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# Seismic Vulnerability Assessment of Masonry Building Thapathali Hostel

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**Abstract**— This study explains how to assess brick structure vulnerabilities using the FEA software E-tabs v21. The chosen structure is a masonry structure constructed using cement-sand mortar in the Kathmandu Valley. The Gorkha Earthquake in 2015 resulted in damages to the structural and non-structural systems, which have been tabulated and recorded for the purpose of model validation. E-tabs v21 software was used to create a finite element model that, for the most part, matches the conditions at the actual site. In accordance with NBC105-2020 and IS875-Part2:1987, loading conditions were applied while material attributes were chosen from a variety of literature sources. The structure was examined for several performance elements, such as time period, base shear, story displacement, joint displacement, etc., to perform vulnerability assessment, and the resulting results were compared with the values recommended by seismic codal provision in NBC 105-2020. Seven separate earthquakes' linear time history data has been matched to the target response spectrum according to NBC105-2020. Using HAZUS principles, fragility curves for the four damage states of minor, moderate, extensive, and complete states has been determined. For the PGA of the site in Kathmandu as suggested by NBC with 0.35g and return period of 475 years, Probability of failure for slight moderate Extensive and Heavy damage states has been determined as 99.42%, 90.87%, 44.39%, and 15.70% respectively.

**Index Terms**— seismic vulnerability assessment, fragility curve, probability of failure .



## 1 Introduction

Nepal is a country that lies in a converging boundary of Eurasian plate and Indian plate. Therefore, this zone is seismically active and frequent earthquakes are quite common in this zone. Different earthquakes in the history of time have caused huge loss in property, life and damage in different infrastructures etc. that has caused larger economic loss to the nation time and again[1] . Hindu temples, Buddhist monasteries, Rana Palaces, and other well-known cultural landmarks in the Kathmandu Valley have typically built using a structural system of masonry walls primarily made of mud mortar and lime surkhi mortar, among other materials, and feature distinctive historic architecture that makes the valley seem like a living museum [2]

The understanding of the stock of masonry buildings necessitates a high level of construction technical knowledge. Due to the variability of the masonry and the limited availability of correct information, it can be challenging to diagnose the structural behavior of these masonry buildings and how depends on a number of elements related to the construction quality. Due to these factors, the majority of first-level methodologies used to evaluate the seismic vulnerability of masonry buildings are overly simplistic and limit themselves to qualitative vulnerability classifications, such as the EMS-98 scale or other method that bases its vulnerability assessments on representative typologies [9]. Two techniques are in use to quantify vulnerability quantitatively: vulnerability/fragility curves and damage probability matrices [10]

In the Kathmandu Valley, there are countless old brick buildings. IOE Thapathali Campus Boys Hostel, which is currently vacant, has been chosen for this study because it shares a structural system with many old buildings made of masonry. This study's methodology will therefore be helpful for quantifying vulnerability during retrofit design.

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## 2 Literature Review

1. G.B Motra et.al (2021) have published a paper named "Structural condition assessment and retrofitting of Shital Niwas building (presidential palace)" and has discussed the various forces like gravity loads, lateral loads and dynamic forces that are anticipated in the service life of the building. They have performed the vulnerability assessment and retrofit design of Shital Niwas building using finite element software Etabs. They have developed the methodology for retrofit design of masonry building. Which will be helpful for design of masonry building in our country like Nepal. They have performed the damage evaluation of the building due to Gorkha Earthquake 2015 and found that the north block and second floor of the east block fall under grade-3 (DG-3), and the remaining part of

the building falls to grade-2 (DG-2) as per EMS-98 classification [3].

2. L. Binda and G. Cardani (2019) have discussed that the lack of building information and structural behavior results in the inadequate design. Poor selections of intervention measures after earthquakes were primarily due to a lack of knowledge regarding the material and structural behavior of the peculiar type of construction techniques used in the past for the buildings. The earthquake in Italy exhibited severe out-of-plane effects (large collapses, local expulsions) that were unexpected and unforeseeable because of the "hybrid" behavior caused by the new and old structures. The Italian guidelines similarly suggested using existing assessment methodologies, although they did not explicitly anticipate that outcome. They suggested the following methods to acquire the data needed for vulnerability assessment:

