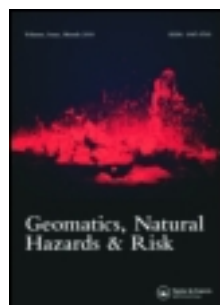


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Public School Earthquake Safety Program in Nepal

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Public School Earthquake Safety Program in Nepal

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Earthquakes are one of the most significant natural hazards in Nepal and there is a long history of destructive earthquakes in the region. Despite the risk of earthquake disasters, however, school construction practice in Nepal has largely ignored the issues of structural safety. Most schools are built without following proper design guidelines. As an effective tool to reduce earthquake disaster risk in the public schools of Nepal, the Public School Earthquake Safety Program was recently initiated in Nepal. In this program, more than 1000 public schools from six districts of Nepal were evaluated for earthquake safety, and various awareness raising and retrofitting programs were implemented. This paper describes the program features, extent of community participation, retrofitting processes and lessons learned while implementing the earthquake safety program. It also demonstrates how school earthquake safety programs ultimately increase the seismic safety of the entire community in the Himalayan regions.

1. Introduction

Nepal has a long history of destructive earthquakes (Rana 1935; Dunn et al. 1939; Chitrakar & Pandey 1986; Bilham 2001; Wyss 2005). From east to west, the sequence includes the 1905 Kangra earthquake ($M_s \sim 7.8$), the 1934 Bihar–Nepal earthquake ($M_w = 8.1$) and the 1950 Assam earthquake ($M_w \sim 8.6$). The Sikkim/Nepal border earthquake of September 18, 2011 was the latest earthquake (6.9 Richter magnitude) in Nepal.

In this century alone, over 11,000 people have lost their lives in four major earthquakes. A study of the seismic record of the region suggests that earthquakes producing a shaking level of IX or more in the Modified Mercalli Intensity (MMI) scale occur approximately every 75 years, while smaller ones occur more frequently. Earthquakes are thus an unavoidable part of Nepal's history, and based on the occurrence frequency, a major earthquake is likely to hit the region in the near future (Ambraseys & Bilham 2000; JICA 2002). Despite this knowledge of seismic history and the disaster risks, public awareness on earthquake hazard risks was minimal until a decade ago. Only after a massive destruction and loss of 721 human lives due to the Udayapur earthquake (Gupta 1988) of 1988 ($M_w \sim 6.6$) the need for an

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Table 1. Earthquake damage scenario of Kathmandu valley with consideration of 2010 demographic conditions in the valley. Detailed procedure of this table is available in Guragain et al. (2008).

Casualty	Deaths:	100,000
	Critical injury:	100,000
	Hospitalization:	200,000
Homelessness	1.5 million	
Damage to buildings	Sixty per cent of all buildings are likely to be damaged heavily, many beyond repair.	
Damage to transportation network	Almost half the bridges could be impassable. Many of the narrowest streets in the valley will be blocked by debris from damaged buildings.	
Damage to utilities	Approximately 95% of water pipes and 50% of the components of water system (pumping stations, treatment plants, etc.) could be damaged seriously. All telephone exchange buildings and 60% of telephone lines are likely to be damaged. It is estimated that most parts of the valley will be without piped water supply for several months and several areas could remain without service for over 1 year.	

organized approach towards earthquake risk management was realized and several innovative initiatives on earthquake disaster risk management were commenced. Nepal is ranked the 11th worst in terms of relative vulnerability to earthquake disasters (BCPR 2004). The World Bank (Arnold et al. 2005) study identifies Nepal as a disaster hotspot, while the Global Earthquake Safety Initiative Pilot Project labels the Kathmandu valley as the most at-risk city in terms of potential death in an earthquake disaster (GHI and UNCRD 2001). If an earthquake of the same magnitude as the 1934 earthquake hits the Kathmandu valley again, it is estimated that more than 100,000 people will be killed. The loss estimation (table 1) clarifies the extent of the problem faced by the Kathmandu valley. In this estimation, only the cases of MMI IX level were used due to unavailability of other parameters.

These data clearly suggest that the earthquake disaster scenario of Nepal is very alarming and it is of utmost importance to prepare for an upcoming earthquake disaster.

When earthquake vulnerability of various public infrastructures of Nepal is talked of, public schools, both the buildings and their occupants, face great risk of earthquake disasters (NSET 2000 and Shrestha 2001). This is because a majority of the school buildings, even those constructed in recent years, have not followed any technical advice or guidance from trained engineers during the design or construction supervision. A majority of the school buildings are constructed with load-bearing masonry wall system, mostly brick masonry in flat terrains of the Terai and valleys and stone masonry in the hills and mountains. There are only few buildings constructed of timber (in Terai), adobe (high mountains and in Terai) and other construction materials. Mud is used as mortar in most cases, although cement-based construction is prevalent in urban and semi-urban areas. A visibly increasing trend in the use of RCC (reinforced cement concrete)-framed construction was found principally in the urban or the urbanizing areas, especially in the neighbourhood of road network. Despite the risk of earthquake disasters, the school construction practice in Nepal has largely ignored the issues of structural safety, especially in terms of structural design. Most of the school buildings were/are built without following proper



Figure 1. Damaged building of Sumnima Pre-secondary School in Panchthar district of Eastern Nepal after the Sikkim/Nepal border earthquake of September 18, 2011. More damage was noticed in the recently constructed building.

design guidelines, which necessitates the implementation of an effective tool for the reduction of earthquake disaster risks in the public schools of Nepal.

High vulnerability of schools was particularly evidenced during the 1988 Udayapur earthquake in Eastern Nepal. About 6000 school buildings were destroyed in this disaster event, but fortunately, it was during non-school hours. Such a massive damage to the school infrastructure disrupted the community and affected approximately 300,000 children for several months. The same situation occurred again after the latest Sikkim/Nepal border earthquake of September 18, 2011 (Raghukanth et al. 2012; Rai et al. 2012). Many schools in Eastern Nepal were damaged (figure 1). Most of the completely damaged school buildings (figure 2) during this earthquake were stone and brick-in-mud type buildings, whereas the partially damaged buildings were brick masonry with cement mortar, RCC-framed structures and steel frame structures with walls of stone masonry with cement mortar. The partially damaged state refers mainly to cracks on walls, partial collapse of wall in one or two sides of the buildings, collapse of cement mortar on walls and so on. These partially damaged buildings were recovered within a few weeks and the schools were run smoothly.

All this recent damage information suggests that the school buildings in Nepal are at high risk of damage during an earthquake event. Therefore, the main objective of this paper is to highlight the school earthquake safety program (SESP), currently being implemented in Nepal, and to provide a comprehensive information of this program. The paper also introduces some initiatives and pilot works undertaken for the earthquake safety programs in schools of Nepal and also highlights program progress and recent deliverable programs.

