) defined the construction materials of structures, year of construction and their quality as major affecting factors in structural vulnerability. By determining some important building parameters and the manner in which they can influence the vulnerability of the building, a particular combination of indicators were chosen as the basis for the structural vulnerability
estimation of the study area. Hence the indicators selected for assessing the structural vulnerability of Srinagar city were; (a) Density of residential buildings (Cutter et al. 2003) (b) Age of residential buildings (Cochrane and Schaad 1992; Dolce et al. 2000; Dolce et al. 2006; Roca et al. 2006; Muck et al. 2012; Daneshvar et al. 2013; Panahi et al. 2013) (c) Height/Number of storeys of residential buildings (Cochrane and Schaad 1992; Dolce et al. 2000; Ayala and Speranza 2002; Dolce et al. 2006; Roca et al. 2006; Muck et al. 2012; Gheitarani et al. 2013) and (d) Construction material of residential buildings (Cochrane and Schaad 1992; UNESCO and UNDP 2007; Eidsvig et al. 2011; Muck et al. 2012; Panahi et al. 2013).

**DENSITY OF RESIDENTIAL BUILDINGS**

There is high need in the metropolitan cities to study the seismic risk, since the seismic hazard although might be low, the resulted risk expressed in terms of damages and human casualties can be high due to the high average density of built up areas (Kontoes et al. 2012). The total number of residential buildings in Srinagar city is 1,82,829 as per Census 2011. The housing density was calculated for all the 68 municipality wards which were then classified into five categories on the basis of housing density into Very High (Housing density > 2000), High (Housing density 1500 - 2000), Moderate (Housing density 1000 - 1500), Low (Housing density 500 - 1000) and Very Low (Housing density < 500) density. On the basis of the categorization of housing density, higher the density, higher was considered its vulnerability and lower the density, lower was considered its vulnerability to earthquakes (Cutter et al. 2003). Figure 1 illustrates the vulnerability classification of municipality wards of Srinagar City according to the density of residential buildings. According to the figure, the highly dense municipality wards are located in the inner parts of the city. The “Very Low Vulnerability” category covering 62% area includes 15 municipality wards; the “Low Vulnerability” category covering 17% area includes 11 municipality wards; the “Moderate Vulnerability” category covering 11.5 % area includes 15 municipality wards; the “High Vulnerability” category covering 4.8 % area includes 9 municipality wards; and the “Very High Vulnerability” category covering 4.7 % area includes 18 municipality wards.

**AGE OF RESIDENTIAL BUILDINGS**

The more a building’s lifetime is, the greater would be the amount of its vulnerability (Panahi et al. 2013). Age is most significant for masonry construction. Steel and reinforced concrete frame structures show little true aging change (Cochrane and Schaad 1992). Older buildings do not enjoy adequate safety and are likely to be vulnerable to severe damage or total collapse under strong seismic excitations (Panahi et al. 2013). Following their age, residential buildings were grouped into five classes on the basis of vulnerability as; Very High (built before 1981), High (built from 1981 - 1988), Moderate (built from 1989 - 1996), Low (built from 1997 - 2004) and Very Low Vulnerability (built from 2005 - present) (Monzavi et al. 2010; Gheitarani et al. 2013). Figure 2 depicts the vulnerability classification of municipality wards of Srinagar City according to the age of surveyed residential buildings. The age of the residential buildings increases from the outer city towards the inner city. The “Very High Vulnerability” class includes 3 municipality wards; the “High Vulnerability” class includes 10 municipality wards; the “Moderate Vulnerability” class includes 24 municipality wards; the “Low Vulnerability” class includes 25 municipality wards; and the “Very Low Vulnerability” class includes 6 municipality wards.
HEIGHT OF RESIDENTIAL BUILDINGS

With respect to height, vulnerability of residential buildings has been classified in two categories as the residential buildings of the study area are mostly two or three storied; Low Vulnerability (having G+1 floors) and Moderate Vulnerability (having G+2 floors) (Monzavi et al. 2010; Gheitarani et al. 2013). Figure 3 illustrates the vulnerability classification of municipality wards of Srinagar City according to the height of surveyed residential buildings. The first category includes 19 municipality wards and the second one includes 49 municipality wards.

