EARTHQUAKE RESISTANT DESIGN
AND CONSTRUCTION PRACTICES IN INDIA

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ABSTRACT

This paper examines the earthquake resistant design and construction practices prevailing in India. Results of a set of studies conducted to estimate the seismic performance of Indian housing stock, are presented. A field survey was conducted in the National Capital Region to assess the expected seismic performance of multistorey buildings, as these are so-called ‘engineered’ buildings and the area represents the best design and construction practices prevailing in India. Common deficiencies found in the buildings are presented along with the preliminary assessment as per FEMA-310 simplified analysis methodology. Regularity of building plans and elevations and adequacy of building structures in shear and overturning is examined. It is observed that a majority of the buildings is inadequate for the ground shaking hazard expected in the area as per Indian seismic design code, indicating a very poor enforcement of code. An investigation of the construction practices prevailing in the area also reveals that the ductile detailing practices as per Indian code of practice are not being followed. The details at beam-column joints are particularly poor.

Results of analytical studies performed to assess the seismic performance of buildings designed and constructed with and without following the code provisions are also presented. Indian code, similar to other national codes, is a prescriptive code exercising control over strength, ductility and drift. ASCE-41 methodology has been used for assessment of building performance and HAZUS methodology has been used for assessing the seismic fragility of buildings. Relative influence of different code provisions on seismic performance of code designed buildings has been studied and some important conclusions about adequacy of code provisions are drawn.

The RC buildings designed as per Indian Standard, have Overstrength Ratio of the order of 2, which results in significant reserve strength. The buildings designed as OMRF or as SMRF, as per Indian Standard satisfy Immediate Occupancy performance level, even for the Maximum Considered Earthquake. Interestingly, performance of OMRF design is marginally better than that of SMRF. The current provision for limiting the interstorey drift, at design load, is responsible for this discrepancy. Capping on the design period, as specified by the code, is the most crucial provision for controlling the expected performance of the buildings. This results in more than two times increase in the design base shear.

The current form of Indian Standard provision for control of interstorey drift leads to many discrepancies. It governs the design, only when capping on design period is applied, although the buildings designed with period capping are generally stiffer than the buildings designed without capping. Further, it is generally not a governing criterion in case of SMRF, in spite of the fact that SMRF design results in more flexible buildings. In probabilistic terms, it results in
higher probability of damage in case of SMRF design, as compared to OMRF design. This discrepancy is due to the specification of interstorey drift limit at design loads, which results in different effective limits on inelastic drifts in case of OMRF and SMRF.
Evaluation of new construction techniques together with increasing understanding of the seismic forces and the building response has certainly contributed positively to decrease seismic vulnerability. The up-gradation of the seismic standards has resulted in accurate and appropriate calculation of seismic forces that would act upon any structure. It is always easy to set standards but to comply with these is a Herculean task. Even after immense progress in earthquake engineering overwhelming large proportion of the building stock still has lower standards of earthquake safety and these would give way in case of earthquake loading. The common people, at present, do not adhere to correct design and construction methodology while using modern seismic design methods or even the use of our indigenous practices. Case study of Uttarartchal State clearly brings forth deterioration of time tested indigenous construction practices and proliferation of nonscientific and improper use of concrete. This adds to the vulnerability of the region that is at present much higher than what it was a decade before when the region last experienced a major quake. The case study highlights three inter-related aspects. First, these bring forth key features of local traditional knowledge and capacity of rural communities for mitigation, preparedness and recovery from earthquakes. The traditional knowledge is embodied in physical planning and building, skillfully using local resources, mutual support systems and informal livelihood mechanisms. Second, these provide an in-depth understanding of the transformation processes (pertaining to changes in built form, land use and ownership, occupational structure and social and economic structure) and their impact on traditional knowledge and capacity and resulting enhanced earthquake vulnerability. Third, these show the implications of post earthquake rehabilitation on disaster vulnerability in the long run. These show how certain decisions during rehabilitation not only reinforce pre-disaster vulnerabilities but also create new ones.
Proposed Rapid Visual Screening Procedure for Seismic Evaluation of RC Frame Buildings in India

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Abstract

Severe damage and poor performance of RC buildings in India during earthquakes are a matter of serious concern. There is a need to develop suitable screening methods for seismic safety of existing buildings so that prioritization may be undertaken on the deficient buildings. RVS methodologies developed in other countries (eg, FEMA, 2002 in the US and METU, 2003 in Turkey) are not appropriate for application in Indian conditions. Systematic studies on calibration of damage data of the 2001 Bhuj earthquake in India has been carried out for the first time in India. An expression has been developed for assigning Performance Scores to buildings based on presence or absence of some very general, broad based and easily observable vulnerability parameters that can be seen from a sidewalk type survey.

