SEISMIC VULNERABILITY ASSESSMENT OF PUBLIC SCHOOL BUILDINGS IN NAWALPARASI AND LAMJUNG DISTRICT OF NEPAL

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SUMMARY:
An assessment on seismic vulnerabilities of school buildings at Nawalparasi and Lamjung districts was conducted using the survey data collection about the condition of school structure. The physical information of 1381 building units from 580 schools had been collected as a data sources for the analysis. The vulnerability of the school was identified considering the physical facilities and theirs conditions and school population. School teachers were mobilized for the survey of their own school. The processes incorporate the participatory approach for the vulnerability assessment with the involvement of school teacher and they were also updated on the conditions of school structures.

Key words: Seismic Retrofitting, Vulnerability & Assessment of Nepali School.

1. INTRODUCTION

This paper is to assess the physical condition of school buildings in Nepal in terms of seismic safety. The highlighted results and the recommendations through this will show the present scenario of school buildings and help for further planning in order to formulate National strategy for a school earthquake safety guide to preparing necessary actions of implementation for safer school construction and prioritizing the actions. School Buildings of two selected districts of Nepal, Lamjung and Nawalparasi are studied as these two districts represent the school building of all three physiographic region of Nepal. Some school buildings of Humla are also studied as the school buildings of higher mountain which were not covered in Lamjung district. Lack of mandatory policy to control design and construction of schools. Some schools supported by donors and/or government require design/drawings but many directly constructed by communities are constructed without any design. The main objectives of the program were a) To understand the prevalent Building Typology of area, b) To understand the extent of seismic Vulnerability of the Particular Building typology & the building element & c) To understand the possible damage/casualties/injuries for Earthquake of different Intensity

2. METHODOLOGY

Following steps were used for the assessment work:

2.1. Survey Questionnaire

Rational of this analysis is based on the survey questionnaire. Specific questionnaire was developed as to collect pertinent information required for seismic vulnerability assessment. This questionnaire was developed based on the national & international experience on previous completed building assessment projects by NSET.

Questionnaire had high intention to gather the information regarding qualitative & quantitative existing condition of school physical infrastructures including occupant quantitative information. The questionnaire was divided into two major sections. Section 'A' with title "School Building Condition Evaluation (educational/physical condition description)" to collect general features of school & its locality. Section 'B" "Building Structural Descriptions" to collects the detail information on building structure on individual basis as per building typology. The format also provides spaces for rough sketch plan of school building helps to show the layout of school at a glance. Diagrammatic multiple options on answers section of questionnaires made surveyor easier for field judgment also on technical options. The survey questionnaire was designed to reduce the probability on record of biased information using graphics. The questionnaire was design to make it easy to use for non technical surveyors and designed to covers all type of schools in Nepal.

2.2. Survey Methodology

Field implementation of prepared survey tools were envisioned as programme that the project districts representing all geographical regions (Terai, hills & mountains) were considered as a sample district for analysis results. Almost all schools from Nawalparasi & Lamjung district were under survey scopes. Existing structure of education administration has been activated on execution. District level headmaster workshop becomes a vital component on implementation part of survey. During this workshop, information collection technique & field test of developed questionnaire had been completed & forth forward for further actions. Headmaster of each school was responsible for the completion of information in questionnaire at school level moreover collections were complete through resource centre (RC).Continuous support from district level project office of NSET & District Education Office of respective district show the active presence during survey & collection mechanism.

2.3. Data Processing

All data entry and editing are accomplished on personal computers developing software as required. Several log-in procedures are followed in order to prepare the survey questionnaires and the institutional records for data entry. The receipt of a completed survey questionnaire and any accompanying comments are recorded by the project engineer of respective district. All survey forms are reviewed as a preparation for data analysis. Some imputation was done for missing information with consultation to surveyor. The correction are recorded, discussed and assigned. Each original survey form is filed as a document record.

2.4. Data Entry

The final step in preparing for data entry is verification of questionnaire and entry was done on standard software.

After data entry few updates on data after extraction from software were done as:

2.4.1. Correction:

Arithmetical and other error requiring correction by edit

2.4.2. Verification:

Confirmation of data by communication and sequence of logic of questionnaire fill.

