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SEISMIC VULNERABILITY ASSESSMENT OF ACADEMIC RC BUILDINGS

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Abstract: Birendranagar Surkhet is an educational hub of Karnali provenance and Surkhet Campus Education is one of the oldest collage of Karnali provenance. Some of the academic buildings of this collage were constructed before 3 decades during this period there was a lack of establishment and implementation of proper code and guidelines. If the seismic characteristics of these existing building is known well it will help to reduce risk, economical losses and causalities during and after earthquake. Many researchers conduct the vulnerability assessment of the existing academic building after Gorkha earthquake 2072 in the eastern Nepal and it shows that many of the existing academic buildings were constructed without appropriate seismic resisting characteristics due to which huge losses was beared by nation . Hence it is necessary to conduct the vulnerability assessment of existing academic building in western Nepal to ensure whether the existing academic building are safe or not from seismic point of view before. In my study seismic vulnerability assessment of academic building will be done among the many existing building of Surkhet Campus Education.

During this assessment non-destructive testing (NDT) is conducted to obtain the material properties of the existing RC building and loading condition are applied according to NBC 105- 2020 . Finite element model, that mostly resembles the actual site condition was prepared by using E-tabs V20 software. In this process structure was analyzed by using Pushover analysis, in which application of incremental control displacement to the structure until it reaches a target displacement, which provide the capacity curve. Time history analysis was performed for seven different earthquake matched to target response spectrum as per NBC 105-2020 which provide us the demand curve. With the help of these two results fragility curve for four damage states: slight, moderate, extensive and complete is generated at interval of 0.2g PGA. Results of probability of failure of respective damage states were taken at 0.35 PGA (Birendranagar) for selected different earthquake data. Finally, seismic vulnerability assessment of Surkhet Campus Education is predict with the help of seismic vulnerability evaluating tool fragility curve.

Key Words: Seismic vulnerability, Academic building, Fragility curve

1 INTRODUCTION

Nepal is located in seismically active region which has long past history of divesting earthquake. The geological location of Indian and Tibetan tectonic plates results to cause large earthquake in the entire Himalayan region. Different earthquake in the history of time have caused causalities, physical injuries, physical damage in different infrastructures which has caused large economic loss to the nation time and again. In Nepal there are various types of building that are in practice, some of them are stone masonry, brick masonry, reinforced concrete and mixed type of building. Though some of them are well designed but majority of the building are constructed without proper guidance and design. This has resulted damage in around 8 lakhs buildings with loss of 8790 people live and injury of 22300 people in recent 2015 Gorkha earthquake.

2 LITERATURE REVIEW

1. (Chaudhary, 2016) On this study authors developed the fragility curve for RC building considering three different RC building models. Fragility curves were developed for each of the buildings using HAZUS methodology and nonlinear static pushover analysis with SAP2000 v14 .Infill wall were not included during analysis of buildings. This paper conclude with the idea to predict the damage level of building corresponding to particular value of spectral displacement .They conclude with different fragility curves for different models of buildings.
2. (PratibhaS. Shetty, 2014) on the study of methodology based on pushover analysis for fragility estimates of RC building using probabilistic approach. It is observed that the analytical base shear values for the derived values of strength based on factor of safety into consideration were almost equal to that of experimental pushover values. Also an attempt has been made to obtain fragility estimates for the reference building assumed to be located in Zone IV and damage states were also established and reported.
3. (Ansari, 2 July 2014) On the study of concentrated probabilistic risk assessment of reinforced concrete tall

buildings subjected to ground excitation. This evaluation is done by developing fragility curves. These fragility curves provide the probability of exceeding the multiple damage states for a given intensity of ground motion excitation. This study includes comparison between fragility curves of fixed base buildings and the ones derived from models considering the Soil Structure Interaction effects to indicate the efficacy. The structural uncertainties are taken into account by generating and modelling random values of material properties using Monte Carlo simulation method.