Ahmedabad is located ~250 km from the epicenter and is placed in Zone III of Indian seismic zoning map. Areas placed in zone III are expected to experience shaking intensity of VII on MSK scale, which is the same as the shaking intensity experienced by the city during the earthquake. Hence, damage data of the 2001 Bhuj earthquake (M 7.7) in the city of Ahmedabad has been used as a basis. 270 buildings that had sustained damage from G0 (no damage) to G5 (collapse) were surveyed in two phases during 2008. The buildings were surveyed for around twelve vulnerability parameters which were then analyzed statistically to arrive at a methodology for conducting RVS in Indian buildings as follows:

Performance Score = 80 + 5 x0 + 5 x1 -10 x2 - 5 x3 - 5 x4 - 5 x5 - 5 x6 - 5 x7 - 5 x8

where, x0 = basement, x1 = number of storeys, x2 = poor quality, x3 = plan asymmetry, x4 = plan irregularity caused by reentrant corners, x5 = open storey, x6 = stub column, x7 = heavy overhang and x8 = short column

The present work considers only RC frame buildings that are prevalent in urban India. Similar method needs to be developed for masonry buildings as well.
Constructional Practices, Climate Change and Disasters – Some instances from Kashmir

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Abstract

The recent years have witnessed a fast change in the weather patterns in most parts of the world Kashmir not being an exception. However, with increasing human interference with nature to the worst possible extent especially with regard to deforestation and unplanned development of colonies, the vulnerabilities too have increased manifold. A place like Kashmir having already witnessed the signs of a rapid climate change, the changes in lifestyle and constructional practices are inevitable. The region has already witnessed two disaster events during the year 2005 in the form of the South Kashmir Snowstorm (2005) and the Kashmir Earthquake (2005). In both these events it has been observed that the traditional constructional practices followed earlier have been more disaster resistant or disaster friendly. In both the disaster events it has been observed that traditionally, people here, having history of a particular disaster would consider the specific disaster resistant features while constructing their dwellings. While as over the period of time, with receding glaciers, declining snowfall, high frequency and intensity of natural disasters, people have shifted to the modern constructional practices without much consideration to disaster mitigation.

An attempt has been made in this article to analyze the relationship between Climate Change, Disasters and Constructional Practices. The study has been supplemented with the help of plates (photographs) taken during the documentation of the two Disasters of 2005 by the author. The lessons learnt and the message emanating from the study reveals that while we can’t afford to remain away from modern development techniques especially the constructional practices, we also can’t afford to give up our traditional wisdom and experiences with regard to disasters. We need to incorporate all possible safety measures in our constructions on modern lines side by side to preserve our heritage and tradition like the Dhaji Dewari and the Taqaq System as well as the Gujjar Dhokas.
Earthquake Safety Elements in Traditional Koti Banal Architecture of Uttarakhand, India

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Despite being located in earthquake sensitive region and often experiencing seismic tremors the State of Uttarakhand in Indian Himalayas exhibits elaborate tradition of constructing multistoried houses. Both the local dialects of the State (Kumaoni and Garhwali) have unique words for identifying four different floors of a building. This is suggestive of common occurrence of multistoried structures in the region. This paper is an attempt to establish that the people inhabiting this rugged earthquake prone terrain had evolved the art of constructing earthquake safe structures well before the evolution of the structural engineering principles governing such a construction.
REQUIREMENTS OF BUILDING MATERIALS FOR
EARTHQUAKE RESISTANT BUILDINGS

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Abstract

During the last decade and half, we have witnessed earthquakes of damaging effects in different characteristic earthquake sources i.e. continental collision boundary (Himalaya); subduction zone (Andaman & Nicobar)’ ancient rift (Narmada, Kutch); non rifted zone (peninsular shield) and reservoir triggered (Koyana). Earthquakes of Killari (Latur) 1993, Jabalpur 1998, Chamoli 1999, Bhuj 2001, Andaman- Sumatra 2004 and Muzaffarabad 2005 have revealed that human and property losses are mainly due to collapse of very large vulnerable building stock in the region.