2.4.3. Imputation:

Partial data requiring computerized imputation such as round off, identity duplex correction.

2.5. Existing School Statistics

Total no of registered community school with in the Lamjung and Nawalparasi district were 481 and 632 respectively as record of district education office. Institutional school was not incorporated in the survey scope but not beyond the scope of disaster.

Total no of school (units) functioning throughout the country in the school year 2008-09 were 31,156 ,out of which ,30,924 are primary,10,636 are lower secondary, 6,516 are secondary and 1,556 are higher secondary levels schools. About 99.3% of total schools had primary grades, 34.1% run with lower secondary grades, 20.9% had secondary and 5% have higher secondary grades. Institutional school running independently increased total units as 39,883.

2.6. Vulnerability Assessment

Weightage on different factors creating vulnerability was generalized based on previous experience and logic for contributing to increase vulnerability. Those factors which were common for all types of structure such as masonry, frame structure and steel/wooden truss with additional factors for particular type has been defined and worked out as annex. The worst condition for each typology Masonry, frame structure and steel/wooden truss structure represent highest on mathematical value as 11.25,7 and 10 respectively. Those values were the sum of maximum Weightage on each vulnerability factors. Vulnerability due to adjacent building, due to shape of structure, no of storey, shape of roof, structure of roof, type of infill wall, presence of gable wall, gable wall with gable bands and defects on wall structure were the main causes of vulnerability.

Arithmetic computation of define weightage on vulnerability factors results for net vulnerability. Vulnerability factor for each structure divides by maximum weightage for particular typology gives the net vulnerability factor. The highest value for this is 1, which indicates worst condition of the structure creating high risk for its occupants. Structure scoring one is out of serviceability limit and must be dismantle and vice versa.

Weightage on vulnerability factors and computation of net vulnerability factors were the mathematical tools for the process of analysis. So what all structure types can be generalized and qualitative result of survey had been extracted. On basis of prevailing code of conduct for structure (Building code) and previous experience on works, net vulnerability factors has been generalized as

Table 2.1. Generalization Of Building Category

S.No.	Building Category	Limiting Net Vulnerability Factor Value
1	Good	≤ 0.2
2	Weak	$>0.2<0.5$
3	Poor	≥ 0.5

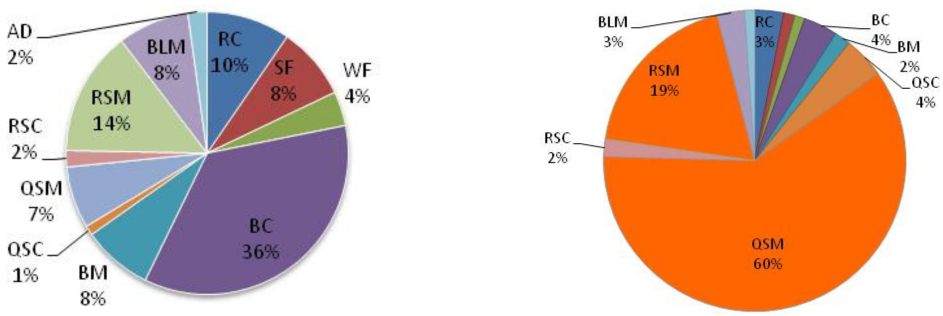
2.7. Identification of Building Typology

Building typology throughout the nation is almost among small variety where only very few circumstances made it differ but not drastic. Before easy availability of cement many of the school built with stone & brick in mud mortar with lending few exceptions. Use of cements on school construction limits on cement mortar for stone & brick .Use of hollow concrete blocks, stone Crete blocks known as block masonry. These all were categorized in structure system as masonry buildings also known as load bearing structure. School building built on steel frame structure with roof truss for GCI sheeting started with the lunching of JICA project, BPEP around 1996 A.D. Such typology was defined as a steel truss structure. Structure built in reinforced concrete comes under frame structure. Building constructed with sundry bricks is an adobe. Considering the probability of the use of wooden logs as a structure system such construction was explained as wooden truss buildings.

Building material act as a vital component for the strength of structure so micro separation on basis of structural material fine the analysis result & prediction of probable losses calculation.