4. (Mary, 2007) On the study of Seismic fragility for a reinforced concrete frame structure representative of 1980's construction in central U.S. The performance of the retrofitted structure is presented in terms of fragility relationship that relate the probability of exceeding a performance level to the earthquake intensity. In addition, seismic fragility relationships were developed for retrofitted structure based on three possible retrofit techniques and several performance levels.

3 STATEMENTS OF PROBLEM

Located in the central of the Himalaya range, Nepal is one of the most earthquake prone countries in world. Many large earthquakes were occurred in Nepal including the Gorkha earthquake. In Gorkha earthquake 498,852 buildings were completely collapsed and other 256,697 were partially damage (Chaulagain & Gautam, 2016). Most of the old masonry and non-engineered buildings were collapsed and partially damaged by the earthquake. Also, some engineered buildings were damaged due to poor workmanship and quality of construction work. Many institutional buildings in Nepal are design, built, furnished based on standardized projects. But on the basic of the limited time and procedure for the planning and fulfillment of the projects, it may have caused the fault to make them more vulnerable to earthquake. In developing county the institutional buildings were constructed many years ago, since than the construction practice and design codes have been changed as a result seismic vulnerability assessment is needed.

4 OBJECTIVES OF STUDY

The aim of this research is to generate fragility curve for the selected academic RC building.

5 DIMENSIONS AND MODELS

The selected building is one of the oldest building of surkhet campus education and detail of the selected building are as following:

Beam Size=230mmX300mm
Column Size=300mmX300mm
Slab Thickness=125mm
Wall Thickness=230 mm
Grade of Concrete: M20 for column and M15 for beam& slab
Grade of steel =Fe-415
Building Dimension = 15×31 m
Seismic Parameter= Seismic Parameter of Surkhet District

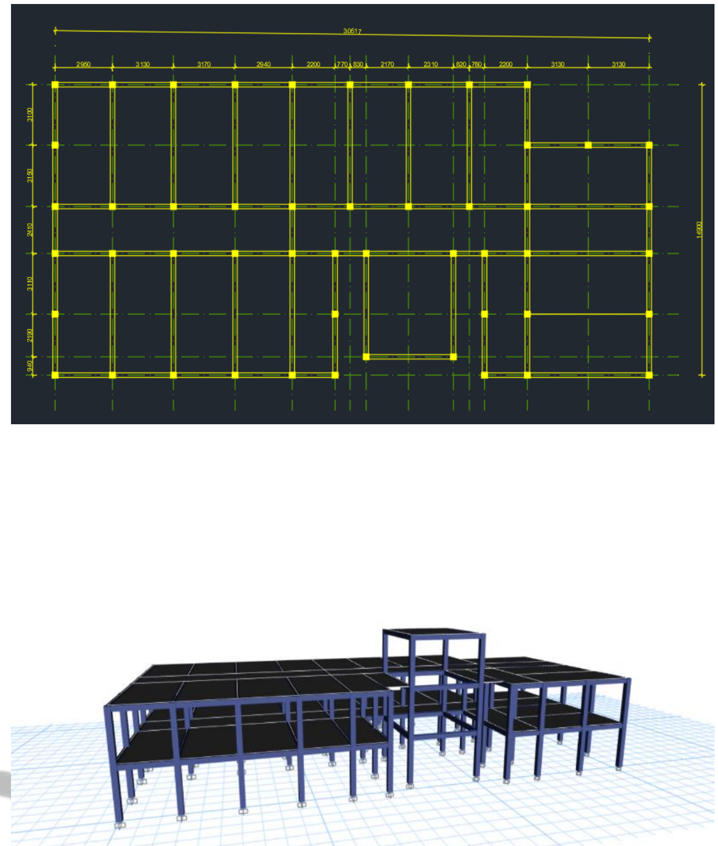

Figure: Beam, column Layout and Model of selected Building

6 DATA PROCESSING PROCEDURES

The structural model for numerical analysis was created and analyzed using the ETABS software (ETABS 2020). The main aim of these analysis is identify the behavior of the spatial frame of buildings by providing static and dynamic loading.