2. Why public schools for earthquake safety program

Nepalese education system can be classified into two main categories: school education (i.e. 10 years of education) and higher education (i.e. post-school or college

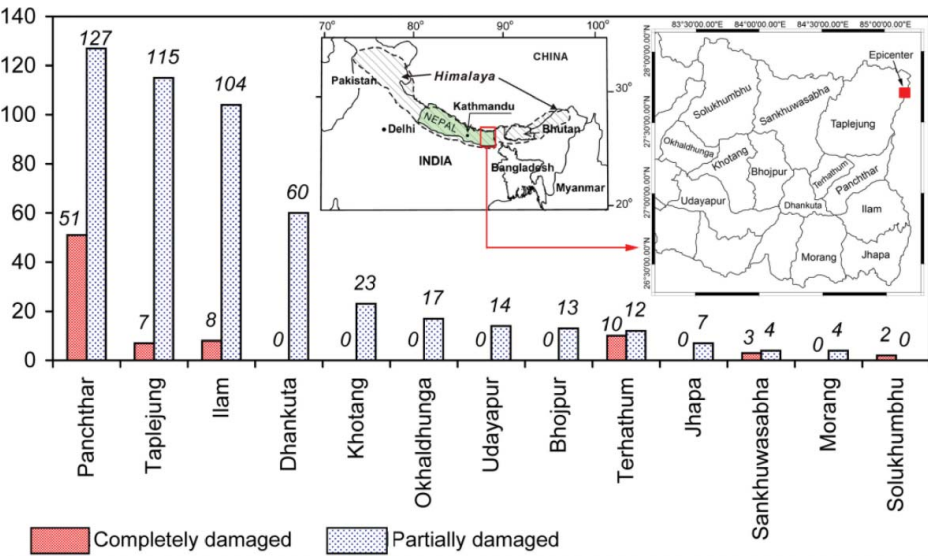


Figure 2. District-wise school damage scenario after the Sikkim/Nepal border earthquake of September 18, 2011 in Eastern Nepal. Severe damages to the schools near the epicentre were also observed (Data source: Ministry of Education, Government of Nepal).

education). The school education includes primary level from grade 1 to 5, lower secondary level from grade 6 to 8 and secondary level from grade 9 to 10. In most of the urban areas, however, private schools provide education from grade 1 to 10, while in rural and sub-urban areas the public schools are the main educational centres that provide compulsory education from grade 1 to 12, including two years of post-school education. Broadly, the schools in Nepal (table 2) belong to one of the following four categories in terms of ownership and funding.

- (1) *Community-aided schools*: fully supported by the government for the teachers' salaries and other operational costs.
- (2) *Community-managed schools*: fully supported by the government for the teachers' salaries and other operational costs, but their management responsibility is undertaken by the community.
- (3) *Community-unaided schools*: either get partial support or no support from the government.
- (4) *Privatelinstitutional schools*: supported by the parents and trustees.

Table 2. Number of schools in different ecological belts (Data source: Department of Education).

S. No.	Level	Mountain	Hill	Terai	Valley	Total
1	Primary	2810	11,262	5687	586	20,345
2	Lower secondary	488	2023	1259	339	4109
3	Secondary	421	2159	1668	898	5146
4	Higher secondary	120	640	498	298	1556
Total		3839	16,084	9112	2121	31,156

In addition to the above categories, there are separate groups of religious schools, such as (1) *Madarsa* (Muslim religion), (2) *Gumbal Vihar* (Buddhist religion) and (3) *Ashram/Gurukul* (Hindu religion).

Public schools are operated through the government and classified as community-aided, community-managed and community-unaided. The management of these schools lies under the local community through the government support. On the other hand, private schools in Nepal are owned by private sector entities and are registered under the Company Act of Nepal and they must receive an approval from the District Education Office (DEO) for their operation. Religious schools are managed and operated by different religious organizations. They are registered under the DEO and are recognized by the government. Only some but not all of these schools receive financial support from the government.

In most cases, public schools in Nepal are the centre of social and cultural life, especially in rural and sub-urban areas. During the post-disaster period, public school buildings can even serve as emergency shelters. Usually, they have playgrounds, which can be used for shelter tents or emergency medical services after an earthquake disaster event. Moreover, the loss suffered by a community due to the collapse of a school building is psychologically much greater than the loss due to the collapse of any other buildings.

Schools play a crucial role after an earthquake disaster in helping the community get back to normal state. Since schools are typically well distributed throughout the neighbourhoods, they are an ideal location to provide shelters for homeless, medical clinics and other emergency functions. Functioning of a school provides a feeling of normalcy to the community, helping people to get back on their feet after a disaster event.

Schools are also particularly tractable for earthquake safety programs. School structures are typically very simple and relatively small, unlike other critical facilities. Therefore, instead of constructing new school buildings with an earthquake-resistant concept, retrofitting the existing school buildings are economically feasible and technically suitable. Also, by raising awareness in the schools, an entire community can be accessed as the lessons trickle down to parents, relatives and friends.

3. Assessment of public school buildings

The study was focused on understanding the typology of the school buildings. Therefore, representative districts, namely three districts of the Kathmandu valley (i.e. Kathmandu, Lalitpur and Bhaktapur), Lamjung, Nawalparasi and Humla were chosen as the sampling areas (figure 3). These districts represent different geomorphological and socio-economical environments of Nepal: Kathmandu valley is the capital of Nepal; Lamjung is the Lesser Himalayan region; Nawalparasi represents the Terai region and Humla lies in the Higher Himalayan region. The Kathmandu valley has many infrastructural facilities with the highest population density, whereas Lamjung and Nawalparasi have nearly the same population density and similar economical and infrastructural facilities. Humla is one of the least developed districts of Nepal with very low population density and infrastructural facilities as it does not even have a direct road link with other parts of the nation.

To assess the school buildings, at first, a questionnaire form (figure 4) was prepared, which could be filled out by the school principal. This questionnaire content

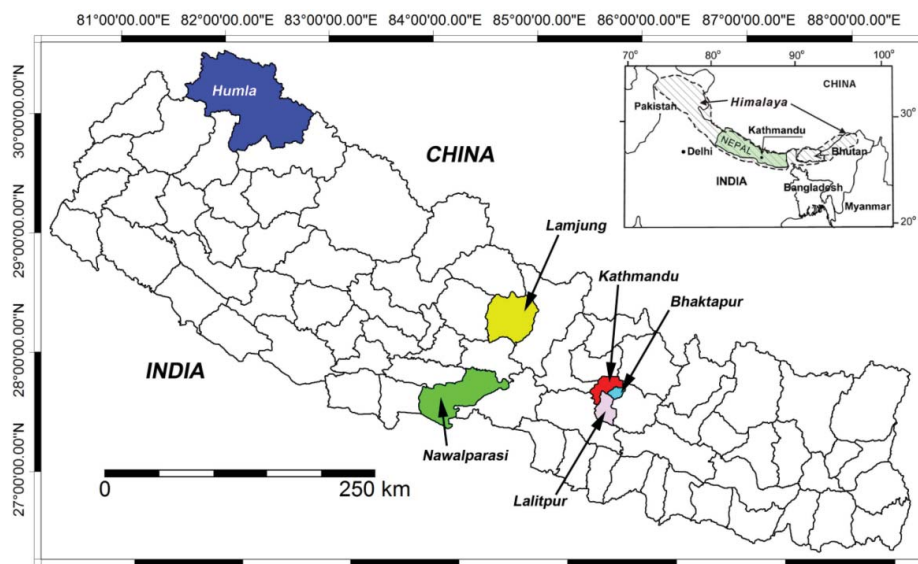


Figure 3. Location map of the study area.

mainly had information on the size of the buildings, density of the students, year(s) of construction, whether or not an engineer was involved in the building design or construction, etc. In addition, simple questions concerning the structural characteristics, presented through illustrations and descriptions, were asked.

As Kathmandu is the capital city with a great number of public schools, a detailed work was done in this area to assess the earthquake safety. For this area alone, a total of 17 seminars were held with the principals of about 65% of the total 643 public schools in the valley, mainly to discuss with them the earthquake disaster risks, the need of planning for earthquakes in the schools and the ways to fill out the questionnaire form appropriately. Consequently, the school principals who participated in the seminars conducted the questionnaire survey, which helped collect data from a total of 430 schools. This led to evaluation and assessment of the conditions of the surveyed school buildings. A similar work was also conducted in other districts so as to collect the information.

4. Condition of school buildings

The model study of the Kathmandu valley (i.e. Kathmandu, Lalitpur and Bhaktapur districts), Lamjung, Nawalparasi and Humla districts suggests that there are approximately 42% of school building units built in brick masonry with cement mortar, about 13% built with RCC-framed structure, about 11% with steel frame structure, about 10% brick in mud and about 9% in block masonry with the materials found in the Terai region of Nepal. The major structure type in hilly regions is quarried stone masonry, making up to about 53% of the structures, with about 22% of rubble stone masonry and the rest of brick masonry, block masonry and others.

