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INVESTING IN FUTURE GENERATION: THE SCHOOL EARTHQUAKE SAFETY PROGRAM OF NEPAL

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SUMMARY

An improvised vulnerability assessment of about 1100 buildings of public schools in Kathmandu Valley, undertaken by the Kathmandu Valley Earthquake Risk Management Project (KVERMP), revealed that none of the surveyed school buildings complied with the requirements of the prevailing seismic code of Nepal. The school buildings have a variety of problems in terms of structural design, materials quality, poor construction methods, and also those due to old age. Opinions differed in terms of the possibility of improving seismic safety in public schools of Nepal: many opted for demolition and new construction. The National Society for Earthquake Technology – Nepal opted for a comprehensive strategy that incorporated concepts of a) incremental safety, b) seismic retrofitting using locally available materials and skills, c) community participation in safety improvement of public schools, d) capacity building, and e) awareness raising. Accordingly, NSET started in 1999 the School Earthquake Safety Program (SESP), which demonstrated the technical, social and cultural feasibility of structural intervention in existing public buildings for improving seismic performance. Since then, SESP has grown much in concept and contents, and is generally regarded as one of the most successful earthquake risk reduction programs of Asia.

This paper describes the identified seismic vulnerability of the school buildings, seismic intervention options, components of the retrofitting program, lessons learned from the program implementation, and the benefit-cost ratio of seismic retrofitting of public school buildings. It is found that small dispersed infrastructure such as school buildings are better candidates of demonstration projects on mitigation. It also demonstrates how school earthquake safety program ultimately increase the seismic safety of the entire community.

INTRODUCTION

Public schools in Nepal, both their buildings and their occupants, face extreme risk from earthquakes. This is because of the fact that the majority of the school buildings, even those constructed in recent years, are generally constructed without the input of trained engineers in design or construction supervision.

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Management of the public schools is largely the responsibility of the local community: the government provides the curriculum and a minimum financial support. The rest has to be managed by the community. Usually very low annual budget is available with the school management system. Such condition increases the likelihood that poor materials or workmanship are used in the construction of the school buildings making them structurally vulnerable to earthquakes. High vulnerability of schools was evidenced during the 1988 Udayapur earthquake (M 6.6 Richter) in eastern Nepal; six thousand schools were destroyed in this event, which luckily took place during non-school hours. Such massive damage to the school infrastructure disrupted the affected community- approximately 300,000 children were not able to properly attend schools for several months after the event, UNDP/UNCHS [1].

School children, especially the youngest, are particularly vulnerable to natural disasters. The loss suffered by a community in the collapse of a school is psychologically much greater than the loss faced by collapses of other building types. Schools house an entire generation and a community's future.

Schools play a crucial role after an earthquake in helping a community to get back on its feet. Since schools are typically well distributed throughout neighborhoods, they are an ideal location for homeless shelters, medical clinics, and other emergency functions. Functioning schools provide a feeling of normality to a community, helping people get back on their feet after a disaster. Schools are also particularly tractable for earthquake safety programs. Schools structures are typically very simple and relatively small, unlike other critical facilities. Therefore it is inexpensive to build new schools in an earthquake-resistant fashion and it can be affordable to retrofit existing schools. Also, by raising awareness in schools, the entire community is reached because the lessons trickle down to parents, relatives, and friends.

Realizing this fact, School Earthquake Safety Program (SESP) has been a continuous endeavor of the National Society for Earthquake Technology – Nepal (NSET) during Kathmandu Valley Earthquake Risk Management Project (KVERMP) and the subsequent Kathmandu Valley Earthquake Risk Management Action Plan Implementation Project (KVERMAPIP) since 1999. The primary objectives of the program were to assess the seismic risk of public school buildings in Kathmandu valley, to identify the measures to reduce the earthquake risk, to conduct awareness raising while implementing the program and to train local masons on earthquake resistant construction for technology transfer. Methodology, components, achievements and the lessons of the program are discussed in detail in this paper.