The beam and column elements were modelled as elastic elements with plastic hinges at ends of members. The plastic hinges represents the concentrated behavior of the structure member during numerical analysis. Default hinges characteristics used for concrete sections was based on (FEMA-356, 2000) and (ATC40, 1996) criteria. Flexural default hinge (M3) was assigned each ends of the beams member and column interacting (P-M2-M3) coupled frame hinges type of hinge property were assigned both lower and upper ends of member.

Pushover Analysis:
Nonlinear static pushover analysis is a powerful tool to evaluate the lateral load response of structures by assuming non linearity in material and geometry (p-delta effects).This method is generally considered to be more realistic in predicting seismic vulnerability of new and existing buildings than method.

Time History Analysis:
The study of seismic response of structural behaviors under the

dynamic loading of representative past earthquake data is known as time history analysis. For linear time history analysis earthquake data are downloaded from PEER ground motion data base and matched to target response spectrum obtained from NBC105-2020.

Fragility Curve:

Fragility curve is an effective tool for vulnerability assessment of structural systems. The fragility curve which is developed from behavior model of structure, capacity and suit of ground motion. Fragility curves can be developed by probabilistic analysis of structural response data.

7 RESULTS

7.1 Inter Story Drift:

Inter storey drift of the selected academic building in x-direction as shown in figure below in storey 3, storey 2 and storey 1 are: 0.001035, 0.002521and 0.002721 respectively. As per NBC 105-2020 the allowable value of the IS-drift is 0.00625 and we can conclude that the value of IS –drift in X- direction is within the allowable limit and the building is critical in storey1 as compared with other storey. The rate of change of IS drift in X-direction was found to be regular and consistent in all the storey level and it was also found that storey1 had higher IS drift than other storey level.

Inter storey drift of the selected academic building in Y-direction as shown in figure below in storey 3, storey 2 and storey 1 are: 0.001558, 0.00404 and 0.003939 respectively. As per NBC 105-2020 the allowable value of the IS-drift is 0.00625 and we can conclude that the value of IS –drift in Y- direction is within the allowable limit and the building is critical in storey2 as compared with other storey. In Y – direction the rate of change of IS drift was found to irregular and inconsistent and it was also found that storey2 had higher IS drift than other storey level

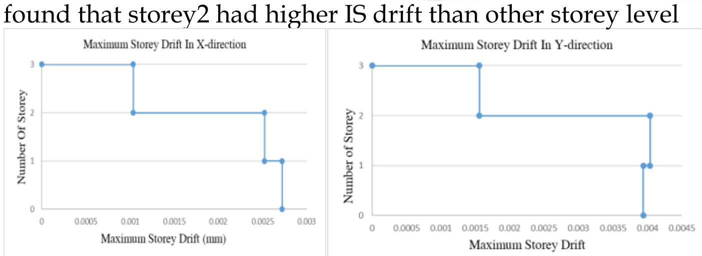

Figure: Maximum Storey Drift

7.2 Pushover Curve:

The resulting pushover curve of the selected academic building along X – direction is as shown in the figure below. The curve is initially linear but starts to deviate from linearity as the beams and columns undergo inelastic actions. When the building is pushed well into the inelastic range, the curve become linear again but with a smaller slope. The maximum displacement is 274.538 mm and the base shear is 2512.5589 KN in Pax.

The resulting pushover curve of the selected academic building along Y-direction is as shown in the figure 22. The curve is initially linear but starts to deviate from linearity as the beams and columns undergo inelastic actions. When the building is pushed well into the inelastic range, the curve become linear again but with a smaller slope. The maximum displacement 386.994 mm and the base shear is 2513.4303 KN in Pay.

