Research Paper Engineering

Earthquake Disasters in Hilly Areas (Case Study Uttarakhand) –Part I

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ABSTRACT

The Himalayan region of Indian subcontinent is well known for its vulnerability to earthquakes. Many authors have done intensive research on disasters in hilly region and hazard mapping to contribute to the essentially required data for estimating a Hazard. One of such disasters was the devasting Garhwal earthquake of late 1991 which was an eye opener to the strengths and failures of building technologies in the seismic hill region. The disaster diverted attention towards salient features of local construction material, the points of vulnerability and listing of recommendations for precaution/rescue in case of such a disaster. Looking at the frequency of earthquakes in India in the past decade the paper aims to remind the sensitive approach required in the architecture of hills and concludes with a methodology for creating or mapping appropriate database which could enable disaster risk management from an architect's point of view.

KEYWORDS Earthquakes, Hilly Terrain, Vernacular Construction

Introduction

Among many disasters in Himalayan region was the earthquake on 20th October 1991 of magnitude 6.6 on the Richter scale with its epicenter located at Maneri (0.5 Kms) east of Uttarkashi. The main shock of 45 seconds was followed by a series of strong and subsequent weaker after shocks. Impact of this earthquake was strongest in the region of Uttarkashi, Tehri Garhwal and Chamoli districts of Uttar Pradesh. Over 1,500 people were killed and a number of further causalities were reported due to injury, exposure shock, contaminated water and inadequate lift support services. According to unofficial reports, over 11,000 houses were severally damaged or had collapsed and 35,000 were slightly or moderately damaged mostly reported from rural areas. Apart from housing and infrastructure a large number of live stocks and a fair proportion of agricultural terraces were devastated. The process of reconstruction by outside agencies took two to four years during which the vulnerable people lived in emergency shelters.

Effects of Earthquake on Predominant House Type

Depending upon the structural design and use of construction material damages were low, medium and severe. Some of the typologies are listed below -

2.1 A traditional house belonging to a poor family was made up of thatch and timber plank roof on stone masonry wall with mud mortar. Damage was limited because of the comparatively low height but corner cracking and wall failure were common.

2.2 A traditional two-storied house has timber plank roof .Walls of stone masonry (random rubble in such mortar or dry stone) are reinforced in the horizontal and sometimes vertical direction by timber bands. Opening for ventilation are small and well framed with the verandah on the upper floor bringing the afternoon sun into the house. The use of timber bands and the light roof mass resulted in a low level of damage of these houses.

2.3. The most common form of traditional house is with a slate cladding on timber plank and beam roof with random rubble stone walls (most often in mud mortar). In this case the intermediate floor is in timber, the upper floor has verandah, which usually faces south. The openings are small and centrally placed. These buildings were extensively damaged in the earthquake because of their heavy roof load, lack of roof trusses and failure of masonry and long walls.

2.4 One typology is in the form of the traditional slate roofed house with the upper floor clad in timber planks. The lower storey walls are in random rubble stone masonry. The verandah extends around the corner of the building to take advantage of the sun. Cattle and agriculture produce are kept on the ground floor. These building suffered damage to masonry which led to partial or complete roof collapse.

2.5 Another typology is of two storied corrugated galvanized iron (CGI) sheet house. The walls in this case are usually built in random rubble stone masonry in mud or occasionally cement mortar. The roof load is light but member of these houses were damaged because of masonry wall failure. This is the preferred house of the future for large sections of population, if only they could afford it.

In order to assess the damage to buildings and identifying techniques for demolition, reconstruction and a new housing, a team from TARU, a professional NGO conducted a detailed field survey of 10 villages and 850 houses in Garhwal. Only 2% of the surveyed buildings were found to have totally collapsed with no standing wall or roof. Severe damage was sustained by 24% of the houses with approximately half of the structural elements having failed or collapsed. These buildings can be considered to have a large high risk of collapse. Heavy damage was sustained by the largest group in which the load carrying capacity of the building was found to be partially reduced. These buildings can be considered at "high risk" especially following snow loading and possible settlement after the snow melts and after the 1992. A moderate damage was sustained by 33% of the surveyed buildings; these are generally occupied and need repair and strengthening.

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Estimated Intensity of Damage By House Type

Based on a comparison of the damage reported by the people and the extent of damage observed, it was found that damage assessment and hence relief was not undertaken with adequate engineering guidelines in a significant number of cases. Table 1 gives us the percentage of damage caused in buildings made of different materials during 1991 earthquake. The major loss is due to the gap in the lack of a Disaster Relief Code, lack of engineering guidelines for damage assessment for the house type in the region and lack of awareness in administration. A major error in the government damage assessment was the estimation of the amount of compensation without reference to the actual costs of demolition, site clearance, recycling of materials and reconstruction. The negligible amount of compensation in relation to the costs of construction led to the rejection of this compensation package in number of locations.