VULNERABILITY ASSESSMENT OF PUBLIC SCHOOL BUILDINGS

Earlier, SESP included a vulnerability assessment of Kathmandu Valley's public schools as an example of how to conduct earthquake risk mitigation projects in Nepal. The purpose of this assessment was not to identify individual schools as vulnerable, but to quantify the risk faced by the entire system. The assessment methodology consisted in creating a questionnaire that could be filled out by school headmasters and collecting data on school buildings for analyzing the vulnerability. This questionnaire included topics such as size of buildings, density of students, year(s) of construction, whether or not an engineer was involved in the building design or construction, etc. Additionally, simple questions were asked about structural characteristics, presented through illustrations and descriptions. The project conducted 17 seminars with school headmasters from 65% of the total 643 public schools in the Valley to teach them about earthquake risk, about the necessity of planning for earthquakes in their school, and how to fill out the project questionnaire. Subsequently, the headmasters conducted the survey and data on 430 schools were returned to the project. The conclusions were extrapolated to the entire building stock of the existing public schools of Kathmandu Valley.

A more detailed inventory and vulnerability assessment of the school buildings on the conventional way would have required several years to complete.

Alarming Findings

The following were the findings of the survey.

1. More than 60%are built using traditional materials (such as adobe, stone rubble in mud mortar or brick in mud mortar) that behave very poorly during earthquakes.

2. The remaining (less than 40%) of the buildings uses more modern materials such as brick in cement mortar or reinforced concrete. Even though modern materials are stronger, these modern Nepali schools are not necessarily safer. Traditional artisans build almost all of these schools without any inputs from an engineer. School buildings built with modern materials are typically taller, have larger rooms and larger windows and doors than buildings built with traditional materials. These features make many modern buildings as dangerous as the traditional ones.

3. Of the nearly 700 school buildings, only three buildings were constructed meeting the stipulations of the Nepal National Building Code (draft). An additional four to five percent buildings had some seismic resistant design features, such as reinforced concrete bands at the lintel level. The vast majority of buildings were built without considering seismic forces at all.

4. Many school buildings are not only poorly constructed, but they also lack proper maintenance. Approximately ten to fifteen percent of buildings were in extremely poor condition due to sub-standard material or workmanship, lack of maintenance, or extreme age. Many buildings have floors that are on the verge of collapse or walls that could crumble and fall at any time. These buildings are dangerous to occupy even in normal times. Another twenty-five percent of the buildings were found to have serious maintenance problems, such as decaying timbers or severely cracked walls that, if not repaired quickly, will deteriorate into extremely dangerous conditions.

Table 1: Seismic Vulnerability of Public School Buildings in Kathmandu Valley

Particulars	Details	%
Total number of Public Schools/buildings	643/1100	
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 (Pull down and reconstruct ASAP!)	10-15
	Can be saved (with structural intervention, Retrofit, Repair and Maintain ASAP)	25
	Good for vertical load (but not for lateral shaking), need retrofitting	65
Vulnerability Assessment (for intensities IX MSK shaking)	Collapsed Grade	66
	Severe Damage or partial collapse (not repairable/not usable after shaking)	11
	Repairable Damage	23

Main Problems of Existing School Buildings

In summary, the main characteristics of the public school buildings of Kathmandu Valley are the following.

a. Almost all buildings are non-engineered,
b. Most buildings were constructed using informal production mechanisms,
c. The buildings are constructed using mainly the traditional weak materials (low-strength masonry, flexible floors and roofs mostly of timber),with heavy wall and roofs, poor quality control, untied gable walls.
d. Most are elongated (rectangular) in plan
e. Most buildings are load bearing masonry structures, and
f. Most are highly vulnerable to earthquakes.

SEISMIC VULNERABILITY REDUCTION IN PUBLIC SCHOOLS

The Initial Dilemma

Many advisors of KVERMP and well-wishers of NSET warned not to initiate any program to address such a huge problem as seismic improvement of public schools. Further, people were skeptic about the feasibility of “retrofitting” in Nepal, considering it excessively expensive.

On the other hand, NSET looked at improvement of seismic performance of existing school and residential buildings, structural and non-structural, as an alternative that deserved high priority for exploration. The country has about 25,000 public schools, and it will take very long time for each of them to have new earthquake-resistant building unless some radical means are found and implemented.

Subscribing to the concept of incremental seismic safety, NSET opted to explore further the feasibility of structural intervention for reducing existing vulnerability of the school buildings. The results are described in the following sections.