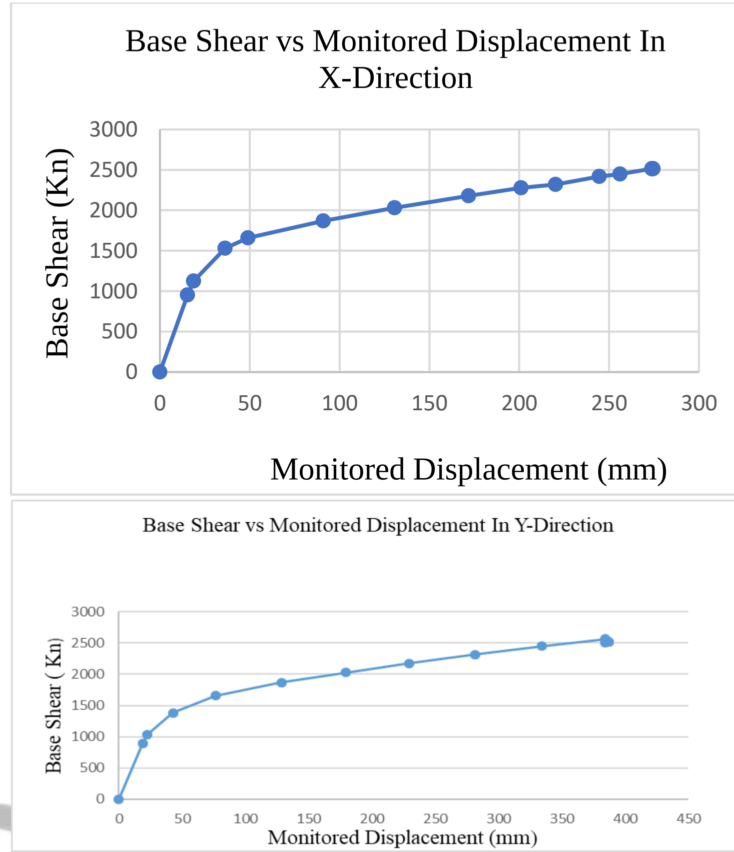

Figure: Pushover Curve in X and Y direction

7.3 Idealization of Pushover Curve:

Idealization of the pushover curve is required to determine the value of yield displacement (dy) and ultimate displacement (du). ACT -19, FEMA-356, Park (1988) etc. describes the various methods ok idealization of pushover curve. During conducting of this study Reduced Stiffness Equivalent Elasto-plastic Yield idealization are used Park (1992). Hu represents the ultimate load which gives the value of ultimate displacement (du) and 0.75 gives the value of yield displacement dy, which are used during the evaluation of damage states for fragility curves.

Based on the reduced stiffness equivalent elasto plastic yield method the idealization of pushover curve along X-direction as shown in figure below is done and the value of the yield displacement (dy) and the value of ultimate displacement (du) are 126.66 mm, 274.538 mm respectively which will we used during the calculation of damage states.

Based on the reduced stiffness equivalent elasto plastic yield method the idealization of pushover curve along Y-direction as shown in figure is done and the value of the yield displacement (dy) and the value of ultimate displacement (du) are 197.33 mm, 386.994 mm respectively which will we used during the calculation of damage states.

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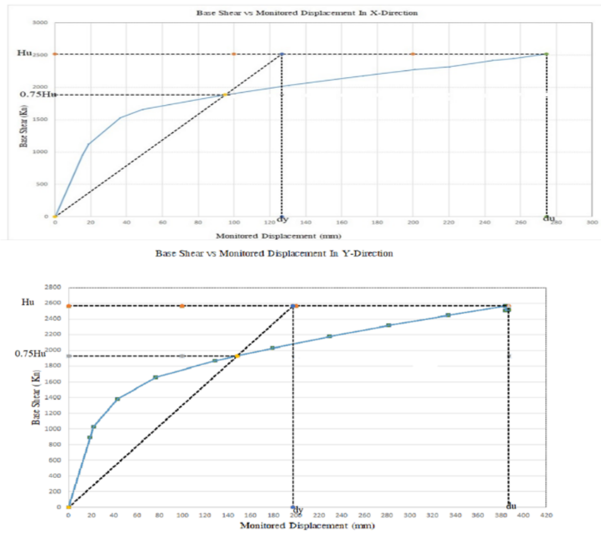


Figure: Idealization of Pushover Curve along X& Y-direction Based on Reduced Stiffness Equivalent Elasto-plastic Yield Method.