Table 1 : Intensity of Damage Occurred in Various Types of Structures

Estimated Intensity of Damage (MSK Scale)	House Type by Material of Roof and Wall (% to all houses of one type)						
	Timber roof on timber walls	Timber roof on mud pathri walls	Thatch roof on mud pathri walls	CGI sheet roof on mud pathri walls	Slate roof on mud pathri walls	RC roof on mud pathri walls	Total Average
Slight	0%	0%	4%	20%	3%	4%	4%
Moderate	50%	50%	43%	34%	30%	27%	33%
Heavy	40%	40%	35%	22%	39%	37%	37%
Severe	10%	10%	17%	22%	26%	29%	24%
Collapse	0%	0%	2%	3%	2%	2%	2%
Total	100%	100%	100%	100%	100%	100%	100%
Number of Houses	26	10	142	52	489	132	850

Source: TARU field study (Base=850 Houses)

The estimated intensity of damage by house type is partially confounded by the influence of distance from the epicenter tract and the geographical specificity of particular house type. Nevertheless, it can be interpreted as a general indication of the relative performance of building systems in the area.

The extent of damage suffered by RCC buildings is largely due to the low quality of detailing and construction techniques. Given the severe constraints of transport of cement, steel, good quality of sand and higher relative costs, it is necessary to actively discourage costing of artisan built RCC roof slabs for reconstruction. (This, however, may not hold true for urban areas whose proper engineering inputs are available).

Observed Mechanism of Failure

Failure types have been classified according to relative frequency of occurrence. The mechanisms of failure are given below in table 2 -

Failure of the corners of masonry walls in tension or under combined stress due to lack of quoins and corner reinforcement.

Failure of masonry mortar (especially mud) in tensions.

Bucking and crushing failure of load bearing walls due to lack of through bonding stone.

Failure of near walls due to ramming of rear retaining walls if separate, or collapse, when the rear walls are built on retaining walls (this has occurred due to abandoning the traditional building practice of locating the building 60 to 90 cms away from retaining walls).

Lack of wall plate restraint and trusses which often led to transverse and gable wall failure.

Failure of RCC columns especially at joints and foundation settlement in RCC structure.

Table 2 : Relative Frequency of Observed Mechanisms of Failure

Type of Failure	Relative Frequency
Masonry wall corner failure in tension and combined stress	Very high
Masonry mortar failure in tension	Very high
Masonry failure due to lack of through stone	Very high
Partial Collapse of roof due to wall collapse	Very high
Ramming of rear retaining wall	High
Settlement of foundations	High
Roof failure due to lack of wall plate restraint	High
Gable failure	High
Overturning of masonry wall	Low
Masonry failure around openings due to racking shear	Low
Total Collapse of roof due to wall collapse	Low
RC column failure at joints	Low

Source: TARU field study (Base = 850)

6. Earth Disaster Mitigation

Garhwal will continue to be a high risk area for earthquake and landslides. The hazard to buildings and settlements in this region has a large number of components including ground shaking, surface faulting, slope failure, resonance, landslide, rock fall and flash floods-factors which have singly or in a compound manner been the cause of extensive damage. The current thrust of relief operations is to resist these problems predominantly through an architectural engineering approach. However, improved silting, land use controls and restricting economic activity are equally effective disaster mitigation interventions but it is important not to lose sight of the overall development process in the region and the potential of post earthquake reconstruction to catalyze local development.

Site Improvement

Site improvement helps reduce effects of earthquake and induced landslide risk. The most cost effective site improvement measures are improving drainage and slope modifications (for example reducing terrace heights and strengthening retaining walls).

Regulation of Land Use

Regulations related to site development and building byelaws must be followed.

Relocation

Settlements and buildings that are presently on hazardous sites should be relocated which is a complex process involving geological, geotechnical, social and economical inputs.

Reducing Vulnerability of Buildings

The principal factors that reduce the vulnerability of buildings are:

1. **Foundation**: Isolated column footings and mixed foundations within the same building lead to differential foundation settlement. The Garhwal region unfortunately has a variety of soil types due to glacial deposits, soft soil and unstable slopes.
2. **Building Mass**: The less the mass, the less is the internal force caused by the earthquake.
3. **Opening**: These should be few, small and centrally located.
4. **Building Configuration**: Simple, symmetrical, rectangular buildings are the most desirable, where the length of the block is not more than three times of the width.
5. **Ductility:**Vertical steel reinforcement at masonry corners increases ductility(its ability to bend, sway & deform large amount without collapse.
6. **Construction Quality & Technology**: The quality of masonry will have to change radically with proper

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through and corner stones and vertical reinforcement, slate roofs rebuilt with trusses and wall plates.

7. Summary and Conclusion

Disasters are natural and cannot be stopped but we can be prepared to mitigate their ill effects by using traditional techniques of construction suitable for the soil type in a particular region which also means permitting or rather promoting only vernacular construction. It is advisable that shelters may be made out of light construction materials like bamboo, wood (locally available) which have light density. Keeping in mind the mitigation measures and factors that can reduce vulnerability; live loss can be certainly reduced. Most importantly older buildings should be retrofitted and for new construction whether in developed or rural dwelling NOC should be given for plans which adhere to seismic provisions.

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