The assessment details of the public school buildings in the Kathmandu valley are presented in table 3. A total of 643 schools in the valley were assessed, out of which

PART A: GENERAL INFORMATION

1. Name of School: _____ 2. Building No.: _____

3. Municipality/VDC: _____ 4. Ward No.: _____

5. Tole: _____ 6. Contact Person: _____

PART B: BUILDING INFORMATION

1. Date of building construction (BS): _____

2. Use of building:

☐ Office ☐ Library ☐ Laboratory

☐ Rental ☐ Class Room ☐ Store

3. Condition of building:

☐ Good ☐ Satisfactory ☐ Bad ☐ Very Bad

4. Position of buildings:

☐ Free Standing ☐ Confined by other buildings in one side

☐ Confined by other buildings in two adjacent sides ☐ Confined by other buildings in two opposite sides

☐ Confined by other buildings in three sides

5. Type of foundation subsoil:

☐ Rock ☐ Gravel / Sand

☐ Soft / Medium soil ☐ Unknown

6. Number of stories: _____

7. Building material and structural system:

S.No.	Building material / structural system	Floor		Roof	
		Rigid	Flexible	Rigid	Flexible
1.	☐ Adobe				
2.	☐ Stone in mud				
3.	☐ Brick in mud (Fired brick)				
4.	☐ Stone in cement				
5.	☐ Brick in cement				
6.	☐ RC framed ordinary				
7.	☐ RC framed – structural designed				
8.	☐ Timber frame with SM/BM				
9.	☐ Wooden				
10.	☐ Hollow concrete block				
11.	☐ Others				

(If flexible roof mention – Tile/CGI/Jhingati/Thath)

8. Configuration:

a) Shape of building

☐ Square ☐ Rectangular ☐ L-shaped ☐ E-shaped ☐ Others

b) Size of the building with sketch

c) Uniformity in elevation

☐ Uniform throughout the height ☐ Walls in cantilever projection

☐ Upper stories smaller than lower stories ☐ Is there soft story problem (open ground stories)

PART C: INTERVENTION FOR SESP PERFORMANCE IMPROVEMENT

S.No.	Possible Intervention Option	Type of intervention	Total Floor Area m ²	Approximate Rate/m ²	Amount NRS	Amount US\$	Remarks
1	Seismic retrofitting	Splice and bandage Jacketing					
2	Demolition and reconstruction	RCC frame					
		Load bearing masonry					

9. Year of Construction/ Age: _____

10. Remarks

11. Sketch/ plan/ elevation/ site condition (optional)

PART D: SURVEYOR

1. Name of Surveyor

2. Date of Survey

Figure 4. A model questionnaire used in the assessment of school buildings.

Table 3. Seismic vulnerability of public school buildings in Kathmandu valley.

Particulars	Details	%
Total number of public schools/buildings	643/1100	58% of total schools
Typology of traditional school buildings	Adobe (sun-dried bricks) or earthen buildings (mud cake buildings)	5
	Stone/brick masonry in mud mortar	56
	Rectangular block (brick or hollow concrete block or semi-dressed stone in cement mortar)	28
	Reinforced concrete frame (RC frame)	11
Existing condition (with extrapolation for 643 schools)	Hazardous for use at present, need immediate construction	10–15
	Can be saved (with structural intervention, retrofit, repair and maintain urgently needed)	25
	Good for vertical load (but not for lateral shaking), need retrofitting	65

15 school buildings were found to be highly vulnerable to earthquake. In the Kathmandu valley, more than 60% school buildings are constructed from traditional materials (such as adobe, stone rubble in mud mortar or brick in mud mortar), which behave very poorly during earthquakes. Less than 40% of the school buildings in the valley are constructed from modern materials, such as brick in cement mortar or reinforced concrete. Modern material buildings typically have more number of stories with larger rooms, larger windows and doors than those built with the traditional materials. These additional features make the modern material buildings as vulnerable as the traditional material buildings. As a whole, out of nearly 650 school buildings, only three buildings were found to have been constructed under the Nepal National Building Code provisions. An additional 4–5% of the buildings were found to have seismic-resistant design features, such as reinforced concrete bands at the lintel level. A vast majority of the buildings were found to have been constructed without considering the seismic forces. In the Kathmandu valley, many school buildings have not only been poorly constructed, but they also lack proper maintenance. Approximately 10–15% of the buildings were found to be in extremely poor condition due to sub-standard material and workmanship, lack of maintenance and/or extreme age. Many school buildings were found to have ready-to-collapse floor slabs and/or ready-to-crumble walls. Such buildings are dangerous to be used even during normal times. Another 25% of the buildings were found to have serious maintenance problems, such as decaying timbers or severe cracks in the walls, which are extremely dangerous even in no-earthquake cases.

As stated elsewhere, this study also suggests that a majority of the school buildings in the sampling districts are non-engineered. Most of the buildings are constructed of low-strength masonry, flexible floors and timbered roofs, without considering the limitations in the use of these materials. They usually have an elongated (rectangular) shape in plan and sometimes are unnecessarily long. Constructed mostly with load-bearing masonry structures, they are highly vulnerable to earthquakes. Major structural problems identified through the survey response are weak construction materials, heavy walls and roofs, poor quality control of construction process, untied gable

walls, lack of integrity between different structural components/elements, more stories than permissible for a particular type of construction and asymmetrical plans and load path.

In Nepal, there is always a lack of mandatory policy to control the design and construction of all school buildings. Although some schools are supported by international donor agencies and/or the government requires design/drawing details, many schools are directly constructed by the communities without incorporating any standard design criteria or technical supervision. Likewise, site-specific hazards are also not considered during the design and construction. Some design details are available, but they may not be entirely suitable for specific sites/locations. At most local levels, people lack the capacity to understand and implement the earthquake-safe construction method.

Funding mechanism in schools is another problem that has deteriorated the quality of school buildings. Sometimes, participation of the government and community at a ratio of 60:40 is found to affect the quality of school building construction. Communities that are unable to generate 40% of the building costs are found to complete the construction with only the available 60% of the budget availed by the government, which forces the community to compromise the quality of the buildings.

5. Earthquake disaster risk on school buildings

As stated previously, the entire territory of Nepal lies in a very high seismic zone and any part of the country may encounter an MMI IX level of shaking anytime. However, the chances of all parts of the country being affected by a single big earthquake are less. So, it is estimated that about one-third of the total territorial area is likely to be affected by a big earthquake event in the near future. In this study, three earthquake scenarios were considered (figure 5) for estimating potential damage to school buildings and associated casualties.

All three earthquake scenarios were considered to generate a maximum of MMI IX level of shaking based on the 1934 Bihar–Nepal earthquake, while the depth and magnitude were not considered in this analysis. As the level of shaking may differ with the distance from the epicentre, it is assumed that about 25% of the total affected area falls in an intensity range of MMI IX to MMI VI.

The earthquake scenario damage to school buildings is estimated on the basis of vulnerability analysis and loss estimation conducted for Lamjung district, Nawalparasi district, Kathmandu valley and some schools of Humla district during the three earthquake scenarios.

As for the methodology, the structural assessment part of the guidelines prepared by Guragain et al. (2004) and DUDBC (2009) was extensively adopted for shaking intensity (MMI VI–IX) and damage grade for different classes of the school buildings. Table 4 illustrates the shaking intensity and damage grade for various kinds of school buildings under consideration.