7.4 Damage states:

The seismic behavior of the building can be predict by damage thresholds. Based on the yield displacement and ultimate displacement many damage states are proposed by many researchers. Based on the review of limit states given by many researchers, it is found that mostly adopted limit states are: slightly damage, moderate damage, extensive damage and complete damage. So for this study I have taken (logomarsino and Giovinazzi (2006)) is used to generate the fragility curve to describe the performance level of the study building.

i) Slight damage = 0.7dy
ii) Moderate damage =1.5 dy
iii) Extensive damage = 0.5 (dy +du)
iv) Complete damage = du

7.5 Linear time history analysis:

After the buildings was analyzed and checked for equivalent static method and response spectrum method. Different earthquake time histories were selected. The earthquake time history selected are based on spectrum characteristics, duration of shaking and amplitude of seismic acceleration in time history curve. After that the load case was defined for matched time histories and the maximum roof displacement values for the different earthquake is:

After addition of shear wall at different location the order of top

Yield Displacement(mm)	Ultimate displacement(mm)	Maximum demand for earthquake (mm)						
		Gorkha	Chi-Chi	Kern	Northridge	Imperial	Loma	Kobe
126.66	274.538	450.53	420.83	402.19	450.38	401.32	398.504	409.4

7. Fragility Curve:

The procedure of seismic fragility generation involves determining damage states i.e. slight, moderate, excessive and complete from capacity spectrum and developing fragility curve for each damage state. For the selected academic buildings fragility curve are developed for four damage states with seven different synthetic earthquake as shown in fig below. The curve represent cumulative probability of failure from 0 to 100% corresponding to peak ground acceleration 0 to 1 and interval of 0.2g PGA.

The probability of failure of selected academic building for seven earthquakes in four different damage states are summarized as: Figure represents the fragility curve of selected academic building for Gorkha earthquake. The damage state of Gorkha earthquake it had , slight , moderate , extensive and complete damage is 98.539% , 83.882%, 63.308% and 42.94% respectively.

Figure below represents the fragility curve of selected academic building for Chi-Chi Taiwan earthquake. The damage state of Chi-Chi Taiwan earthquake it had , slight , moderate , extensive and complete damage is 97.229% , 76.57%, 59.696% and 34.537 % respectively.

Figure represents the fragility curve of selected academic building for Kern Country earthquake. The damage state of Kern Country earthquake it had , slight , moderate , extensive and complete damage is 94.996% , 67.493%, 61.83% and 41.312% respectively. Figure 26 represents the fragility curve of selected academic building for Northridge earthquake. The damage state of Northridge earthquake it had , slight , moderate , extensive and complete damage is 95.573% , 69.576%, 65.331% and 45.579% respectively.

Figure represents the fragility curve of selected academic building for Imperial Valley earthquake. The damage state of Imperial Valley earthquake it had , slight , moderate , extensive and complete damage is 91.156% , 56.339%,58.527% and 41.861% respectively. Figure represents the fragility curve of selected academic building for Loma Prieta earthquake. The damage state of Loma Prieta earthquake it had , slight , moderate , extensive and complete damage is 91.761% , 57.861%,56.736% and 38.439% respectively. Figure represents the fragility curve of selected academic building for Kobe earthquake. The damage state of Kobe earthquake it had , slight , moderate , extensive and complete damage is 94.117% , 64.574%,57.527% and 36.535% respectively.

