Seismic safety of schools in Kathmandu Valley, Nepal: problems and opportunities

NZSEE 2002 Conference

J.K. Bothara, A.M. Dixit, M. Nakarmi, S.B. Pradanang, & R C. Thapa

Dept. of Civil Engineering, University of Canterbury, Christchurch, National Society for Earthquake Technology- Nepal, Kathmandu.

ABSTRACT: The National Society for Earthquake Technology-Nepal (NSET) has been in existence for approximately eight years and has received support from the New Zealand Society for Earthquake Engineering to interact with the international earthquake engineering community. It has initiated and undertaken (with national and international organizations) many mitigation measures such as building asesimic retrofitting and construction, publication of materials, extensive training and awareness raising, and a national earthquake safety day each January. This paper outlines one of NSET's projects, which is showing real potential to bring about change to existing practices.

The Kathmandu Valley Earthquake Risk Management Project (KVERMP) implemented by NSET placed a special focus on schools. It assessed the seismic vulnerability of public school buildings of Kathmandu Valley and identified intervention options. School buildings in Nepal are highly vulnerable to any future earthquake. The loss suffered by a community in the collapse of a school may psychologically be much more as it houses entire future generation. Schools are ideal for temporary shelter, medical clinics, and other emergency functions. Functioning schools provide a feeling of normalcy. They are also particularly receptive to earthquake safety programmes. Furthermore, introducing seismic safety into a school is a step forward for awareness raising, for introduction of seismic safety at the community level, and technology transfer. The strengthening of a school becomes a model for domestic construction, as schools are matter of concern for all.

1 INTRODUCTION

There are 643 public schools in the Kathmandu, Lalitpur and Bhaktapur districts of Kathmandu Valley. These range from pre-primary to higher–secondary levels, with multiple buildings in most school campuses. The Kathmandu Valley School Earthquake Safety Program (KVSESP), a component of KVERMP, collected information on some 60 % of these schools and assessed vulnerability of more than 900 buildings. Seventy-eight percent of these buildings used typical Nepali construction techniques. The rest are standardised two-room steel sheds constructed by the Earthquake Affected Area Reconstruction and Rehabilitation Project (EAARRP) after the magnitude 6.4 Udaypur earthquake of 1988.

The school safety has been considered as a path to the safer community, with the greater goal of introducing seismic safety as a culture. The methodology seeks maximum involvement of the local community in the overall school earthquake safety programme. Technical and logistic support comes from KVERMP (and presently from NSET-Nepal) for technology transfer to local craftsman, and awareness raising of the community.

2 SCHOOL BUILDINGS

2.1 *Production Mechanism*

Nepalese school buildings are mostly procured by the community itself, mostly employing a local skilled artisan to direct operations. The process is characterised by the high degree of informality - community members make decisions on even the strength factors. In urban areas, some input from technicians is also common because of building permit processes. However, even these urban buildings do not incorporate earthquake-resistant features. Even those schools funded by foreign donor agencies are not required by the donors to be earthquake-resistant. The larger part of the funds for construction of school buildings also comes from the community. The buildings in rural areas are constructed with very little capital input as the local community provides labour and collects materials, etc.

Traditional artisans, who generally come from the local community, play a vital role in the construction activity, and the community relies on them heavily for all type of advice. They provide overall technical and organizational support - even though none of them has formal training. Many of them are illiterate.

2.2 *Construction Materials*

Construction materials for school buildings fall into two groups: traditional and modern. Traditional materials such as earth, stone, timber and bamboo are naturally occurring, and are used with very limited processing or quality grading. These types of the buildings, mostly constructed out of municipal areas, tend to be beyond the control of urban building regulations and planning requirements. Cement and steel bars are the modern materials. These were introduced in the late seventies in abundance. The use of these materials is more concentrated in dense urban areas (the valley floor) and in urban fringes where affordability and accessibility to the materials, information and transport are comparatively easy. Traditional materials are common in old buildings in urban areas, and on the outskirts and the valley rim, or wherever affordability and accessibility is low. The use of construction materials is shown in Figures 1, 2 & 3.

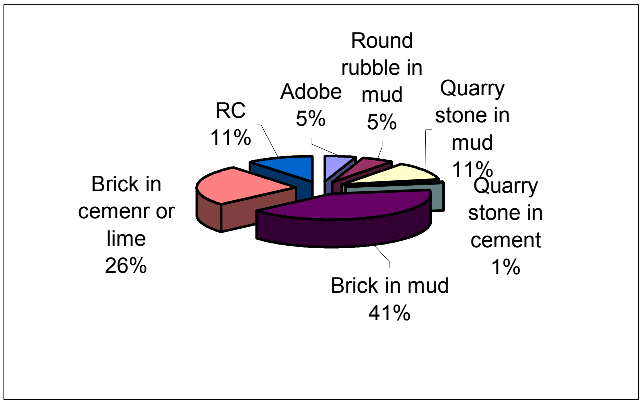

Figure 1: Walling materials

Most of the informally constructed buildings were constructed over long periods of time – even decades, depending on requirements and the availability of resources. Thus, variations in the types of materials, workmanship and technology are common - even in the same building.