3. Shyam Sundar Basukala et al. (2017) have conducted a research named “Seismic vulnerability of traditional masonry building a case study of byasi, bhaktapur”. In their paper, they discuss that the majority of Nepal's historic structures are made of masonry. They mention that as masonry constructions are weak under tension, they eventually crumble. Therefore, it is crucial to carry out vulnerability assessments to prevent potential harm to the environment, persons, and property. For the case study, seismic vulnerability testing has done by them on old masonry buildings that were built in the Byasi region of Bhaktapur. Out of 147 buildings, five load bearing masonry buildings have chosen by them for SAP 2000 V10 modeling, taking into account opening percentage, storey, and type of floor. The vulnerability of the chosen building has assessed using a variety of rapid visual screening techniques (FEMA 154, EMS 98). The linear time history analysis has used to determine how the Selected Building responded. For the chosen building, they have carried out a linear time history analysis and identified the seismic vulnerability of masonry structures using fragility curves, which show the likelihood of failure for various levels of shaking intensity for various damage states, including slight, moderate, extensive, and collapse. HAZUS (Hazards U. S.) was utilized in their research [16].


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## 3 STATEMENTS OF PROBLEM

Preserving heritage structures, especially unreinforced masonry buildings like the Thapathali hostel in Nepal, are crucial due to their cultural and historical significance. In seismic-prone regions, such structures face vulnerability issues, often overlooked due to the preference for reinforced concrete construction. The seismic assessment of these buildings requires a focus on lateral resistance, ductility, and potential weaknesses like discontinuous walls. Retrofitting poses challenges, necessitating local modifications, reduction of irregularities, and high-tech measures. Urgent research is needed to understand the seismic behavior of such structures, using traditional materials and contemporary methods, to ensure their conservation while meeting safety standards.

## 4 OBJECTIVES OF STUDY

Perform seismic vulnerability assessment of Masonry Building

(Boys Hostel Thapathali Campus)..

## 5 DIMENSIONS AND MODELS

Dimensions of various structural and non-structural elements. Architectural plan and elevation of Thapathali hostel have prepared from the field measurement on 2nd March 2023 to 10th March 2023. Anticipation of possible load path. Load paths have anticipated from the visual inspection.

Masonry thick shell=480mm,360mm,240mm,120mm
RC slab=100mm (stair slab) , 150mm(floor slab)
Type of mortar =cement sand 1:4 ratio
Brick Class =Class A
Seismic Parameter= Seismic Parameter of Kathmandu Valley

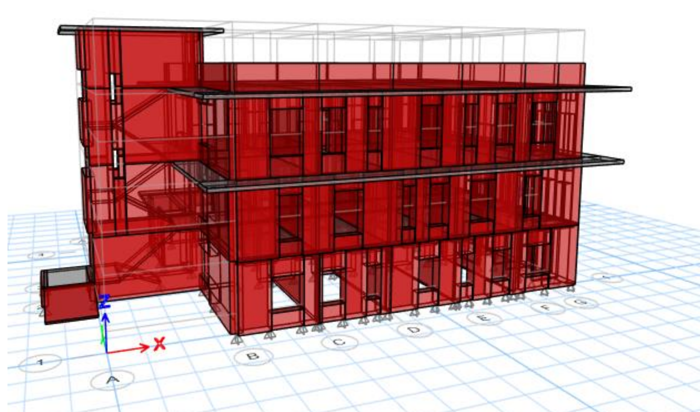

Figure 1: 3-D model of masonry Building (Thapathali Hostel )

## 5 DATA PROCESSING PROCEDURES

Modeling of the building have done with the help of finite element modeling software E-tabs V 21.1.0. The constructed model is a close imitation of the real building; whose behavior is comparable to that of the model. Using the chosen mechanical properties, a three-dimensional macro model has created. The behavior of masonry panels has simply represented by the macro-element parameter as an average. Masonry walls between 120 to 480 millimeters thick have modeled as bi-dimensional thin shell elements.
For the examination of the current building, the design acceleration response spectra based on NBC 105: 2020 have employed. The building is located in Kathmandu, and its soil type is D, and its seismic zone factor is 0.35 (Table 4.5 NBC 105-2020), along with its importance factor of 1.25 (Table 4.6 NBC 105-2020).
In order to conduct a linear time history analysis, earthquake data are downloaded from the PEER ground motion database and matched to the target response spectrum acquired from the NBC105-2020.The magnitude and peak ground acceleration values are used to choose the earthquake data. Dynamic loading conditions are used when performing analysis in linear time history analysis. The analysis has been performed for the on the seven different time history data listed below. The data are chosen to have distinct spectrum properties, different frequencies, and varying acceleration amplitudes on time history curves.
Data analysis is done by the following steps
Step 1: Selection of building and definition of material properties in FEM software
Step 2: Assigning of Different load to the model
Step 3: Analysis of the model by Response Spectrum and linear time history analysis Method
Step 4: Vulnerability assessment using fragility curve