It is estimated that more than 9000 school buildings, which is more than 10% of the total school buildings in Nepal, would suffer partial to complete collapse resulting in very high casualty. Figure 6 shows the overall school building vulnerability at the national level if all schools were to be hit by an MMI IX level of shaking. In this figure, DG represents damage grade. It was found that about 40% school buildings lie under a damage grade of five (DG5) at an intensity of IX. Similarly, 35% are of DG4, 21% of DG3 and 4% of DG2. Although it is not expected that all parts of the

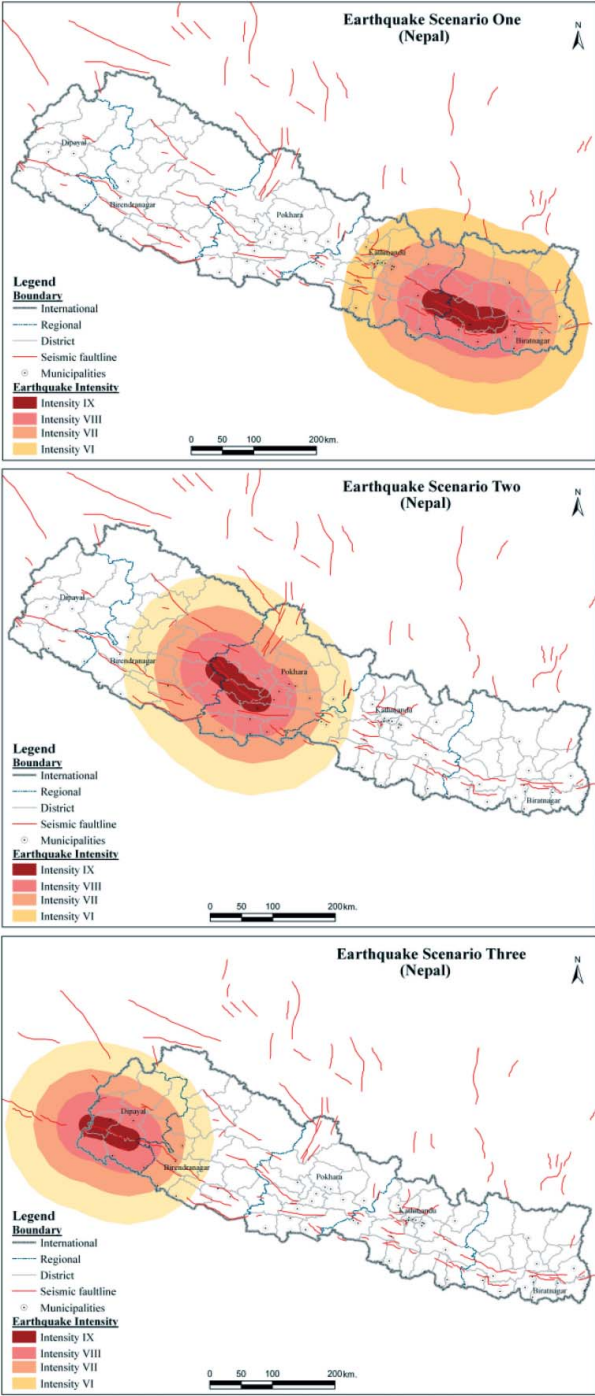


Figure 5. Three earthquake scenarios used to estimate damage potential of school buildings in Nepal. The most prominent faults of the region are considered as rupture line.

Table 4. Shaking intensity (MMI VI–IX) and damage grade for different classes of buildings considered in this work.

Shaking intensity (MMI)		VI	VII	VIII	IX
(a) Building fragility: adobe + field stone masonry building					
PGA (%g)		5–10	10–20	20–35	>35
Damage grade for different classes of buildings	Weak	DG4	DG5	DG5	DG5
	Average	DG3	DG4	DG5	DG5
	Good	DG2	DG3	DG4	DG4
(b) Building fragility: brick in mud (general) building					
PGA (%g)		5–10	10–20	20–35	>35
Damage grade for different classes of buildings	Weak	DG3	DG4	DG5	DG5
	Average	DG2	DG3	DG4	DG5
	Good	DG1	DG2	DG3	DG4
(c) Building fragility: brick in mud (well built with wooden bands) + brick in cement (ordinary)					
PGA (%g)		5–10	10–20	20–35	>35
Damage grade for different classes of buildings	Weak	DG2	DG3	DG4	DG5
	Average	DG1	DG2	DG3	DG4
	Good	–	DG1	DG2	DG3
(d) Non-engineered reinforced concrete frame buildings (≥ 4 story)					
PGA (%g)		5–10	10–20	20–35	>35
Damage grade for different classes of buildings	Weak	DG1	DG2	DG4	DG5
	Average	–	DG1	DG3	DG4
	Good	–	DG1	DG2	DG3
(e) Non-engineered reinforced concrete frame buildings (≤ 3 story) + engineered reinforced concrete buildings + reinforced masonry buildings					
PGA (%g)		5–10	10–20	20–35	>35
Damage grade for different classes of buildings	Weak	DG1	DG2	DG3	DG4
	Average	–	DG1	DG2	DG3
	Good	–	–	DG1	DG2

country would be affected at the same time, the above results would help in developing a vulnerability reduction program at national level. The vulnerability of the school buildings in a single earthquake scenario in any part of the country reveals that only about one-third of the territory of Nepal will be affected.

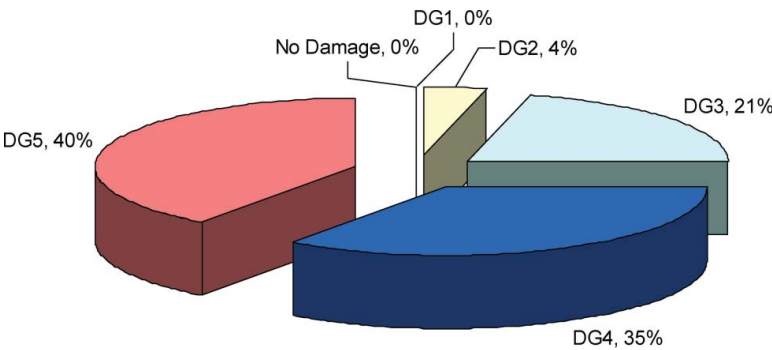


Figure 6. Nation-wise damage grade at an earthquake intensity of MMI IX (DG: damage grade).

Table 5. Potential numbers for school buildings affected by a single earthquake scenario.

Earthquake intensity	Estimated number of school buildings in earthquake-affected areas with different potential damage grades						Approximate number of schools affected by one earthquake among a total of 82,170 school buildings in Nepal
	No damage	Slight damage (DG1)	Moderate damage (DG2)	Heavy damage (DG3)	Partial collapse (DG4)	Complete collapse (DG5)	
MMI IX area	0	0	260	1450	2400	2730	6840
MMI VIII area	0	260	1450	1950	2160	1020	6840
MMI VII area	260	1450	1950	2160	930	90	6840
Total	260	1710	3660	5560	5490	3840	20,520

Furthermore, if we consider potential reconstruction after an earthquake, about 12% of the total school buildings in Nepal (potential DG4 and DG5) will require reconstruction, with the remaining schools requiring retrofitting.

Table 5 assumes an earthquake damage scenario of all the buildings suffering MMI IX level of shaking. Similarly, from the analysis presented in figure 6, it is understood that about 75% (DG4 and DG5) of the schools need intervention. Among them, 60% require retrofitting and approximately 15% require demolition and reconstruction. The potential national level casualty rate in a school is based on the realistic earthquake scenario assumed, as shown in figure 5 and calculated in terms of potential damage to school buildings based on the vulnerability studies of selected districts of Nepal. If the earthquake scenario were to occur during school hours, there would be more than 110,000 deaths and about 300,000 serious to moderate injuries. Table 6 gives the details of estimated casualties during an earthquake scenario. The models defined by Coburn and Spence (1992) and as described in RADIUS (2000) were used to estimate the number of casualties, in this table. Flow chart of casualty estimation is presented in figure 7.

6. Preparing public schools for earthquake disaster risks

In a country like Nepal, people are sceptic about interceptive work for earthquake disaster risk management in schools and residential buildings. Similarly, the option of retrofitting a building or demolishing and reconstructing are considered excessively expensive. A study (NSET 2000) shows that when structural intervention for

Table 6. Estimated casualty at schools during earthquake scenarios.