However, the building typology in the major part of the valley is by far governed by the availability of local materials and technology.

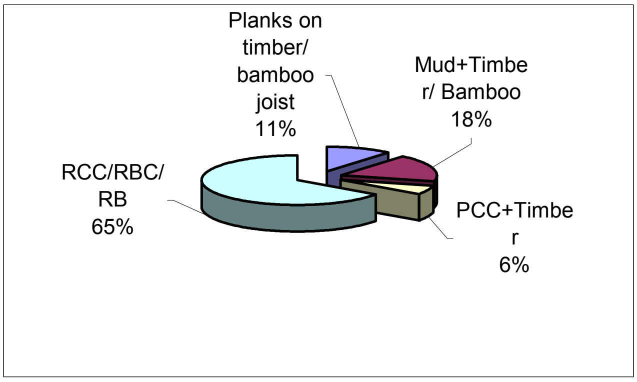

Figure 2: Flooring materials

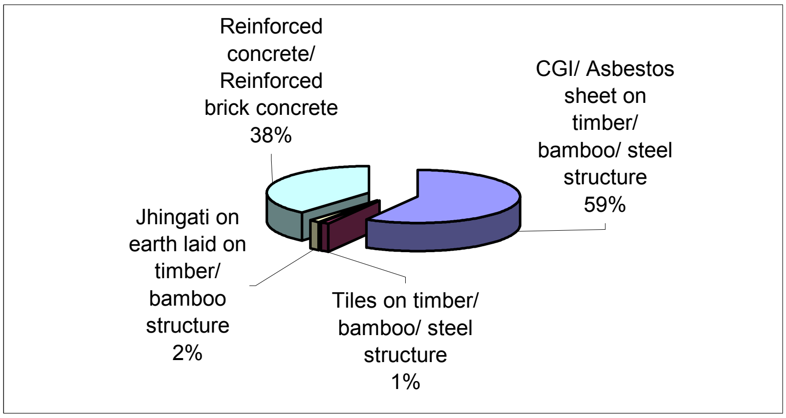

Figure 3: Roofing materials

2.3 *Building Typology*

2.3.1 *Buildings built with Traditional materials*

The buildings are built of stone in mud mortar where stone is available. Walls are generally thick and with limited openings. Fired bricks and adobe are common wall materials where stone is not available. Most of the school buildings are one to two-storey, but a few are up to four stories. Headroom is relatively low at around 2.1 to 2.4 m. Floors are generally made of a thick layer of soil on a timber/ bamboo structure. Roofs are generally duo pitch with gable walls at the ends. Roofing is of clay tile (with or without a base of earth), or corrugated steel sheets on timber or bamboo structure. Corrugated iron (CGI) is rapidly replacing any other roofing material due to its low maintenance. The use of both reinforced brick concrete and reinforced concrete (RC) flat slab is rapidly increasing for floor and roof construction. Figure 4 presents traditional building.

a) Brick in mud mortar b) Random rubble in mud mortar

Figure 4: School buildings constructed in traditional materials.

2.3.2 *Buildings built with Modern Materials*

There are two types of construction in this group: (a) modern load-bearing masonry buildings and (b) reinforced concrete framed buildings. Buildings with 230 mm thick load-bearing, un-reinforced masonry (URM) walls with a 1:6 cement mortar are common. These usually have cast in-situ reinforced concrete floors and roof slabs. Timber floors and a corrugated iron roof on a timber structure are also common.

Reinforced concrete framed construction is basically infilled RC frames with unanchored masonry walls generally constructed after erection of the frame. The structures are characterised by light frames with 230 x 230 mm to 300 x 300 mm columns with four to six 12 mm diameter bars and 4.75-6 mm diameter stirrups at 2-300 mm centres. These buildings even lack normal detailing required for vertical loads. Figure 5 shows a modern school building.

Figure 5: School buildings constructed in modern materials

2.4 *Condition of School Buildings*

A visual inspection of buildings showed that at least 10-15 % of them are in a severely bad condition - to an extent that even their use in normal times is hazardous. Crumbling of walls, floors, loss of integrity, and distortion in shape are the common problems. These building need immediate demolition and reconstruction. The next 25 % are in fair condition, either because of weak construction materials, material degradation, old age, and a low level of repair and maintenance. These buildings have not lost their integrity and shape. Such buildings can be rehabilitated with some effort if immediate action is taken. The rest of the buildings are in relatively good condition and are safe for vertical loads.