## 6 RESULTS

### 6.1 Seismic Parameters Results of Masonry Building

After the loads were assigned to the model was analyzed and the results obtained are checked. The frequency of the motion for the building is within 33HZ that is 19.15 HZ in the 25th mode in which model mass participation was above 90% which is ok as per the value suggested by the NBC 105:2020.

#### *6.1.1 Time period*

Time-period of the building suggested by Cl. 5.1.2 of NBC 105:2020 is

$$T_1 = 0.05H^{\frac{3}{4}}$$

As per Cl 5.1.3, the time period is to be amplified by 1.25
Where; H= Height of building from foundation or from top of rigid basement 11.105 m in our case. Thus, unamplified and amplified time period suggested by the code is 0.306 sec and 0.383 sec. Our time period obtained from the model is quite near but a little bit lower than the expected which may be due to the higher stiffness of the structure due to rigid slab assumed in the floor with 150 mm thickness. Thus, the time period obtained is realistic.

#### *6.1.2 model mass participation ratio*

the modal mass participation ratio reaches to 94.71% and 97.44% in UX and UY direction in 25th mode, which is above the least mass participation mass ratio of 90% suggested by the NBC 105:2020.

| Mode | 1 | 2 | 3 | 4 | 5 | 6 | 7 | ……. | 25 |
|---|---|---|---|---|---|---|---|---|---|
| Sum UX | 0.0003 | 0.8195 | 0.8550 | 0.8553 | 0.8554 | 0.8555 | 0.8658 | …….. | 0.9471 |
| Sum UY | 0.6856 | 0.6943 | 0.8520 | 0.8762 | 0.8919 | 0.9306 | 0.9314 | ……. | 0.9744 |

#### *6.1.3 maximum story displacement*

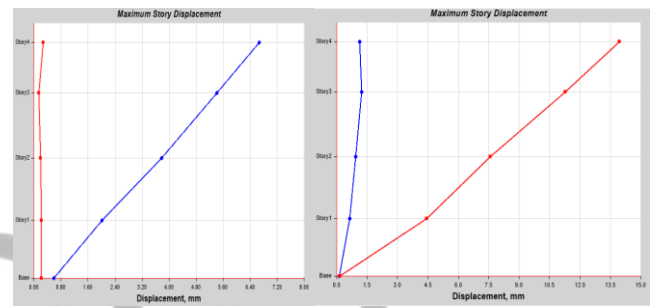


Figure 2: Maximum story displacement for EQX and UQY in ultimate limit state condition

### 6.2 Linear time history Analysis

After evaluation of the structure using the Equivalent static method and Response spectrum method, the linear time history analysis has been performed. The time histories of the earthquakes were chosen based on the characteristics of the seismic spectrum, the length of the shaking, and the magnitude of seismic acceleration. Section 3.5.2 contains the accelerograms for the chosen time histories. Time history data were matched to the target response spectrum after the linear time history data were obtained from the PEER ground motion database. The base shear values derived for the various earthquakes are displayed in the table below after the load case was determined for matching time histories:.
For the seven different earthquakes linear time history analysis was performed and the roof displacement was determined. Maximum value of roof displacement was scaled for different peak ground acceleration 0.1g to 1g and then converted in to spectral displacement which is the demand of the building. Linear regression analysis was performed for the different peak ground acceleration and spectral displacement of different earthquake as equation
Sd = 68.962 *(PGA)

The likelihood of failure beyond the capacity and demand is estimated and plotted for various states.
The probability of exceeding the Slight, Moderate, Extensive, and Complete damage states is obtained as 99.419%, 90.867%,

44.394%, and 15.701%, respectively, for 0.35g peak ground acceleration, the peak ground acceleration recommended by NBC 105-2020 for Kathmandu with a return period of 475 years. Thus, the 0.35g PGA has a 44.394% chance of causing serious injury. To stop the building from being damaged, further action is needed. The component-level damage probability is not provided by this probability curve; rather, it merely provides the probability of various damage states as defined by the HAZUS and the global probability of structural collapse.