CONSTRUCTION MATERIAL OF RESIDENTIAL BUILDINGS

Categorization of buildings and assignment of vulnerabilities on the basis of their construction material type is more common (Cochrane and Schaad 1992). The highly vulnerable buildings include mud brick structures, masonry building and buildings with weak structures (Hosseini et al. 2009). Cochrane and Schaad (1992) proposed construction material type as the most feasible vulnerability assessment tool. Strong resistance refers to reinforced concrete constructions, medium resistance to mixed concrete-timber and thin brick-wall constructions and weak resistance to simple timber and very light constructions (Eidsvig et al. 2011). The results of the researches done by experts on the laboratory experiments and observations from the previous earthquakes indicate that sun-dried mud brick buildings are the most vulnerable structures which totally collapse during an earthquake with magnitude greater than 6 (Mahdizadeh 2011) and vulnerability of masonry, concrete and steel buildings decrease respectively (Tavakoli and Tavakoli 1993; JICA and CEST 2000; Ghayamghamian and Khanzade 2008; Ghayamghamian et al. 2012; Panahi et al. 2013). Buildings constructed of ductile components such as steel tend to withstand earthquakes much better than those constructed of brittle materials such as unreinforced masonry (Langenbach 2009).

In Kashmir, many types of construction practices are used with a variety of materials (UNESCO and UNDP, 2007). Surveyed residential buildings were divided into four categories of vulnerability according to the materials used for their construction as Concrete buildings (having Low Vulnerability); Brick and Iron buildings (having Moderate Vulnerability); Brick and Wood buildings (having High Vulnerability); and Sun-dried mud brick and Wood buildings (having Very High Vulnerability) (Monzavi et al. 2010; Gheitarani et al. 2013). Figure 4 depicts the vulnerability classification of municipality wards of Srinagar City according to the construction material of surveyed residential buildings. The “Low Vulnerability” category includes 13 municipality wards;
the “Moderate Vulnerability” category includes 8 municipality wards; the “High Vulnerability” category includes 33 municipality wards; and the “Very High Vulnerability” category includes 14 municipality wards.

![Figure 3: Vulnerability classification of municipality wards of Srinagar City according to the Height of surveyed Residential Buildings](image)

**Source:** Field survey 2014-2015

![Figure 4: Vulnerability classification of municipality wards of Srinagar City according to the Construction Material of surveyed Residential buildings](image)

**Source:** Field survey 2014-2015

Based on the degree of vulnerability of certain selected indicators of Housing density, Age of structure, Type of material used for construction and Number of floors (Monzavi et al. 2010; Gheitarani et al. 2013) the structural vulnerability of Srinagar city was classified into three categories of Low Vulnerability, Moderate Vulnerability and High Vulnerability. From the average values of the four indicators of Density, Age, Height and Construction material of residential buildings, the municipality wards were grouped into the former vulnerability categories and were spatially represented as in Figure 5.

![Figure 5: Vulnerability classification of municipality wards of Srinagar City according to the Density, Age, Height and Construction Material of Residential buildings](image)

**Source:** Field survey 2014-2015
The figure illustrates that by considering the impact of all the selected indicators on structural vulnerability of Srinagar City, the inner areas of the city depict higher vulnerability than its outer surrounding areas while as the peripheral areas of the city depict lower vulnerability.

RESULTS

The residential buildings located in the inner parts of the Srinagar city are old, densely populated, having Ground+3 floors and constructed with poor construction materials and these reasons lead to their higher vulnerability while as the outer city areas consist of newer constructions, have low density of adjacent buildings and are made up of construction materials having stronger resistance to earthquakes which makes their vulnerability to earthquakes low.

CONCLUSIONS AND SUGGESTIONS

In order to ensure effective measurements, mitigation strategies have to be focused on areas of high and very high earthquake risk (Muck et al. 2012). The growing vulnerability emphasizes the need to incorporate earthquake resistant features in constructions practices (Manohar et al. 2012). Throughout the history of building there have been devices used to enhance earthquake resistance (Ayala and Speranza 2002). Seismic evaluation of existing buildings and strengthening of those, which do not have acceptable seismic safety, constitutes one of the mitigation activities (Ilkisik et al. 2010). There are simple ways to reduce the vulnerability of surviving buildings through the process of retrofitting, as apart from being more cost-effective than rebuilding, retrofitting offers important advantages that make it a viable and attractive option (UNESCO and UNDP 2007). The Government should arrange for regular structural vulnerability checks of residential structures which should be performed by trained civil engineers so that they can bring out the major concerns affecting the vulnerability of the structure. Newspapers and media can be used to make the general masses aware about the common concerns of structural vulnerability which they can handle at the personal level.

REFERENCES