2.5 *Vulnerability of Schools*

The existing school buildings suffer from many weaknesses due to poor technology and weak and improper use of construction materials. The traditional buildings mainly lack connections between components and integrity in a global sense. They are constructed of inherently weak materials. Even buildings with modern construction materials suffer from a serious lack of integrity between structural members, under-sized structural sections, and lack of ductile detailing. Good construction practices are often disregarded. All these factors have made this building stock vulnerable – to a degree that even a small seismic event will cause severe damage.

Nepalese classrooms are always overcrowded and the door almost always opens inwards. There remains very little space for circulation.

The seismic vulnerability assessments done for these school buildings show a very grim situation. Over 66 % of the school buildings are likely to collapse, and the next 11 % will be beyond repair, if the valley experiences MSK intensity IX shaking. Such shaking during school hours could kill more than 29,000 students and teachers and severely injure a further 61,000. An earthquake producing at least this intensity of the shaking has been experienced every 100 years in the valley, the last time in 1934 (MMI intensity X).

3 INPROVEMENT OF BUILDING STOCK

3.1 *Intervention vs. no intervention*

The fatal earthquake scenario of school buildings could cripple the national economy for not only years, but also possibly decades. However, the loss scenario can be greatly reduced if proper programmes to construct new buildings earthquake safe and upgrade existing buildings are actioned. If the Nepalese do not act now, it could cost thousands of lives and the reconstruction cost may even exceed tens of millions of dollars. Table 1 sets out the benefits of intervention. If we act today, it will have the much longer benefit of improving the overall seismic safety of the community.

Table 1: Benefits of Intervention

Criterion	**Options**					
	No Intervention			Intervention		
	VII	VIII	IX	VII	VIII	IX
Building damage %	0	11	66	0	0	11
Un-repairable Damage	4	65	11	0	0	46
Repairable Damage	73	24	23	61	100	43
Mortality (Thousands)			29			5
Severe Injury (Thousands)			61			
Direct building loss (M)			US$7			
Awareness raising opportunity	None			Very High		
Mason Training Opportunity	None			Very High		
Earthquake Preparedness	None			Very High		
Introduction of safety culture	None			Very High		

3.2 *Dilemma: Demolition and Reconstruction vs. Retrofitting*

One set of professionals prefers demolition and reconstruction of existing school building stock, especially those constructed in weak materials. This also gives the opportunity to re-design the teaching spaces for today's needs. The major benefit would be that the buildings could be reconstructed using modern materials with state-of-the-art technology. But the question is: would the cost be affordable? Retrofitting cost estimates come to less than 25 % of the reconstruction cost for a large majority of the building stock. Lead-time for the reconstruction would be unaffordably long. Disposal of the materials of demolished buildings is another large problem. The reconstruction option is a radical one, which could never be realised across the board.

Of course, demolition/reconstruction and retrofitting should not be rival options, but complementary ones. Existing buildings, which cannot be retrofitted because of their dilapidated condition, need demolition/reconstruction. A building constructed in weak materials cannot be retrofitted at reasonable cost to be equal to a building constructed using state-of-the-art techniques. However, retrofitting can be a step forward for seismic safety at an affordable cost. Any effort to increase seismic safety of a school should be affordable in terms of the local economy and incremental in nature in order to make an impact on the community. It can then be used to convince people to retrofit their own houses of which are many thousands.

3.3 *Hassles*

Limited manpower: The country is largely starved of skilled manpower for earthquake-resistant construction. Although a number of engineering colleges, polytechnics, and vocational schools exist, training on earthquake-resistant construction is still viewed not as an integral part of long-term earthquake mitigation strategies. Even many professional engineers are unaware of the potential hazard and earthquake protection measures. Similarly, construction artisans do not get any formal training. Their skills are inherited or learnt from other masters.

Mid-career training: There are very few opportunities for mid-career tradesmen to update their knowledge with recent developments in earthquake-resistant construction. This is, again, because of a lack of experts on the subject.

Limited resources: The country is one of the poorest in the world, with a per capita income just US$210/ year. The government provides almost no funds to schools for improving school buildings unless there is a specific project. Local communities are, in general, not able to afford all the capital input, although they can contribute labour and local materials.

Professional ethics: Systems to control professionals, standardise professional ethics, and accept professional liability do not exist. Peer review is not considered an essential part of overall design.

