



A NEW METHOD FOR SEISMIC VULNERABILITY ASSESSMENT OF SCHOOL BUILDINGS BASED ON FIELD DATA

D. Gautam⁽¹⁾, R. Adhikari⁽²⁾, R. Rupakhety⁽³⁾, P. Koirala⁽⁴⁾

⁽¹⁾ Chief Executive Officer, Interdisciplinary Research Institute for Sustainability, Kathmandu, Nepal, dipendra@iris.org.np

⁽²⁾ Associate Professor, Cosmos College of Management and Technology, Lalitpur, Nepal, rabinraadhi@cosmoscollege.edu.np

⁽³⁾ Professor, University of Iceland, Iceland, rajesh@hi.is

⁽⁴⁾ Structural Engineer, PACE Consult, Kathmandu, Nepal

Abstract

The 2015 Gorkha earthquake in Nepal damaged more than 28000 school buildings across the affected areas. Nepali school buildings can be broadly categorized as special moment resisting frame, brick masonry, stone masonry, timber, and composite (steel and masonry) construction. This paper proposes a new methodology to define seismic vulnerability of the identified school building classes. The proposed methodology is based on field measurements of around 5000 buildings in central Nepal. Structural, non-structural, architectural, site conditions, seismic enhancement and retrofitting, and multi-hazards parameters were accounted for to develop a scoring system. The scores were later categorized into very high, high, moderate, low, and very low vulnerability levels. Weighting system was introduced by sensitivity analysis of individual components and the scores were first estimated for individual buildings. When determining the vulnerability scores of individual buildings, scores were distributed among the parameters considering the weighting factors for structural, non-structural, architectural, site condition, seismic enhancement, retrofitting, and multi-hazards parameters. As per the building types as many categories as applicable were considered and the score levels of 10-50 were assigned to each parameter. Thereafter, final vulnerability scores as the aggregate sum were obtained. The scores were modified later considering the level of seismic strengthening/retrofitting. The vulnerability levels were compared with the empirical fragility functions derived using the field damage assessment reports. The comparison highlighted that the newly proposed field-measurement and observation-based method could effectively represent the level of vulnerability and hence can be effectively implemented for pre-earthquake vulnerability level depiction for school buildings in Nepal.

Keywords: seismic vulnerability; vulnerability assessment; school building; RC; brick masonry; stone masonry; timber; Gorkha earthquake; Nepal.



1. Introduction

Seismic vulnerability assessment of buildings is important to assess their expected performance during potential earthquakes. If found deficient, performance levels can be improved by strengthening/retrofitting of the buildings. To judge the condition of a building, various seismic vulnerability assessment methodologies are in practice (e.g. [1], [2], [3], among others). Emergence of vulnerability assessment frameworks occurs generally after an earthquake that provides a rational basis of calibration of assessment method using empirical data. Emergence of new methods from Italy, Portugal, Iran and other countries in recent years coincides that vulnerability assessment methods could be effectively developed and calibrated with the observational data. However, it is pertinent to note that due to lack of uniformity in collected data, biases are always expected hence expert opinions are necessary to assure the quality of the collected data which ultimately results in a more realistic vulnerability assessment framework.

The 2015 Gorkha earthquake in Nepal caused extensive damage to structures and lifelines. About a million buildings were either collapsed or partly damaged and 8790 people lost their lives according to the official records of the Government of Nepal. The magnitude 7.8 earthquake also caused extensive damage to school buildings as highlighted by the damage of more than 28000 buildings in 31 out of 75 affected districts [4]. The damage statistics as well as the fragility functions and damage probability matrices are reported by Adhikari and Gautam [4]. During the Gorkha earthquake a mixed impression of seismic performance was displayed by the school buildings. For instance, several reinforced concrete buildings collapsed due to lack of adequate ductile detailing; however, many other masonry school buildings survived due to various factors such as less weight, single-storied construction, feeble shaking, among others. Thus, it is understood that the seismic vulnerability of Nepali school buildings needs to be quantified thoroughly taking into all relevant factors. To do so, a systematic method is necessary to conduct the analysis/assessment and predict the level of vulnerability for individual building. We propose a new method to assess seismic vulnerability of school buildings which is based on a weighted scoring system.