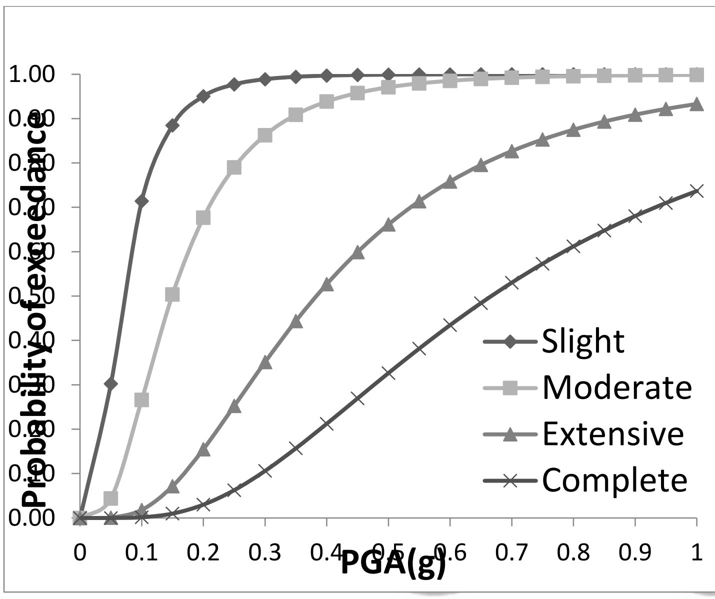


Fig 3 : Fragility curve for Thapathali Hostel obtained using Linear Time History Analysis

### 6.3 Vulnerability Assessment Global compression and shear Check:

On Calculations this research reveals that the building's shear demand is smaller than its whole basement walls' shear capacity. Therefore, no additional measures are needed for the structure to handle the shear demand. The structure is secure when compressed. However, the aforementioned research is based on the analysis of global capacity and demand, not on the examination of specific piers. We have performed the pier wise vulnerability assessment after defining pier and after analysis determining pier wise force and pier wise vulnerability have been checked. Due to the building's substantial length and breadth, it is expected that tension and compression caused by overall building swaying are insignificant.

### 6.4 Model Validation using Field Comparison

The different structural parameters like modal time period, modal frequencies, base shear, inter-storey drifts, modal mass participation ratio are within permissible limit and as per the value suggested by the codes. Thus we can say that our model is representing the true behavior. Field comparison of some of the overstressed pier in analysis had some crack in the wall but not for all. Thus, Failure to meet one or more criteria does not directly represent collapse of element. In masonry, if one pier is deficient, forces get redistributed on adjacent piers so that, collapse is not threatened immediately. Some tension is common in masonry, as it gets redistributed by increase in compression. However, element already critical in compression cannot bear any further tension. Thus, our model is representing the true behavior of the building.

## 7 CONCLUSION

Model for the Thapathali Hostel was prepared and analyzed in E-tabs V21.1.0 and vulnerability curve was determined according to the revised NBC105-2020. The major conclusion obtained from the vulnerability curve are there is 71.42% probability of exceedance of slight damage at 0.1g PGA and at 0.4g PGA probability of moderate damage reaches to 93.84%. From the fragility curve obtained from the analysis, we can estimate the probability of different damage states for different value of PGA using the vulnerability curve obtained above. This vulnerability gives the global vulnerability of whole structure and do not represent the vulnerability of individual piers. For the PGA of the site Kathmandu suggested by NBC with 0.35g and return period of 475 years, Probability of failure for slight moderate Extensive and Heavy damage states as specified by HAZUS are 99.42%, 90.87%, 44.39%, and 15.70% respectively. Thus, there is large i.e. 44.39% chance of extensive damage for the building thus, additional intervention is required for the building preservation.

The actual capacity of the building is determined from the value suggested by the HAZUS but not from the direct capacity determination from modelling approach. The modelling parameters are taken from the literatures and true behavior of the building is not known to us thus we have not considered the effect of strength loss with time, material deterioration due to different loading environment, environmental factors etc. This is the limitation of our study.

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