Table 2.2. Prominent School Building Typology In Nepal

S.No.	Typology	Abbreviation	Category
1	Adobe	AD	Masonry
2	Quarry Stone in Mud	QSM	
3	River Stone in Mud	RSM	
4	Quarry Stone in Cement	QSC	
5	River Stone in Cement	RSC	
6	Brick in Mud	BM	
7	Brick in Cement	BC	
8	Block Masonry in Cement	BLM	
9	Reinforced Concrete	RC	Frame Structure
10	Steel Frame	SF	Steel frame
11	Wooden frame	WF	



Nawalparasi District

Lamjung District

Figure 2.1. School building typologies in nawalparasi & lamjung district

2.8 Risk Assessment

2.8.1 Building Damage Matrix

Adobe, Round rubble stone masonry & wooden frame structure for the particular concern has been categories on same damage grade matrix due to its phenomenon behavior as a response to the ground acceleration. This consideration is also based on the practical consequences of input and involvement of different level of technical during construction. Brick in mud, quarry stone in mud and round rubble stone in cement grouped as one on damage grade matrix due to its similarity on phenomenon response during ground acceleration. Similarly Brick in cement, block masonry & quarry stone in cement grouped on one. Steel frame structure & Reinforced concrete structure having different mechanism of load transformation that previous are placed in one unit.

Prediction of possible damage for buildings highly depends on the response on rate of ground acceleration for a particular building. Building typology, construction techniques were key factors to strengthen the building. If other minor factors remain as dominant causes building typology becomes vital and analysis result based on same facts.

Table 2.3. Damage Grade And Damage Pattern

Damage Grade	Damage Pattern
DG1	Slight Damage
DG2	Moderate Damage
DG3	Heavy damage
DG4	Partial Collapse
DG5	Collapse

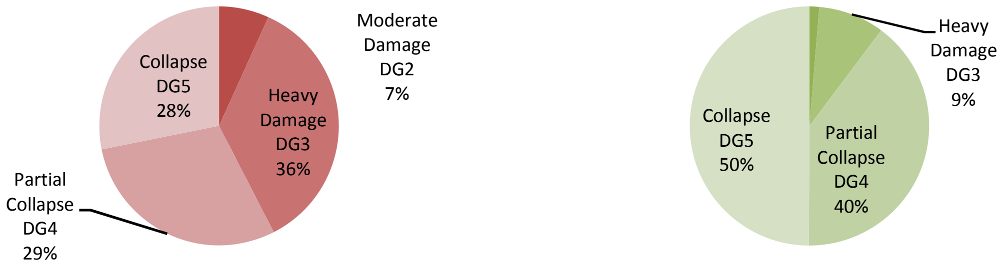


Figure 2.2. Potential damages of school buildings at MMI IX

2.8.2 Casualty Estimation

Casualties caused due to the earthquakes are damage of building and structures. Information related to the number of people inside the damaged building at a time of earthquake is necessary for casualty menstruation. Collapse or different level of damage on buildings is the major causes for the death and injury estimation. People inside a building during day time and at night are different. It also depends on the purpose of building that what purpose it was on used. These affect on the ratio of building usage and also fluctuation on casualties' calculation. Schools Populations are higher during day and almost null during night. School day and the day of holiday might change the prediction. Normal school day has been considered for the analysis which is extreme and represent worst scenario of physical damage of school population.

Ideal condition for the method of casualties estimation is that the earthquake accelerate ground during normal hours of school and assumed that all student remains inside the buildings. Probability of sudden death of occupants at time of collapse is high among trapped population. Such coefficient as building typology is considered as per Radius tools for educational institutions. Details have been explained as flow chart and table below.