2. Proposed methodology

The parameters incorporated in field damage assessment forms were broadly categorized into five classes as: workmanship and age factor, geometry, structure, seismic components, and modifiers. The first four parameters were assigned the weightage as 20%, 20%, 50%, and 10%; however, the fifth parameter was assigned to be a modifier which either modifies the overall vulnerability score or does not affect it. The total vulnerability score obtained from four parameters with the component weights as depicted in Fig. 1 are modified by the modifiers, structural pounding and retrofitting, and final vulnerability scores are obtained. Based on the final vulnerability score, the vulnerability levels are assigned to each building. For each component, vulnerability score of 1-5 was assigned based on the level of vulnerability. The score 5 indicates high level of vulnerability and 1 indicates low vulnerability. After assigning scores to each component, the weighted sum of all the components for each class was taken. The final score for all four classes was again summed up as the weighted sum and total vulnerability score was obtained. The total vulnerability score (TVS) was then subject to modifications considering the modifiers. We depicted five vulnerability levels, viz. very low (score < 17%), low (17% < score < 34%), moderate (34% < score < 49%), high (49% < score < 59%), and very high (score \geq 59%). The vulnerability level was assigned using the sensitivity of the component weightage. Meaning, if the structural vulnerability is high, then the overall vulnerability should remain high and so on. The final vulnerability scores obtained from the analysis were then assigned the vulnerability level. After obtaining final vulnerability scores, pilot visit and independent checks were conducted in some schools of each typology. Some adjustments for some parameters were also done after the field visit.

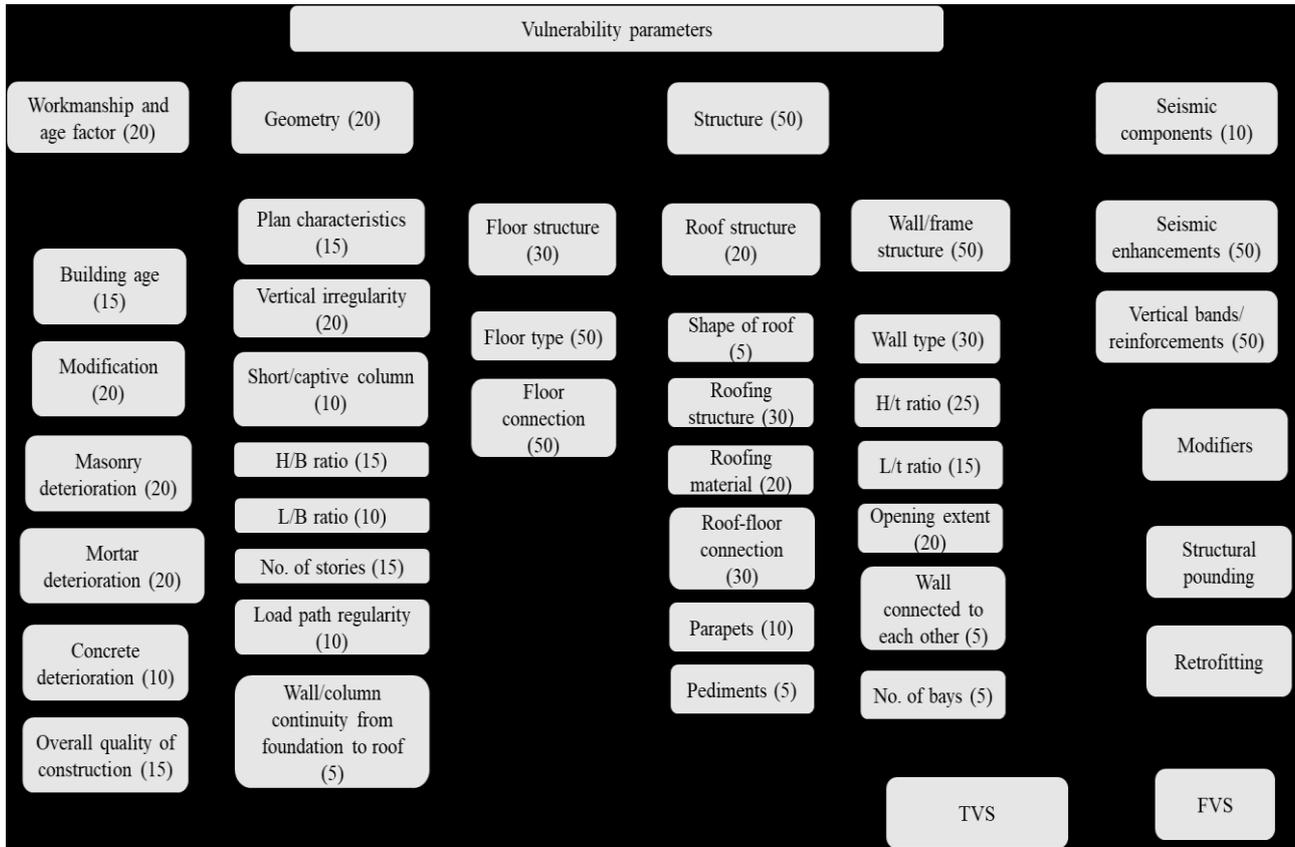


Fig. 1- Newly developed vulnerability assessment framework

3. Results

We used the newly proposed framework to 3415 buildings, among them 968 were reinforced concrete buildings. Distribution of the vulnerability level in 968 RC school buildings is presented in Fig. 2. As shown in Fig. 2, most of the buildings depicted moderate level of vulnerability; whereas, 2% showed high vulnerability level and none of the buildings showed very high vulnerability level. Similarly, load bearing (LB), steel frame (SF), and timber frame (TF) school buildings depicted the highest number (34% < vulnerability score < 49%) among the assessed school buildings. Some load bearing masonry constructions also depicted very high level of vulnerability (vulnerability score $\geq 59\%$). However, as expected, 30% of load bearing school buildings depicted high level of vulnerability. The majority of RC and steel frame school buildings depicted low to moderate level of vulnerability as shown in Fig. 2.