Earthquake-affected areas	Death		Seriously injured		Slight to moderately injured		Uninjured	
MMI IX Area	54,270	8%	42,450	7%	158,160	24%	560,120	61%
MMI VIII Area	34,920	5%	27,250	4%	171,760	26%	594,660	64%
MMI VII Area	22,610	3%	17,650	3%	181,740	28%	616,580	66%
Total	111,800	6%	87,350	4%	511,660	26%	1,771,360	64%

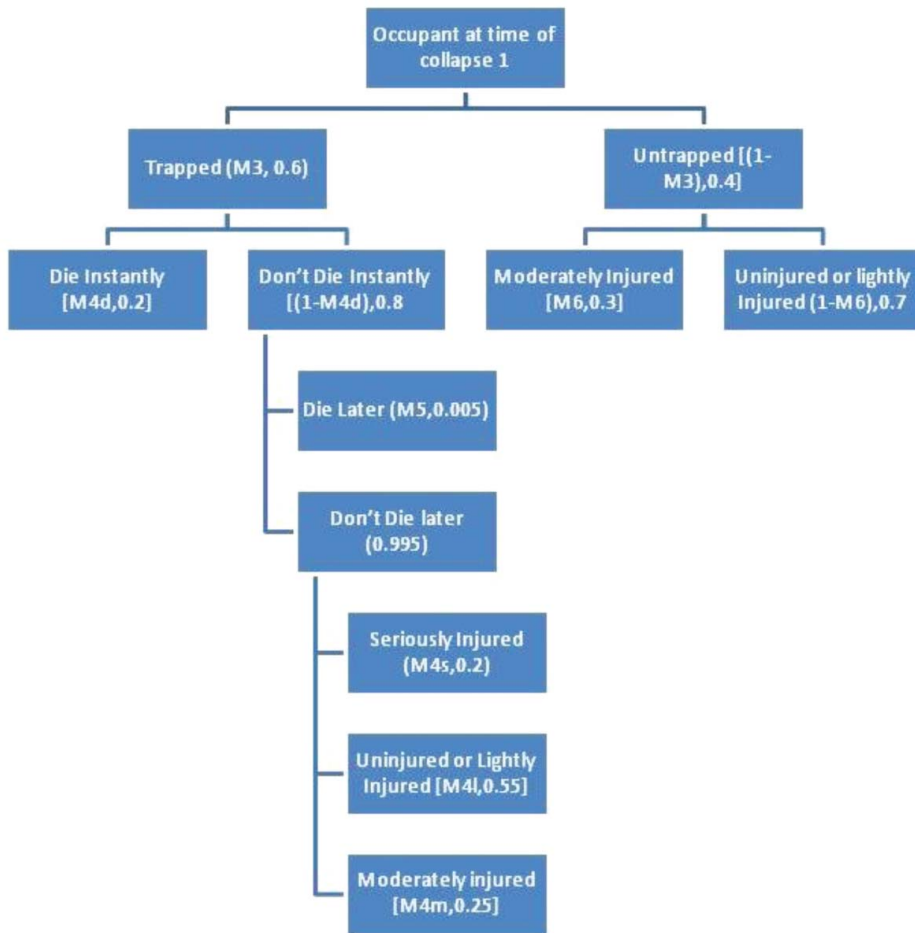


Figure 7. Flow chart for casualty estimation.

reducing existing vulnerability of the school buildings is not considered, in Kathmandu alone, the expected loss in terms of death or injury will be more than 29,000, and in terms of direct building loss, it will be more than 77%, which has been estimated at an economical damage of around US\$ 7 million (Table 7). The resulting societal trauma, need for rescue and relief, and degradation of life standard would be of unimaginably high scale. By structural intervention, life of children could be saved and the school buildings, as one of the biggest assets of a community, could be protected. Besides, it will also provide an opportunity for social dialogue, increased awareness, preparedness planning and masons' training, thereby providing an opportunity for replication and hence inculcating a culture of earthquake safety.

So, to overcome these issues, a comprehensive work for Public SESP has been designed. In fact, the SESP consists of three closely interlaced sub-components: (1) training of technicians/masons, (2) training of teachers, parents and students on earthquake preparedness and preparedness planning and (3) seismic retrofitting or earthquake-resistant reconstruction of public school buildings. The details of each sub-component of the SESP are described in the following sections.

Table 7. Comparative evaluation of the benefits of structural vulnerability reduction of school buildings in the Kathmandu valley.

Criteria	Intervention scenario at different intensities of shaking				Non-intervention scenario at different intensities of shaking			
	VII	VIII	IX		VII	VIII	IX	
Building loss	%	%	%		%	%	%	%
Level of damage	0	0	11		0	11	11	66
Collapse	0	0	46		4	65	11	11
Un-repairable damage								
Repairable damage	61	100	43		73	24	23	23
Life loss (approx.)								
Direct economic loss due to building damage	—	—	5000		—	—	—	29,000
Societal trauma	Approximately US\$ 7.5 millions							
Requirements for rescue/relief	Low							
Earthquake awareness/preparedness planning, establish dialogue, trainings	Low				High			
	Very high				High			
					None			

6.1. Technician/mason training

The whole execution of the program is designed as a tool for developing skilled manpower in earthquake-resistant construction practice in local level. In all the processes of seismic retrofitting and reconstruction, engineers of both governmental and non-governmental organizations work with masons showing them the details and explaining the complete procedures of earthquake-safe construction. Particular focus is placed in explaining the meaning of the processes of concrete curing, proper reinforcement details, what earthquake-resistant elements do, how the retrofit elements, such as splints, bands, corner pins, etc., function to withstand the earthquake force, etc.

Besides the training in the form of explanation, separate training classes are organized in the evenings. The main target groups are the craftsmen of the respective areas and villages, but the classes are typically open to all interested, even for local people. The technical knowledge of earthquake-resistant construction is given to them systematically. Participation of villagers and craftsmen are always higher than the number of masons directly involved in the construction process in the village. This is due to the raised level of earthquake awareness. They have seen their future in this 'modern' technology that they should be equipped with. Participants were very enthusiastic. Obviously, the local people, during the various training sessions, exhibited a huge concern over matters like how their own houses are built and over the weaknesses of the prevailing construction practices. Masons paid much attention to know about for and against the aspects of their conventional practices, need to adopt new methods, extent of change, solution to problems that the change may bring about and its harmony with the seismic retrofitting and reconstruction of school buildings, which they witnessed. It is noteworthy that once trainees were convinced and equipped with seismic resistant techniques, they also asked the methodology to convince and teach others about it.

The training courses follow a hierarchical procedure starting from problem identification to end at testing of methods learned. Several tests were conducted to support the knowledge in relation with the effect of placement of a reinforcement rod in beam/slab, quality of work governed by material and workmanship like excess water effect, curing effect, etc. Local masons could well understand the language of retrofit, earthquake-resistance design and the importance of quality control.

More than 2000 masons from various school communities of Nepal have already been trained in the skills of seismic retrofitting, earthquake-resistant construction and quality control. Few of these masons have been trained to be the trainers. In fact, these trainers are given the responsibilities of supervising the construction works at different schools under the program. Based on the experiences gained from the mason training, a curriculum/guideline for mason training has also been prepared.

6.2. Earthquake awareness program and publications

The SESP was implemented with maximum participation by the government institutions (such as the Ministry of Education and DEOs), District Development Committees and Village Development Committees, the School Management Committees, non-governmental organizations, parents and students. The government agencies provide funds and policy guidance, while the actual implementation of construction works is handled by the school management committees with technical inputs and

supervision. Such implementation mechanism, together with the formation of central-, district- and school-level advisory committees, considerably widened the outreach of the program and its ownership. All this has resulted in greater awareness of the communities on earthquake disaster risks and risk reduction. It is seen that, nowadays, new constructions in the settlements surrounding the schools have also been incorporating seismic-resistant elements, mostly by consulting the SESP masons. A strong replication potential of the program concept, and hence sustainability of efforts, is thus evident.