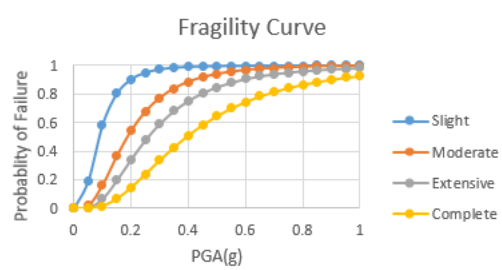
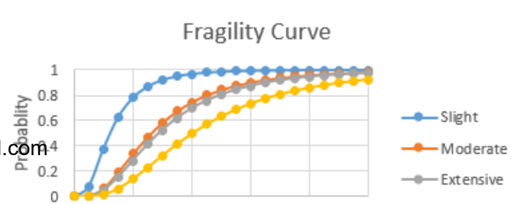


Figure : Fragility Curve Gorkha Earthquake



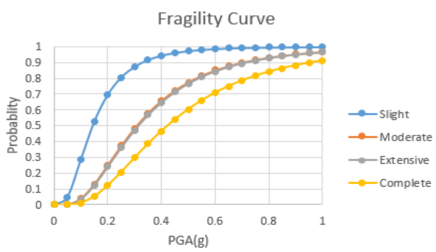


Figure :Fragility Curve Loma Earthquake

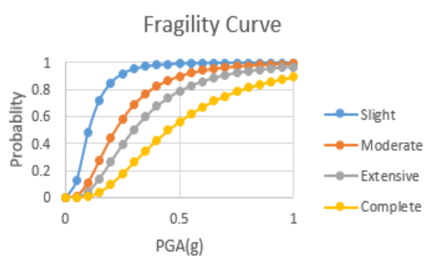


Figure : Fragility Curve Chi- Chi Taiwan Earthquake

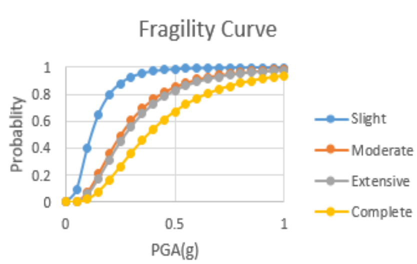


Figure : Fragility Curve North ridge Earthquake

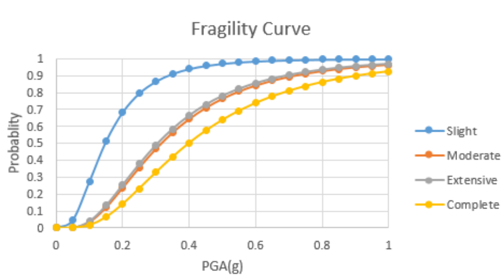


Figure : Fragility Curve Imperial Valley Earthquake

8 CONCLUSION

In my study the selected building represents the status of seismic vulnerability of existing RC academic building in Karnali provenance. This study achieved the case study of academic building of Surkhet Campus Education. The structural performance in various damage states i.e. slight damage, moderate damage, extensive damage and complete collapse was studied rationally. For this the numerical analysis was done with finite element software ETABS. For this, nonlinear static and linear dynamic analysis of academic building were performed by finite element based software program ETABS. In dynamic analysis, building models were subjected to different synthetic earthquake. In my study, the fragility function is derived with plotting the probability of failure at every 0.20 g interval of peak ground acceleration. The main conclusion for the analysis are summarized by following:

- The fragility curve was fatter at lower PGA and stiff at higher PGA in all the damage grades. The fragility curve of selected building at different earthquake was found as probability of complete damage is nearly 50% at PGA 0.35g (475 year of return period), which shows that the building is vulnerable and having low performance level.
- The rate of change of IS drift in X-direction was found to be regular and consistent in all storey level, it was also found that storey1 had higher IS drift than other storey level so storey1 is more critical as compared with other storey. Similarly in Y – direction IS drift was found to irregular and inconsistent, it was found that storey2 had higher IS drift than other storey level so storey2 is more critical as compare with other storey.
- The results indicate that the fragility curves of buildings in different earthquakes mostly depends on configuration and properties of building structures. However, the earthquake time history has minimal effect on its performance.

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