Table 2.4. Basis Of Estimation For Trapped Population Inside Building

Damage Grade	Damage Pattern	Trapped
DG1	Slight Damage	No Trapped
DG2	Moderate Damage	No Trapped
DG3	Heavy Damage	Trapped (60%)
DG4	Partial Damage	Trapped (60%)
DG5	Collapse	Trapped (60%)

Figure 2.3. Flow chart for casualty estimation

Few results of data analysis, had been summarized in graphical and tabular form below:

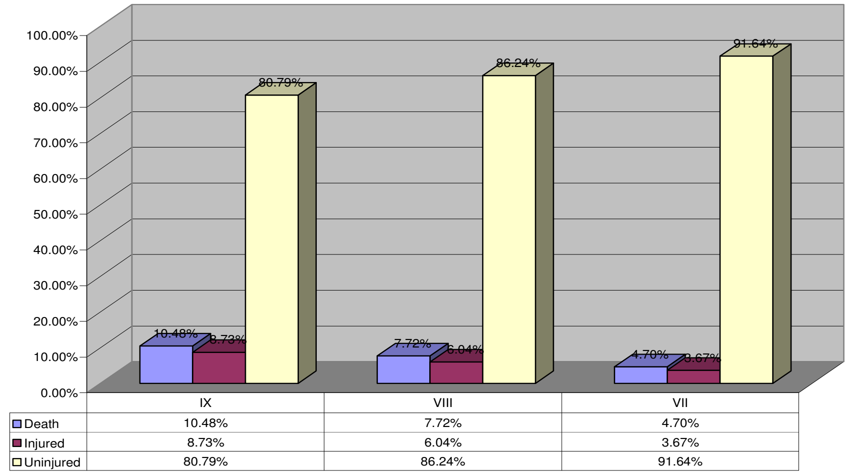


Figure 2.4. Chart for combine result of casualty and injury, lamjung & nawalparasi district

The chart below explain the result of casualty and Injury percentage at different intensity VII to IX while considering the statistics of both district in combine. At intensity IX about 10.48 % of occupant could died and about 8.73% were seriously injured which was very hard to recovered means about to death if unable to get timely treatment. Though they are live, these people could have some cert of remarkable physical damages for remaining life time. Remaining 80.79% could not be severely but these people could have recoverable injury having complex to simple one.

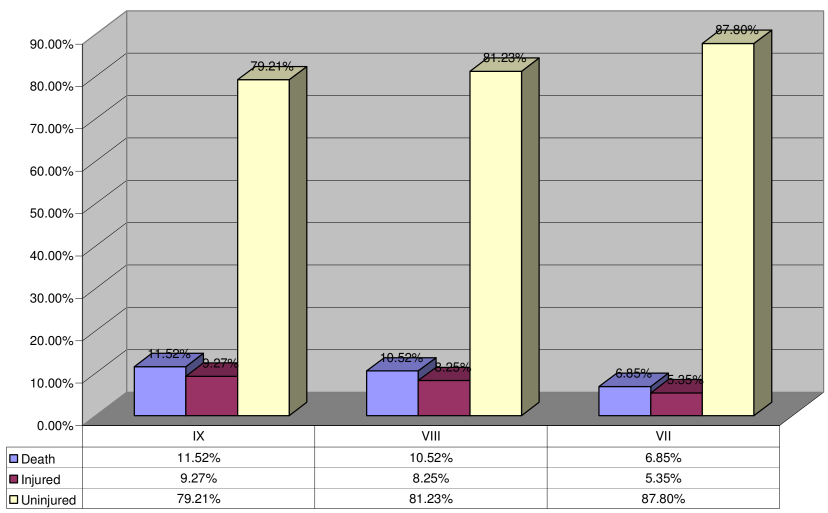


Figure 2.5. Chart for casualty and injury lamjung district

Based on the school building vulnerability analysis, it was found that about 11.52% of students could lose their lives in IX intensity, 10.52% in VIII intensity and 6.85% in VII intensity if the earthquake occurs during school hour.

Similarly, based on the school building vulnerability analysis for Nawalparasi district, it was found that about 9.83% of students could lose their lives in IX intensity, 6.10% in VIII intensity and 3.45% in VII intensity if the earthquake occurs during school hour.

Table 2.5. Casualty and Injury at Different Intensity

Physical Loss	Nawalparasi Result			Lamjung Result			Combine Result		
	MMI IX	MMI VIII	MMI VII	MMI IX	MMI VIII	MMI VII	MMI IX	MMI VIII	MMI VII
Death	8046	4969	2812	5410	4943	3218	13456	9912	6030
Seriously injured	6855	3882	2194	4353	3873	2512	11208	7755	4706
Uninjured	66503	66503	76398	37204	38152	41236	103707	110705	117634

2.9. Loss and Casualties

Results of loss and casualties climax the crisis due to the poor structural condition of school buildings. Result on Death around 10% itself is very high, seriously injured around 8% trigger the fact of about to death and 80% uninjured figure not explaining totally uninjured it covers residual injury which may last forever to minor injury. Direct impact on fatalities calculated as twenty four thousand six hundred sixty four children on two districts. This shows great void to new generation on associated community. Similar situation was predicted for nation scenarios too.