Providing training to students and teachers on earthquake preparedness was one of the major and most effective programs. During the project period, any of the activities conducted at the district or local level were considered as an opportunity to make more people aware of disaster safety.

The orientation program consisted of understanding the existing earthquake vulnerability, its reduction measures, personal and collective safety and preparing for the emergency. Many teachers and students were provided training on earthquake preparedness. It includes information provided on the earthquake disaster risks, risk-reduction measures, earthquake preparedness (figure 8), response planning of schools, earthquake drill procedures and a mock drill. The number of teachers who underwent the training is more than 2000 including the training received through principals' workshop. More than 10,000 students participated in the earthquake awareness trainings.

Also, each school was provided with the assistance to prepare emergency preparedness and response plans. For this purpose, six schools were chosen from selected districts and they were asked to prepare emergency preparedness and response plans through the assistance of experts. The plans were developed in associ-



Figure 8. Awareness lectures to teachers, students and technicians on earthquake safety and earthquake-resistant building construction.

ation with the school management committees, teachers and senior-grade students. Some of the parents were also involved in preparing the plans. These schools now conduct regular earthquake drills and improve their plans after proper evaluation. All the schools have managed to get basic first aid items to respond during an emergency. The demonstration of light search and rescue of victims is performed during every drill. Few booklets are also published for students, to give enough information about a disaster and how to live with it.

6.3. Retrofitting practice

Based on the results of the school survey, the seismic performance of about 75% school buildings in Nepal must be enhanced. In general, two options are available for seismic performance enhancement of the school buildings in Nepal: (1) demolish and reconstruct and (2) retrofit. This work makes a comparative evaluation of these two options. The first option of ‘demolishing and reconstructing’ by adopting seismic guidelines is easy from a technical point of view, and is also attractive, but there is very high excitement, societal impact and opportunity to learn more in the second option of ‘retrofit’ (table 8). On the economic ground also, the first option is far more expensive than the second (table 9). It is not only costly but the magnitude and duration of disturbance to the existing school functions will also be very high in the demolishing and reconstructing procedure (i.e. more than 1 year in comparison to 3–4 months in the retrofitting option).

A quantitative evaluation of the effectiveness of seismic retrofitting was done by subjecting two identical brick masonry buildings in mud-mortar to a pull-down test. This typology of the buildings was similar to most of the selected school buildings in this study. The model pulldown test of the identical buildings (retrofitted and non-retrofitted) suggested that the mud-mortar non-retrofitted building collapsed in 17 ton of the pulldown loading as compared with the numerically predicted 18.22 ton of the loading. A similar building was retrofitted with 16-gauge galvanized iron (GI) wire meshing on both faces of the walls with 1:3 cement sand mortar. The retrofitted building tested with 1.55 times the pulldown load compared with the similar non-retrofitted building without any visible cracks. Finally, it was concluded numerically and experimentally that the capacity of the existing school buildings can be increased up to a desired value with proper designing.

Table 8. Comparison between retrofit and reconstruction options.

No.	Criteria	Demolition and reconstruction	Retrofitting
1	Involved costs	High	Low
2	Time for building strengthening	More than a year	3–4 months
3	Disturbance to school function	High	Low
4	Problem associated with disposal of scrapped materials	Big problem	No problem
5	Technology (adaptability)	Usual (hence, no excitement)	New (hence, high excitement, but need to train)
6	Societal impact (Replicable)	Low/medium	High

Table 9. Comparison between retrofit and reconstruction costs (as of 2012, 1, US\$ 1 = NRs. 85).

Building type	Demolition and reconstruction (to the same standard as present) (NRs/m ²)	Seismic retrofitting, including repair and maintenance (R&M), (NRs/m ²)			Benefit of retrofitting over reconstruction	
		Retrofit	Repair and maintenance			Retrofit
Masonry in mud mortar	7575	2152	1076	Masonry in mud mortar	7575	2152
Masonry in cement sand mortar	8608	2044	602	Masonry in cement sand mortar	8608	2044

As for the fragility curves for different types of school buildings, the curves available in the Nepal National Building Code (NBC 1994) were modified as shown in figure 9. As the school buildings are designed for minimum life safety level of damage at MMI IX level of shaking, it was assumed that the retrofitted school buildings may be safe at minimum DG3 level of damage in MMI IX.

A national experts' workshop was held in 2010 to realize the first implementation approach. The workshop recommended that the program should first be implemented from the Kathmandu valley because the seismic risk of the Kathmandu valley is the highest among the mega cities of the world. Similarly, in case of an equivalent shaking as in the 1934 Bihar–Nepal earthquake, estimations of more than 100,000 casualties, 200,000–300,000 injuries and more than 60% building collapses were made in the Kathmandu valley. Of this, more than 29,000 deaths and around 40,000 injuries were estimated due to poor school infrastructures and low level of emergency preparedness in schools. Due to the population density of the city, casualties during an earthquake will be the highest in the Kathmandu valley. Since retrofitting is still a new practice and there are very few sufficiently trained engineers,

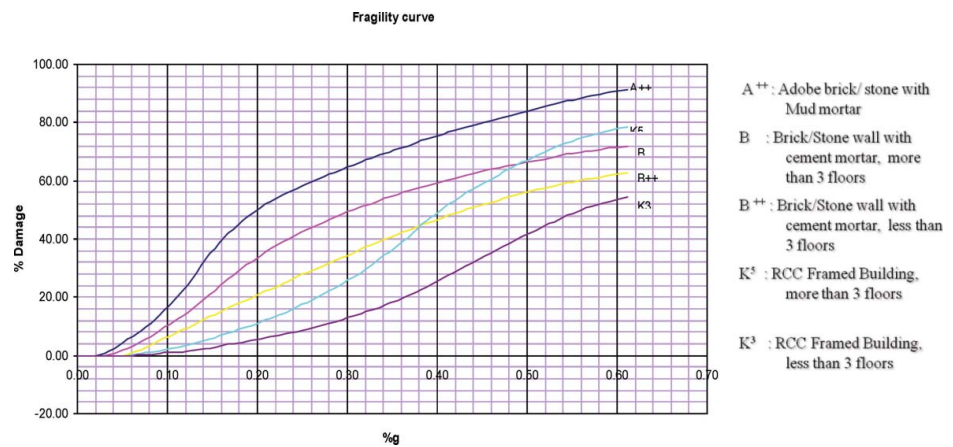


Figure 9. Fragility curves for different types of buildings (NBC 1994).

technicians and masons in this field, the first phase is an opportunity to begin training the professionals in Kathmandu. Similarly, the technical human resources required can be developed during implementation of the program in the Kathmandu valley. In the meantime, the Department of Education (DOE) can train their engineers during assessment, design and retrofitting. Management capability of the department can also be enhanced during the initial phase of implementation in the valley to ensure the implementation in other parts of the country in a smoother manner. The work in Kathmandu surely helps to build up confidence of the government and other implementation agencies, and also the experience gained in Kathmandu can be replicated in other parts of the country. Moreover, successful implementation in Kathmandu can attract international donor agencies to fund similar programs in other districts of the country. Likewise, people of other parts of the country will have a tendency to copy the things being implemented in the Kathmandu valley. Hence, this was an opportunity for the government to create awareness and disseminate the importance of disaster risk reduction nationwide. The first implementation in Kathmandu also helped to explore different techniques, to improve the previously developed techniques and to adopt appropriate techniques of retrofitting where and when needed. Since retrofitting is a relatively new practice in Nepal, specific norms for different components are not available yet. While implementing the retrofitting program in the valley, certain norms and associated costs are also worked out.

6.3.1. School retrofitting in Kathmandu valley and Nawalparasi district. After assessing the earthquake safety of the school buildings, some guidelines were prepared and pilot retrofitting works were carried out in the Kathmandu valley and Nawalparasi district to enhance the SESP. These pilot works are basically targeted to disseminate information about earthquake safety of the school buildings. In selecting appropriate school buildings for retrofit, various aspects such as location, typology, age, visibility, community participation, number of students and the impact in awareness are considered. The following criteria were used for selection of schools in initial stage of retrofitting in the Kathmandu valley.