Priority from government: The UNDP funded the Nepal Building Code Development Project (NBCDP) in 1992 after the 1988 East Nepal earthquake, which killed 721 people. Even after the government realised the vulnerability of the building stock, it is still struggling to implement it. The NBCDP prepared short-term to long-term plans for introducing seismic safety, but they are still waiting to be implemented. A Building Act to regulate building construction activity and enforce the code was passed in 1998, but is still waiting to be enacted.

No recognition for traditional materials and skills: The formal education system and its trainees do not recognise informal/ non-engineered construction materials and skills which produce more than 98 % of the country's building stock. This has created a big gap between two of the stakeholders in the construction industry (i.e. between craftsman and technicians). The craftsmen are still waiting to be recognised as stakeholders. Whatever training is undertaken in engineering schools discriminates against masonry construction, depicting it as an obsolete option, although it will still govern the future.

Communication gap: Seismic resistance technology for both new and old construction methods exists at an affordable cost, and the house owners are receptive to it. The major gap is the dissemination of the information and technology.

3.4 *Opportunities*

Economic front: The vast majority of the existing school buildings in the Valley will be in use continuously for decades to come. Fortunately, for 70 % of the existing buildings in the Valley, retrofitting is a cost-effective option. For new construction, seismic safety can be introduced at an affordable cost.

Community participation: The work done by NSET-Nepal for improving the seismic safety of school buildings by involving the local community as a major stakeholder has a large impact on that community. People have accepted the technology, as is reflected by the replication of earthquake-resistant construction introduced in school building construction.

Craftsman: Artisans could be used as messengers. They can easily bridge the gap between owner-builders and technicians as they have greater accessibility to them. It is observed that masons are quite receptive to retrofitting and aseismic construction. Earthquake-resistant design/construction and the associated quality control and technology can be easily transferred to them. Their lack of an academic background is not a problem. Of course, training needs to be on-the-job, and more interactive and informal rather than through rigid classroom sessions. Such training could be conducted at a very nominal cost as part of construction activity.

Awareness raising: Introducing seismic safety in schools is a great tool to make the student/local community aware. This is because knowledge imparted to children is more sustainable as it will be reflected some 10-20 years later. Furthermore, it has been observed that people who used to take a fatalistic approach now like to discuss issues on seismic safety. It can be considered as a big step forward.

Formal training: Few engineering colleges and polytechnics are eager to have courses on earthquake-resistant design and construction. The problem is they do not have manpower to run course.They are trying to develop staff who can deliver it.

Building code: The building code is ready for use. It is purposely made incremental in nature so it can encompass both formal and informal construction. It has ready-to-use guidelines for both non-engineered and pre-engineered construction. Similar guidelines have also been prepared for school building construction by NSET-Nepal.

Government initiative: The Nepalese government is constructing school buildings as part of some specific projects. There is enough room for the projects to develop their construction activity as a model for dissemination of the technology and information. Of course, it will require much more innovation. Furthermore, the government could require the incorporation of earthquake resistance to be a prerequisite for funding of any school building construction.

International initiative: The construction of 43 % of school buildings has been funded all or in part by an international organization. In no case did the international involvement translate into making the building safer. In the future, international organisations that support school construction must make sure that all of the schools they fund should incorporate earthquake resistance.

4 **CONCLUSION**

- No radical change is possible. Radical changes will cause unfavourable repercussions on overall construction activity.
- Schools could be good places to be developed as models for the transfer of technology,

dissemination of information, mason training, etc., as they are places of common interest, and the population affected is large.

- A back-up training system for the upgrading of masons is necessary in the long term. A similar programme for professional designers is also an immense need.
- Involving the community means more sustainable work in the long term.
- Bottom-up and top-down approaches should be undertaken simultaneously.

REFERENCES

2000, Seismic Vulnerability of the school buildings of Kathmandu Valley and methods for reducing it, the Kathmandu Valley Earthquake Risk Management Project implemented by National Society for Earthquake Technology, Kathmandu, Nepal.

Basnet, S, Bothara, J. K., Dixit, A. M. & et. al. 1999, Seismic Hazard and Risk Management in Kathmandu Valley, Nepal; proceedings of Seminar on Urban Earthquake Damage Assessment, Building Research Institute, Tsukuba, Japan, Vol. 33.

Bothara, J. K., Parajuli, Y. K., Sharpe, R. D. Arya, A. S., 2000, Seismic safety in owner built buildings, 12th World Conference on Earthquake Engineering, Paper no. Auckland, New Zealand.

Coburn, A. & Spencer, R. J. S. 1992, Earthquake protection, J. Wiley & Sons, New York, USA

Shrestha, H. M. 2001, Construction management for earthquake risk reduction works in schools of Kathmandu Valley, a report submitted in partial fulfillment of the requirement of the M. Sc. Degree in construction management, Nepal Engineering College, Kathmandu, Nepal.