3. LOSS ESTIMATION RESULT FOR NATIONAL STRATEGY DEVELOPMENT

3.1. Data Extrapolation

The outcomes of combine results of two districts in percentage on each category were adopted as a benchmark percentage for nationwide. It has been assumed that at a time, the coverage of Earthquake limited to one third part of the nation. One third of national statistics with benchmarked percentage extrapolate the result mathematically.

3.1.1. Considering Scenario Earthquake at national Level

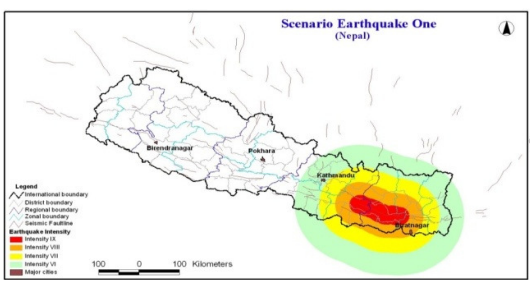


Figure 3.1. Scenario earthquake one at national level

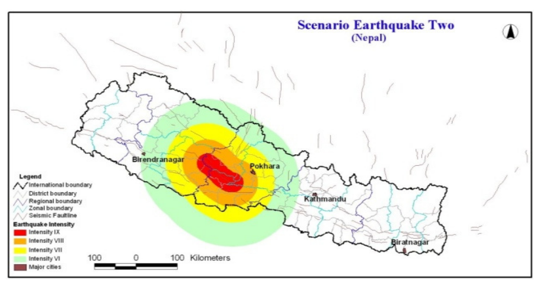


Figure 3.2. Scenario earthquake two at national level

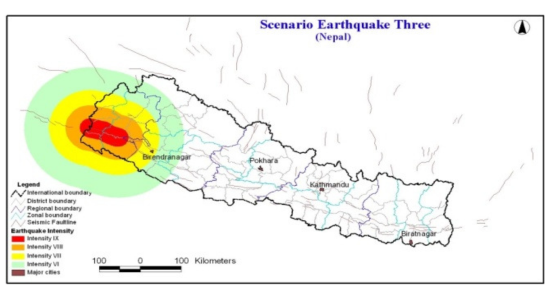


Figure 3.3. Scenario earthquake three at national level

3.2. National Wise Building Typology Distribution of School and National Level Risk

After math of vulnerability assessment bilks on the worst situation of structural hazards since maximum school building erected without showing prior concern on structural safety by incorporation the quality measures shown by prevailing building codes. Apart from this construction material available within the territories needs higher degree of technical judgment to identify appropriate one. Proper configuration and implication even of selected good quality material were also challenges in green field. Absence of Technicalities resulted on less performing structure even though they were proven as sound structure type like R.C.C.This were the major challenges on safety culture of entire community not only in the schools.

Analysis result extracted that our school buildings stand with following major typology:

Table 3.1. National School Building Typology

Building Typology	Percentage
Masonry	89.43 %
Reinforced Cement Concrete	6.08%
Steel Frame	4.49%

Though building typology itself was not the indicator for safe and unsafe structure but the culture of adding new storey as per need of space increases the risk factor .The physical condition and practical judgment on existing masonry structure drive to declare the situation of high risk for its occupants. About 90 percentage of school building were found as masonry and it was clearly understood that lots of school building which we have were in vulnerable for earthquake. Similarly other type also highly depends on material quality, workmanship and technical input. So lagging on those facts were exist there and likewise construction might not perform well as predicted and piles on as a property loss during the shaking.