- Schools from the valley where the maximum intensity of the earthquake, as in 1934, was observed.
- Schools from the core city areas of the valley where an easy evacuation space is not available and the environment outside the school premise is not favourable (such as narrow streets, densely populated and vulnerable buildings on the way to evacuation space, etc.).
- Relatively old buildings with unbalanced load paths, higher number of stories and bigger spans of rooms.
- School buildings constructed with low-strength materials, such as sun-dried bricks and mud, brick or cement in mud and so on.
- Schools prone to other hazards, such as landslides.
- Vulnerable masonry school buildings, masonry buildings of poor construction, poor configuration and those constructed without following the building code.
- RCC-framed structure buildings constructed without the guidelines of the DOE (inadequate size and strength of structural elements, more than permissible number of stories).
- Day-to-day visibility of the school in community to create awareness.

The DOE is the main implementing agency of the Public SESP. It is responsible for overall program management including financial support, technical human resources and monitoring and evaluation of the program.

A central-level steering committee, comprising high-level officials from various related authorities, is also formed to provide guidance and supervision of the implementation of the program. At the same time, a high-level technical committee is formed to provide guidance in technical matters including reviewing and verification of designs and detailing.

A survey of all the existing school buildings is required for assessing the vulnerability levels and to estimate the actual cost and other necessary resources. Initial visual surveys are conducted through a structured checklist, which is filled out for each building. These checklists are filled out by the teachers after attending an orientation program. Technical personnel of the DEO provide technical guidance to the teachers and resource persons and monitor the work done by the teachers of each school. Filled out forms are collected at each DEO through the respective resource persons of each resource centre. All documentation and analysis are done and sorted for each district. However, certain data and results, such as the number of school buildings and number of school buildings to be retrofitted and/or reconstructed, are sorted by the resource centre. The results helped in planning and implementing the activities in each resource centre.

Detailed assessment and design for retrofitting is done for each building unit, but grouping of similar building types is also done while implementing on a mass scale. Grouping is done after assessing a certain number of buildings. It helps to reduce the amount of time and money for detailed design significantly, which results in reduced number of trained professionals for design. Possible grouping mechanism is as follows:

- similar types of materials and construction technology;
- similar number of storey;
- span limit;
- similar vulnerability factors;
- certain floor area

Typical retrofitting techniques with standard designs are developed for general cases with specific details prepared on the basis of design requirements for structural safety. The cost of each building is calculated separately. For a multi-hazard approach, costs of other mitigation measures and extra intervention are calculated and included in the estimated cost. Assessment and design is based on a multi-hazard approach. Mitigation measures for other site-associated hazards, including landslides, inundation, flash floods, fire and high wind, are also incorporated in the design and cost estimates of each individual school.

There are a number of different technologies for seismic retrofitting, based on the type of construction and vulnerability condition of the building. However, the applied technology is appropriate in the Nepalese context, which encourages the use of locally available materials and the involvement of local human resource. While achieving the primary goal in enhancing the level of safety of the structure, the applied technology has a potential of replication in other buildings giving an opportunity of skill enhancement and training of the masons involved. The following are commonly employed techniques for load-bearing structures:

- RCC splint and bandage technique,
- RCC jacketing on both faces of the walls with steel reinforcement,
- jacketing on both faces of the walls with GI wire mesh,
- combination of jacketing and splint and bandage with steel or GI wire mesh,
- jacketing with gabion wire mesh on both sides (for low-strength masonry buildings with stone and mud),
- timber splints and bands for RCC-framed structures,
- introduction of shear walls,
- jacketing of columns and beams,
- foundation underpinning,
- strengthening of infill walls with RCC bands.

The techniques and detailed procedure of intervention were worked out during design and after detailed assessment of each individual building. Implementation of retrofitting works goes beyond merely making the building stronger, assisting schools to prepare for better response during and after an earthquake. It therefore comprises the following activities along with the retrofitting:

- supervision of retrofitting work,
- quality assurance,
- awareness training to students, teachers and parents,
- preparation of earthquake preparedness and response plan,
- conduct earthquake drill.

Table 10 lists the number of school buildings to be retrofitted by the community and graded contractors in the whole of Nepal. Out of 700 school buildings to be retrofitted, approximately 140 school buildings are to be retrofitted in the Kathmandu valley through specialized contractors. Most of these buildings are relatively larger in size and multi-storeyed RCC-framed structures, although some are historically important and require highly technical expertise and equipment. Since the community and School Management Committee have little to no capacity in implementing the retrofit of such structures, specialized contractors are preferred in this case.

Figures 10 and 11 show some photographic evidences of the retrofitting work. After the experience in the Kathmandu valley, one school of Nawalparasi district was also retrofitted (figure 12). Since most of the schools were built through

Table 10. Tentative numbers of schools in Nepal which are going to retrofit for 2012–2016.

Implementing agencies	Number of buildings per year					Total
	2012	2013	2014	2015	2016	
Design by DOE and implementation through the community	80	120	160	120	80	560
Design by specialized agency or experienced consulting firms and implementation through the contractors	20	30	40	30	20	140
Total per year	100	150	200	150	100	700

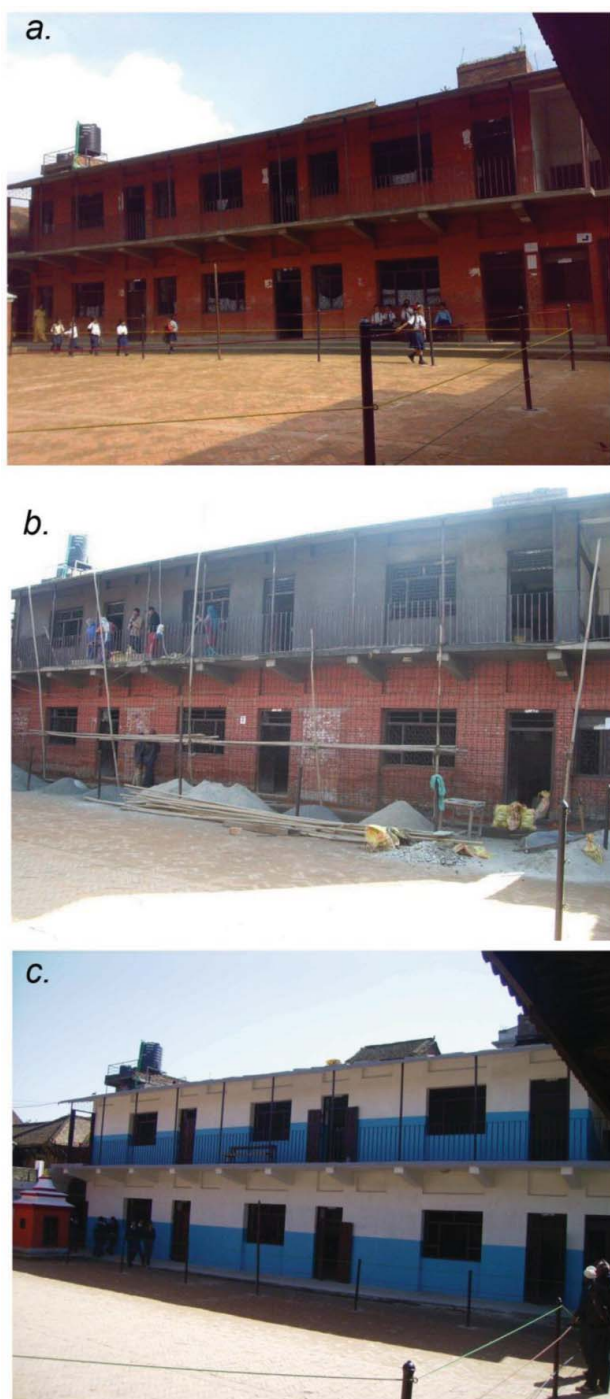


Figure 10. Retrofitting works in the building of Adarsh Secondary School in Bhaktapur district, Kathmandu valley: (a) is before retrofitting, (b) is during retrofitting works (jacketing on the wall with steel reinforcement) and (c) is after completion of retrofitting.