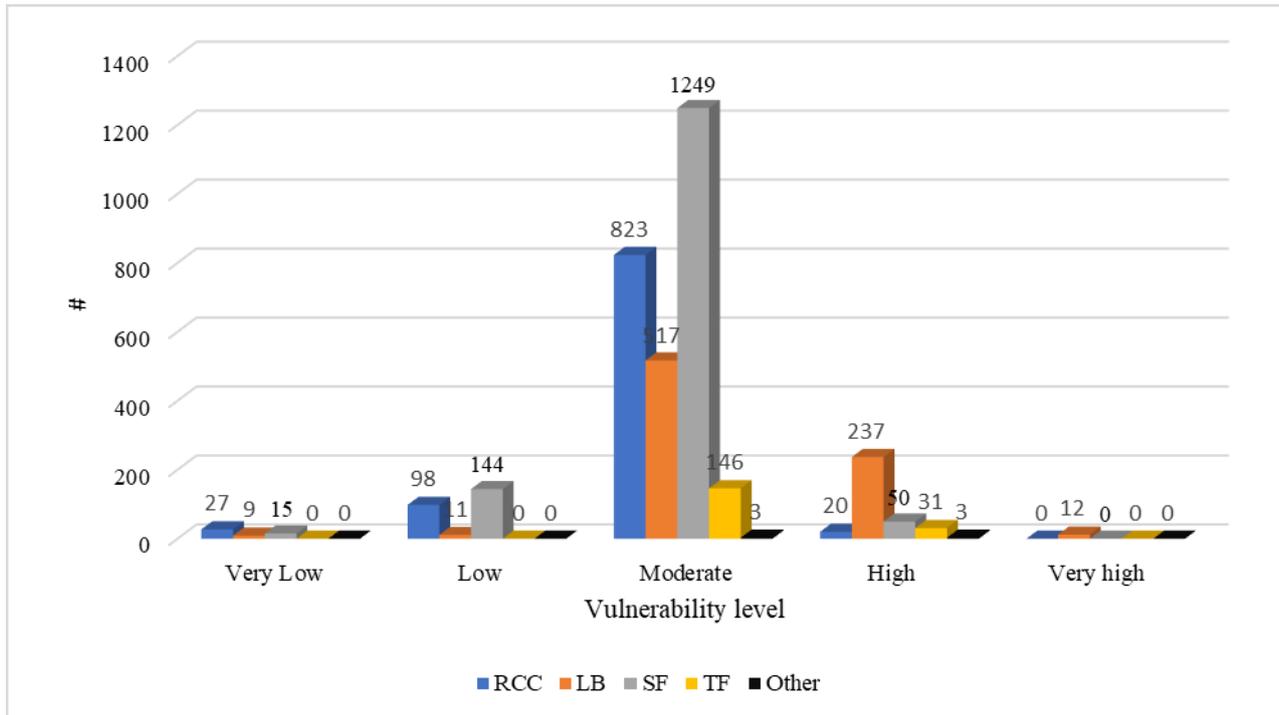


Fig. 2- Distribution of assessed RC school buildings as per the vulnerability level

A summary of the distribution of vulnerability among the various building types is also presented in Table 1.

Table 1.

Building type	Very Low	Low	Moderate	High	Very high	Total
RCC	27	98	823	20	0	968
LB	9	11	517	237	12	786
SF	15	144	1249	50	0	1458
TF	0	0	146	31	0	177
Other	0	0	3	3	0	6

The vulnerability levels of each individual buildings were then cross validated with the observed damage occurred during the 2015 Gorkha earthquake in Nepal. It is found that the buildings categorized under moderate to very high sustained significant damage. However, development of damage matrix together with the ground motion and dissemination of correlation between the classification system and empirical vulnerability is underway.

4. Conclusion

A new weightage-based vulnerability framework is developed and implemented in 3415 school buildings. The preliminary cross validation performed with the actual damage data of 2015 Gorkha earthquake clearly highlights that the newly developed method reliably represents vulnerability levels of RC, load bearing, steel frame, and timber frame buildings. Furthermore, most of the school buildings in Nepal could be categorized as moderately vulnerable structures and thus considerable damages may occur during future earthquakes. The pilot field visit and independent assessment by experts also justified the applicability of the newly proposed method.



5. Acknowledgement

The authors acknowledge the support provided by the World Bank, Nepal via PACE consult, Kathmandu for the database and field visits to calibrate the methodology. Rajesh Rupakhety acknowledges the funding support provided by University of Iceland Research Fund.

6. References

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