3.3. Probability of Damage

Following table shows the probability of damage of school buildings at different intensity of Earthquake;

Table 3.2. National Wise School Building Damage Probability At Intensity IX

Damage Grade	Building Unit	Percentage (%)
No Damage	0	0
DG1	0	0
DG2	3587	3.84
DG3	19831	21.22
DG4	32758	35.05
DG5	37292	39.90

Table 3.3. National Wise School Building Damage Probability At Intensity VIII

Damage Grade	Building Unit	Percentage (%)
No Damage	0	0
DG1	3587	3.84
DG2	19831	21.22
DG3	26666	28.53
DG4	29509	31.57
DG5	13875	14.84

Table 3.4. National Wise School Building Damage Probability At Intensity VII

Damage Grade	Building Unit	Percentage (%)
No Damage	3587	3.84
DG1	19831	21.22
DG2	26666	28.53
DG3	29509	31.57
DG4	12656	13.54
DG5	1218	1.30

3.4. National wise damage grade at intensity IX

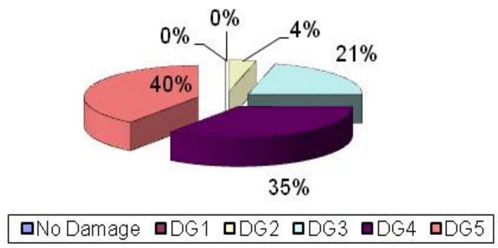


Figure 3.4. National level damage grade at intensity IX

This chart shows that 40% school building comes under damage grade five DG5 at intensity IX.Similarly 35% were of DG4,21% DG3 and 4% DG2.

3.5. National wise casualty/injury in all schools of Nepal at intensity IX

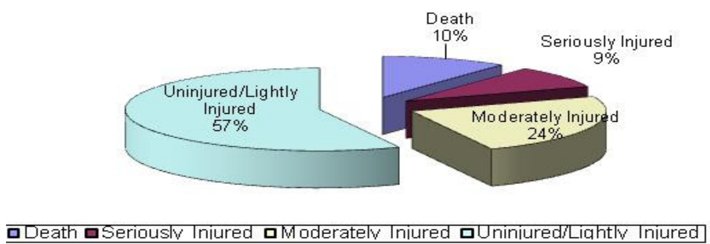


Figure 3.5. Casualty/Injury in all school of Nepal (at intensity IX)

This chart explains the death of 10% people throughout the country under effect of shock having intensity IX at a time followed by 9% seriously Injured, 24% moderate injury and 57% light injured or uninjured.

3.6. National wise casualty/injury in all schools of Nepal at intensity VII

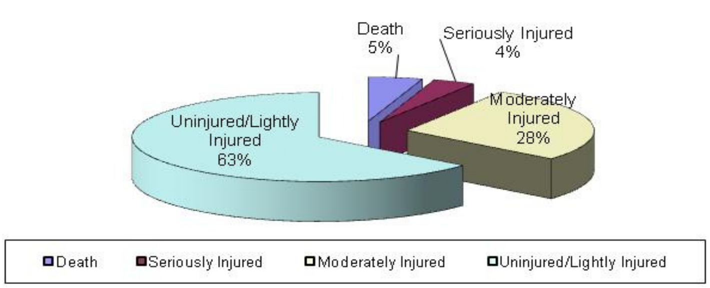


Figure 3.6. Casualty/Injury in all schools of Nepal (at intensity VII)

Above chart explains the death of 5% people throughout the country under effect of earthquake shock having intensity IX at a time followed by 4% seriously Injured, 28% moderate injury and 63% light injured or uninjured.

4. CONCLUSIONS AND RECOMMENDATIONS

Earthquake risk assessment of school buildings in Lamjung, Nawalparasi and Humla districts shows very much vulnerable situation of school structure due to its construction methodology and adaptation of construction material without sound technical knowledge and advices, the input of technical human resources found to be very limited due to different region like no availability of technical person.
Masonry structure was most common building typology and many of them were silence on earthquake resistant component like bands, stitches and others. Frame structure miss to tie infill walls with the frame.
This assessment shows the gap between the professional, academia, and the community. The gap in awareness, knowledge on technology for proper implementation during constructing school Buildings. Advantages of using teachers on identification of vulnerability develop a standard approach to disseminate the technique to inspect and update about the physical condition of school buildings.

ACKNOWLEDGEMENT
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