Benefits from Intervention

Two scenarios were considered, no intervention, and intervention- for seismic improvement of school buildings. In the no- intervention scenario, the expected loss was found to be more than 29,000 school children dead or injured, and more than 77% of the buildings incurring direct building loss the cost of which was estimated at around US$ 7 million. The resulting societal trauma, need for rescue and relief, degradation in life standard would be of unimaginative scale. By intervening structurally, we could save the lives of some 24,000 children and protect the school buildings, one of the biggest assets of a community. Besides, it would also provide an opportunity for social dialogue, increased awareness, preparedness planning, and masons' training thereby the opportunity for replication- hence inculcating a culture of safety. The imperative was to act!

Comparative Evaluation of the two Options - Retrofitting versus Demolish and Reconstruction

Table 3 presents two options available for seismic improvement of school buildings and makes a comparative evaluation of the options. The options are i) demolish and reconstruct, and ii) retrofit. The first option seems easy from technical point of view. It is also attractive but there remains very high excitement, societal impact and opportunity to learn more in second option. On economic ground also the first option is far expensive than the second option. It is not only cost but also, magnitude and duration of disturbance to existing school functions will also be very high in first option (more than 1 year in comparison to 3-4 months in second one).

Table 2: Comparative Evaluation of the Benefits of Structural Vulnerability Reduction

Criteria		Intervention scenario at different Intensities of shaking (MSK)			No Intervention scenario at different Intensities of shaking (MSK)		
		VII	**VIII**	**IX**	**VII**	**VIII**	**IX**
Building Loss		%	%	%	%	%	%
Level of Damage	Collapse	0	0	11	0	11	66
	Un-repairable Damage	0	0	46	4	65	11
	Repairable Damage	61	100	43	73	24	23
Life Loss				5000			29,000
Direct Economic Loss due to Building damage							US $ 7M
Societal Trauma		Low			High		
Requirements for Rescue / Relief		Low			High		
Earthquake awareness / preparedness planning, establish dialogue		Very High			None		
Mason Training Opportunity, Replication Potential		Very High			None		

Table 3: Comparison between Retrofit and Reconstruction Options

No.	Criteria	Demolition & Reconstruction	Retrofitting
1	Involved Costs	Medium to high	Low to medium
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 (Replicability)	Low/Medium	High

Table 4 compares cost required for demolition and reconstruction and retrofit option for buildings constructed from different construction materials. It also presents economic benefits of retrofitting over demolition and reconstruction. Even if existing buildings were repaired and maintained besides retrofitting, the saving would be 58 to 75% of reconstruction cost. Lowest benefit would incur in building with weak materials as compared to newer buildings with good construction materials (cement, steel). While making such comparison, it was assumed that the buildings under intervention are non-engineered, and that the skilled masons could undertake the retrofitting works with community participation, and under guidance from a trained technician.

Table 4: Comparison between Retrofit and Reconstruction Costs

Building Type	Demolition and Aseismic Reconstruction (to the same standard as present) (NR/ m^2)	Seismic Retrofitting (Including Repair & Maintenance, R&M), (NR/ m^2)			Benefit of Retrofitting over Reconstruction	
		Retrofit	Repair & Maintenance	Total	Retrofit without R&M	Retrofit with R&M
Masonry in Mud Mortar	2,500	725	375	1100	75	60
Masonry in Cement	3,118	710	180	790	77%	75%

PROGRAM COMPONENTS

Currently, the School Earthquake Safety Program consists of three closely inter-knit sub-components, namely, (1) Training of masons, (2) Training of teachers, and parents on earthquake preparedness and preparedness planning, and (3) seismic retrofit or earthquake-resistant reconstruction of public school buildings.

Mason Training

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

Besides the training in the form of explaining-as-you-go, separate training classes are organized in evenings. The main target groups are the craftsmen of the respective village, but the classes are typically open to all interested. The technical knowledge of earthquake-resistant construction is given to them systematically. So far Participation of villagers and craftsmen was always higher than the number of masons directly involved in the construction process in the village. This was due to the raised level of awareness on earthquake. They have seen their future in this 'modern' technology that they should be equipped with. They have so far been very enthusiastic.