Post Disaster studies, especially after Bhuj earthquake, have given the engineering community - both architects and structural engineers - number of important lessons to be adequately addressed so as to mitigate the effect of such hazards in future. Existence of non-engineered buildings, no doubt, has been one of the major cause of collapse of buildings in most of the affected regions but poor quality of construction materials was also observed to be an important cause of failure of RC structures specially in Ahmedabad area, which is about 300km away from the source of the earthquake. Indian Standard Codes for Earthquake Resistant Design & Construction prescribes, besides other things, use of proper quality of building materials in a proper way. It is important to follow the provisions of the codes in a sincere way in construction of buildings for mitigating the effect of such hazards in future. Earthquake resistant buildings are required to have the ability to sway back and forth during an earthquake and to withstand earthquake effects with some damage, but without collapse. For this the structure, particularly their main elements, need to be built with ductility in them. To achieve the required performance it is also important to have right selection of building materials and techniques.

‘A house saved is a house constructed’. Therefore, it is necessary to carry out seismic analysis of existing buildings to make them safe against earthquake forces using established seismic retrofitting techniques. For retrofitting a number of innovative materials are used, which should be of proper specification and should be used in a proper way.
Managing with Vulnerable Built-infrastructures in India
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Abstract
Natural events like earthquake, cyclone, flood etc. of moderate intensity/magnitude turn to disasters when they affect inappropriate, unplanned and fragile built-infrastructures. The repeatability of earthquakes and mass scale destruction in the Bhuj area in the yrs 1819, 1956 and 2001 reminds us that we have not carried forward the lessons from past events. During Bhuj (2001) earthquake about 20000 cattle were lost, nearly 80% of the salt mining facilities were damaged, 19000 handicraft artisan lost their working tools and over 213000 agricultural structures or assets were destroyed or damaged. Such events clearly demonstrate the high risk from intensive damage and highlight the need for a comprehensive disaster risk mitigation programme. The scale of damage is often insurmountable destroying human lives, property and social fabrics of the country. Growing population, ill-planned habitat and non-engineered building practices have compounded the risk of many urban and rural conglomerations. Thus, assessing the multi-hazards and risks of built infrastructures, taking appropriate structural and nonstructural mitigation measures and managing the post-disaster events efficiently are some of the challenging tasks of disaster management.

Country has developed National Building Code (2005) and hazard specific codes of practices and guidelines for about last five decades. In spite of availability of such documents, enforcement mechanism, applicability and implementation is found most deficient. Existing Town and Country Planning Acts, Master Plans, Area Development Rules and Building Bye-laws and Regulations do not address safety requirements of build environment.

Though after Yokohama (1994) conference there is subtle shift in Government policy from response, relief and rehabilitation to mitigation, prevention and preparedness, the emphasis is on Capacity Building and spreading general awareness among all stakeholders. To carry the natural disaster risk mitigation programme forward, there is a need for trained manpower. This paper attempts:

1. To address issues related to proper performance of the existing buildings and housing stock to withstand the forces of natural hazards in future,
2. To create mechanism for carrying out safety audit and facilitate adequate financial support for retrofitting and strengthening wherever necessary.

To ensure empowerment and accountability of the various actors involved in building construction, namely, the owner, the builder/developer/promoter, the architect, the structural engineer, supervisors, the local body personnel involved in approval of plans, inspection of constructions and issuing of building use permits.
Abstract
North Eastern parts of India are highly prone to earthquakes. The entire region falls under Zone V (corresponding to MMI IX or more) as per the seismic hazard map of the country (IS1893-2002). The seismic activity of the region is attributed to the subduction zone created due to the collision of Indian and Eurasian plate boundaries. This region had been hit by two great earthquakes in 1897 (Shillong M 8.6) and 1950 (Assam, M8.7). The region keeps on facing earthquakes of lesser magnitude on regular basis.
Realizing the high hazard potential and vulnerability of the region local people have developed construction practices to face earthquakes safely. The region has two famous earthquake safe construction practices, which have been emerged over a period of time and have proven their resilience against earthquakes. Housing construction practices followed in the region had played a significant role in reducing the impact of regularly occurring earthquakes. These techniques are ‘Assam Type House’ and ‘Thatch House’. These housing typologies are common throughout the Northeast India. Majority of such houses are used for residential purposes. Typically these houses are built with light weight locally available material like bamboos, wooden planks, thatch etc. Such houses have a proper system of bamboo/wooden beam-column and fulfill the earthquake safety requirements of rectangularity and simplicity. These housing types have demonstrated some of the basic principles of earthquake safe construction of non-engineered buildings like appropriate sitting and location on firm soils, good building configuration i.e. its form and shape in plan and elevation; location and size of major structural elements; number, location and size of openings; and connection details of non-structural elements with main structural system. Due to proper connection between different elements, such houses have a proper integral action due to which they act as a single unit. The paper will examine these techniques and propose few modifications to improve the earthquake resistance of these buildings.