Figure 11. Retrofitting of school buildings in progress: (a) Gorakhnath Secondary School, Kirtipur, Kathmandu (jacketing on the wall with steel reinforcement), (b) Janaudah Lower Secondary School, Lalitpur district, Kathmandu valley (close view of steel reinforcement placing), (c) Chundevi Higher Secondary School, Kathmandu (steel reinforcement anchoring to the wall), (d) Saraswati Secondary School in Thecho, Lalitpur district, Kathmandu valley (micro concreting after steel reinforcement).

community initiation, retrofitting was also implemented through community mobilization wherever possible. A community-involved mechanism helped to reduce the cost of retrofitting/reconstruction as locally available materials were provided at a subsidized rate. The implementation period was a little longer because the

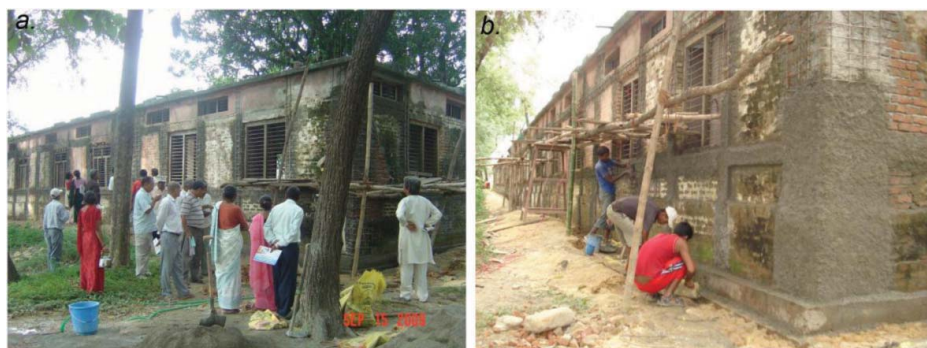


Figure 12. School retrofitting in Nawalparasi district. (a) Community is inspecting the retrofitting work. (b) Retrofitting work by splint and bandage method in progress.

community mobilization only took place briefly during their free time/season. Involvement of the community, however, was essential for a successful implementation of the program, which ensured a feeling of ownership by the community.

The management of required materials, construction workers, community mobilization in construction/retrofitting, awareness programs and school emergency planning was done by the school, in association with the parents and local people. The School Management Committee was also responsible for the day-to-day supervision of the work and continuation of the school preparedness in future. All financial and technical aspects of the project were made transparent and a monthly statement was made public. Technical professionals and an expert committee of professionals assisted the school and community throughout the implementation of the program.

7. Visible impact of SESP

Although a direct impact survey was not conducted in this work, many changes have been noticed both in community and implementation sectors. Major visible impacts of the SESP are described in the following sub-sections.

7.1. *Impact in the concept of line agencies*

Although many of the indirect impacts cannot be observed visibly, in the initial period, officials at the DEO and school resource persons were enthusiastic about school earthquake safety. However, the attitude changed conspicuously following their engagement and participation in the series of interaction and orientation. They have internalized the earthquake risk and realized the need for school safety. The DEOs of all selected districts provided continuous support to the training, awareness and school retrofitting process, although it was not as part of their regular program.

7.2. *Attitude change in teachers and students*

After the SESP, awareness level of teachers and students has increased. Many schools have also been conducting earthquake drills on a regular basis since the beginning of SESP.

7.3. *Attitude change in masons*

Masons have also started to implement earthquake-resistant construction techniques in their communities. They have even started to suggest that local people construct new houses incorporating earthquake-resistant construction techniques.

7.4. *Changes in neighbourhood schools and communities*

Many schools in neighbouring areas have requested the National Society for Earthquake Technology (NSET), Kathmandu for technical assistance after they learned about the program activities, attended the earthquake orientation programs and visited the nearby retrofitted schools. Engineers involved in SESP usually provide such assistance by reviewing the design, providing practical guidance during construction

and conducting earthquake orientation and training programs in the vicinity of the schools. The people in the districts and nearby communities are now well aware of the aspects of earthquake safety and this has become one of the most talked topics in their free time. Awareness level among the school's family and the community regarding earthquake safety and skills of keeping themselves safer is now increased.

It was also noticed that in most of the places, people have lesser interest in community work but their participation in school safety activities is really encouraging.

7.5. *Concept for curricula development*

Now the government agencies have understood that earthquake disaster safety needs to be addressed and incorporated into formal curricula at all levels of school education. They have also realized that earthquake safety needs to be formalized and institutionalized into a regular national program as one of the development initiatives.

7.6. *Resource person in lead role*

In Nepal, each and every school has the provision of a resource person and he or she will respond to help teachers of few schools of surrounding areas for various teaching materials and required training. During the implementation of SESP in selected schools, it was realized that resource persons can play a significant role in providing orientation to the teachers, disseminating knowledge and information to schools and monitoring the school activities. Thus, it will be very effective if they are trained and given the responsibility of awareness, raising and educating the school family about earthquake safety.

7.7. *Lesson learned*

After implementing SESP in the selected districts, some lessons have also been learned. It is understood that any effort in raising earthquake awareness always pays. It pays more if the effort is pervasive from the central to the local level. From the survey and analysis, it was found that a majority of the school buildings are vulnerable and schools face extreme seismic disaster risk. Unless there is a nationwide comprehensive earthquake safety program for school safety and its timely implementation, there will be a huge casualty and destruction. It was also realized that local masons do not have adequate capacity to implement designs of earthquake-resistant buildings as provided by the DOE. Unless the capacity and skills of local masons is enhanced, the desired quality and safety of construction cannot be achieved. It was also understood that the funding provided by the government to the schools for construction is insufficient to complete the construction in desired quality and time. Hence, it further contributes to increased vulnerability of school buildings. There is a provision of funding for small-scale repair and refurbishment of school buildings, which covers most of the schools in a district. If this amount is utilized in retrofitting the vulnerable school buildings, although less in number, the existing risks can be reduced significantly. Moreover, there is limited capacity of engineers and technicians on building assessment, design and implementation of retrofitting work. It is necessary to enhance their capacity through intensive as well as practical trainings. In many cases, the school family does not have an understanding of the importance

of earthquake preparedness and emergency planning in schools. These things are new to them, but after an orientation program they were found to be very positive towards preparing plans and conducting drills once they were provided orientation. For this reason, a general orientation on emergency planning and conducting drills should be provided to all schools.

8. Concluding remarks

In Nepal, studies of the earthquake catalogue indicate that a devastating earthquake is inevitable in the long term and likely in the near future. Towards building earthquake-safe communities in Nepal, the Public SESP is recognized as one of the most effective programs. This paper discussed a few important issues in relation to this program through the introduction of primary materials used in constructing the school buildings, building typologies, factors affecting school building construction and their vulnerabilities, possible retrofit schemes and various factors affecting the cost. The paper also argued why it is absolutely necessary to implement retrofit intervention and discussed the available incentives for retrofitting the school buildings and future strategies for such interventions. It further elaborates the likely consequences if no intervention is made.

The knowledge, program, technology and training to be given to the community under the SESP were compatible to what they accept and practice. It implies that the community-based approach should start from sustainable and reliable low-cost technology options for mitigation and preparedness so that people not only understand the logic, but also accept and use it. SESP consistently adopted simple technical approaches, which made the SESP initiatives cost effective and understandable to the laypersons. SESP has been accepted by governmental and non-governmental sectors and is now being replicated by the related communities worldwide because of its comprehensive approach.

The SESP helped much to convince the local government, people and local political leaders also on the affordability and possibility of constructing earthquake-resistant public school buildings using slight improvements in the locally employed methods of construction.

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