Obviously, the common people, during the training session, show high concerns over the matters that how their own houses are built and the weaknesses of the prevailing construction practices. Masons pay much attention to know about the positive and negative aspects of their conventional practices, the need to adopt new methods, extent of change required possible solutions to problems that the change may bring about and its harmony with seismic retrofitting and reconstruction of school. It is noteworthy that once trainees could be convinced and equipped with seismic- resistant techniques, they also demanded that the methodology to be communicated to other villagers. Karna et al. [4]

The training courses follow hierarchical procedure starting from problem identification to solve the problems using examples, exercises etc. Several tests are conducted to support the knowledge in relation to effect of placement of reinforcement rod in beam/slab, quality of work governed by material and workmanship like excess water effect, curing effect etc

It has always been very encouraging that the local masons understood the language of retrofit, earthquake-resistance design and the importance of quality control. They could remember the advice of their great grandfathers regarding earthquake resistant design. So far 55 masons from the ten school communities have been trained in the skills of seismic retrofitting, earthquake – resistant construction and quality control. Based on the experiences gained from the mason training, a curriculum/guideline for Mason Training has been prepared.

Photo 1- *Masons Training class*

Photo 2- Certificates awarded to the trained masons

Awareness Raising, Training of Teachers, Parents, and Children

SESP was implemented with maximum participation of the central and local government institutions, school management systems, the parents and the students. The government agencies provided nominal funds and policy guidance, while the actual implementation of construction works was handled by the school management committees with technical inputs and supervision from NSET. Such implementation mechanism, together with the formation of central -, district -, and school level advisory committees at central and district government level, considerably widened the outreach of the program and its ownership.

An Earthquake Kit has been developed for training the teachers and the parents on earthquake preparedness planning and establishment of evacuation and fire drills in the schools. Several meetings were held with the local communities and the school officials, NSET will continue its efforts in implementing such training program in the schools.

All these efforts have resulted in greater awareness in the communities on earthquake disaster risk and risk reduction possibilities. A qualitative judgment on the impact will be made following the completion of the second leg of the social impact survey. However, it is seen that new constructions in the settlements surrounding the schools are 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

Photo 3- Community Meeting an awareness program

Technical Assistance during Construction

NSET carries out survey and, design, and also assists to implement the construction. Usually, the local masons are engaged in the construction; contractors are avoided. NSET also provides construction supervision. During construction, the masons are trained in aspects of earthquake safety. A mason who had been trained earlier is posted at each construction site at NSET's cost. The mason supervises the day-to-day construction and trains the local masons on-the-job. NSET engineers conduct classroom training in the evenings. Usually, such training programs are attended not only by the masons, but also by the parents and other members of the community.

REPLICATION POTENTIAL

In all the communities where SESP has been conducted, people in the adjacent areas have been replicating the construction methods employed in school building to construct their private houses without intervention from NSET. Excepting some minor details, most of the newly-constructed houses in the vicinity of the school adopt all basic earthquake-resistant construction elements like seismic bands, stitching of masonry walls at the corners, vertical tensile rebars etc. It shows higher level of acceptability on what masons were trained. It can be said that the process of replication would gain strength in future to set a new technological culture in construction. In this respect, the SESP has much higher social value compared to other risk reduction programs that hardly have been able to transfer technology to the grass root level in the past decade.

Photo 4- Replication of technology on Local level

LESSONS LEARNED

Focus on School Earthquake Safety drew criticism
NSET and KVERMP were initially criticized for focusing only on public schools. Many people questioned why private schools and hospitals, a critical facility for post-earthquake response, were not chosen. Additionally, people asked why cinemas, private schools and colleges were not examined. NSET continued bringing explanation for its focus on school. However, given the limited resources available, NSET continued the focus on schools, noting that the work on schools was building NSET's capacity to evaluate the vulnerability of other systems in the future. The school survey examined many previously unknown attempted activities: the costs of conducting a survey of building vulnerability, the technical expertise required for this type of survey, the costs involved in strengthening existing vulnerable buildings, the types of techniques to use for strengthening typical Nepalese structures, the interest of the community in strengthening buildings, the ability to attract funds (local and international) to this type of work, and the levels of earthquake risk acceptable in Nepalese society.

Initial Skepticism was Short-lived
Low level of awareness and uncertainty of earthquake event brought criticism during initial stage of the program implementation. NSET being an NGO was another reason for an initial apathy because of generally tarnished image of several of NGOs. However, open financial policies and transparency exercised, limiting the role of NSET as technical/management assistant, giving the local school

management committees the decision-making responsibilities helped develop the required level of mutual trust, and the program ultimately received all out cooperation from all concerned.

Retrofitting a School is an important awareness raising opportunity

The lesson was not simply that a school could be retrofit. More important lesson was that for an additional $10-15k, local masons could be trained while retrofitting the school and the villagers could have their earthquake awareness raised. Strengthening the school was important and attractive, but more attractive outcome of the project was retrofitting the school, AND training the masons, AND convincing the masons that the good techniques are better than the poor techniques AND raising the awareness of the villagers, AND teaching the children and teachers what to do during and before an earthquake. All these extras come for a small relative increase in the cost of retrofitting, and they could be possible only because of the retrofitting.

"What is accepted by the Community" is more important than "What is necessary?"

The knowledge, program, technology and training to be given to the community for disaster management should be compatible to what they accept, and practice. It implies that the community-based disaster management package should start from low-cost and low 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 initiatives cost-effective and understandable to the laypersons. It also helped to focus the project on implementation of risk reducing actions, our major aim. SESP was accepted and also replicated by the related community also because of the comprehensiveness of approach. Efforts on physical improvement were combined with intensive interaction and two-way dialogue with the community, training and education, and establishment of mutual trust and confidence.

Community-based Approach is Key to Risk Management Efforts

Despite the traditional fatalistic outlook, issues of disaster management are becoming popular with the people. The traditional thinking of only the government being responsible for relief and prevention works is being replaced by realization of the need to start working at the community level. Disaster risk reduction is not the highest priority of the people in view of more pressing needs such as infrastructure, sanitation, health, education and environment. Moreover, most communities do not have enough financial resources. Therefore, making disaster risk reduction programs self-sustaining is rather difficult, and requires innovative thinking. At the same time, since the benefit-cost ration is very high in view of the prevailing low level of preparedness, ways should be identified to initiate and support community-based disaster management programs.

Transparency Pays

A School Reconstruction Advisory Committee was formed to provide necessary advice. It was headed by the Chairman of the District Education Committee, and included representatives of the local village level government, prominent people and the members of the school management committee. All aspects of the reconstruction activities, including finance and other problems were discussed in the fortnightly meeting of the advisory committee. This committee provided the necessary political support to the project and helped increase its outreach.

A 5-member School Retrofitting Committee, consisting of the chairman of the school management committee, the headmaster, the NSET engineer, and two local representatives, implemented the project. This committee made all decisions with NSET's guidance. The committee operated a bank account with the headmaster and the NSET engineer as the joint signatories. This committee also helped achieve transparency, help to optimize the limited resources, fostered mutual trust.

The whole process was conducive for peoples' participation. While the local community provided 25% of labor as in-kind contribution, the reconstruction was done totally by the local community with NSET providing only the technical inputs and helping in fund-raising.

Training Program for Mason is essential for a Successful School Earthquake Safety

The training program helped much to convince the local masons on the affordability and possibility of constructing earthquake -resistant buildings using slight improvements in the locally employed methods of construction.

Small Dispersed Infrastructures are better Candidates for Initial Mitigation Investment than Large Concentrated Infrastructure

A significant proportion of public schools in developing countries are small and simple structures constructed with traditional materials. This condition offers the school building as the excellent objects for the mitigation specialists to work and learn from.

When SESP was started, NSET was criticized for excessive focus on public schools and neglect of other facilities. Many people questioned why hospitals, a critical facility for post-earthquake response, were not chosen. Additionally, people asked why cinemas, private schools and colleges were not examined. The project team continued explanation for its focus on school did not quell the criticism. However, given the limited resources available, KVERMP continued the focus on schools, noting that the work on schools was building NSET's capacity to evaluate the vulnerability of other systems in the future. The school survey examined many previously unknown attempted activities: the costs of conducting a survey of building vulnerability, the technical expertise required for this type of survey, the costs involved in strengthening existing vulnerable buildings, the types of techniques to use for strengthening typical Nepalese structures, the interest of the community in strengthening buildings, the ability to attract funds (local and international) to this type of work, and the levels of earthquake risk acceptable in Nepalese society.

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