Fragility Analysis of Religious Matepani Gompa in Pokhara

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Abstract— **Nepal lies in the tectonic plate zone between Indian and Eurasian plates and due to the movement of those plates numbers of earthquakes have occurred in past. Nepal faced a disastrous earthquake on April 25 and May 12 of 2015. These earthquakes have been ranked among the most significant ones due to their effects. Nepal's earthquake caused considerable damage to buildings like residential building, religious building, historic building etc. Nepal government has high focus on reconstruction of residential building and less focus on religious building so the goal of this research is construction of fragility curve of religious building (Matepani Gompa) which helps to make seismic risk mitigation plans for gompa.**

The purpose of this study is to generate fragility curve of matepani gompa. Linear time history analysis has been carried out on religious building in pokhara using SAP2000V19. The seismic response of matepani gompa obtained from time history analysis. The Fragility curve defines the possibility of damage to the building from mild damage to sever damage including collapse under earthquake based on different peak ground acceleration (PGA). Capacity values obtained from HAZUS for RCC building were used to generate fragility curve. The Fragility curve demonstrates the possibility of level of damage experienced by the building during seismic event.

In conclusion, the outcomes of the research indicated that the clear picture of the seismic performance level of the Matepani Gompa and that structure shall be strengthened to increase the safety of that building.

Keywords—*Fragility Curve, Gompa, Earthquake, Religious Building*

I. INTRODUCTION

A. Background

The importance of historical and architectural character that reflects the identity and the unique character of the communities are respected by every citizen of the nation. It is important to preserve historic resources for the social, Cultural, economic and environmental sustainability. Those resources could be the main ingredient for the livability and quality of life, reducing negative impacts on the environment and yielding economic vitality and reward. So, there is a need for sustainable and structurally sound historic buildings that will reduce the structural failure in future.

Earthquakes are one of the most destructive calamities that take a lot of lives, injuries and economic losses leaving behind a trail of fear. It cannot be denied the fact that the globe is facing a threat of natural disaster from time to time. Hence the application of the building and seismic codes becomes important. Furthermore, use of quality material, skilled workmanship and building insurance could be made mandatory to prevent the loss of lives and property due to Earthquake and other calamities. The occurrence of earthquake is unpredictable. To minimize the effects its effect, design of earthquake resistant structure become more important. Due to the continuous collision of tectonic plates that have historically caused the country's deadliest tremors, Nepal is extremely prone to earthquakes. Almost every year, various magnitudes of earthquakes occur that results in heavy loss of lives and property. Nepal has a long history of deadliest Earthquakes. In terms of seismic hazard, Bureau of Crises Prevention and Recovery of the United Nations Development Program designates Nepal is the 11th most vulnerable country in the world [1].

Nepal lies in a high earthquake intensity region. Almost entire country falls in high intensity scale of MMI IX and X for the period of generally accepted recurrence. The seismic zone of Nepal is divided into three zone elongated in northwest-southwest direction. The middle part of the country has slightly higher shaking hazard then the northern and the southern parts [2].

The seismic belt of Nepal is one of the most active belts in the world. There are records of many destructive earthquakes in the past. Nepal has an earthquake risk that is believed to be among the highest in the world.

The risk to life and property from earthquake is well known. The collapse of buildings is the leading cause of earthquake damage. Recent advances in earthquake engineering have been largely enabled by a better understanding of the dynamic behavior and seismic performance (Stiffness, Ductility, Deformation, and Strength) of structures. As such, the performance-based design approach permits the selection of specific performance goal based on a variety of parameters, such as the owner's needs, the function of the structure, the seismic risk, and the potential economic losses. As part of the current seismic safety effort, more emphasis has been focused on operation, leading to a vulnerability assessment and rehabilitation of religious buildings (Matepani Gompa).

B. Study Area

The Buddhist monastery is situated on top of the small forested hill above Matepani, east of Mahendrapul, Pokhara, which is about five kilometers from downtown Pokhara. The centre of attractions on that area are the wall paintings, magnificent monuments, statue of Lord Buddha and the religious values.

C. Statement of Problem

The latest earthquake in Nepal (2015) disasters has highlighted, once again, poor functioning of the existing

historic buildings. It showed the need to renovate all these structures which have been designed and built with old regulatory criteria, inadequate or those that have been built before the development of design codes and standards. Even significant progress has been accomplished in new criteria of earthquake resistant designs, application of these design standards are still lacking in the existing and new structures. Hence it is important to identify the degree of seismic performance.

Even significant progress has been achieved in standards and criteria of earthquake resistant building design in Nepal, The application of such standards are still lacking.

D. Objectives of the Study

The general objective of this study is to derive the fragility function of Matepani Gompa with seismic loading in terms of PGA. The specific objectives are as follows:

1. Development of analytical displacement based seismic fragility curves reflecting the characteristic of existing religious Matepani Gompa.
2. Interpretation of the structural vulnerability of the religious Matepani Gompa in terms of the probability of failure obtained from the fragility curves for different values of ground acceleration and all states of damage.

E. Scope

Vulnerability can be defined as the chance of damage of buildings in a seismic event. Matepani Gompa also has certain level of vulnerability. Vulnerability can be quantified by generating fragility curve. In the typical framed concrete structures, where it is required to identify the yield hinges. Whereas, the distributed cracking on the structure of masonry buildings can be found, which features opening, closing and reopening, due to the less value of the tensile strength. In this study, linear time history analysis of frame structure was carried out to determine demand displacement of religious matepani gompa.

Fragility curves are often developed for structures of a particular region and even for a particular type of structures or structure. The characteristics of earthquakes vary from region to region and thus their effects on structures also vary. Fragility curves also depend on type of structures and the capacity of structures taken into consideration. So every fragility curve has its own boundary and these limitations have to be clearly understood during utilization of fragility curves for seismic loss estimation. In the current study fragility curves will be develop for religious building of Pokhara. Whereas for capacity of building, the guidelines of technical manual HAZUS has been followed.

F. Limitations

The finite element studies of the buildings should be carried out using homogeneous shell element in SAP2000. Effect of nonlinearity could not be considered in dynamic analysis.

II. LITERATURE REVIEW

A. Fragility Curve and Analysis

Fragility curve gives the probability of function of ground motion intensity that exceeds the limit state, and is mostly used to show fragility information. For a specific class of system or component, fragility curve can be developed. It can also use to analyze different seismic rehabilitation and to improve the seismic design.

There are many ways to generate the fragility curve, among them two common approaches for the determination of fragility curve: first approach is based on damage data obtained from field survey after an earthquake and the second approach is based on numerical analysis of the structures through time history analysis or the simplified methods. The calculation of fragility curve does not have any specific method; it can be generated depending on the circumstances of the event of ground motion. For instance, field data method can be useful for characterizing the performance of the seismic event on the structures, whereas, the numerical analysis method can be used to develop fragility curve for a specific structural system with well-defined limit state.

One of the most effective tool for the assessment of the vulnerability of the structural system is fragility analysis. A fragility curve is a graphical representation of the seismic vulnerability of a structure, derived from the behavior model of structure, capacity, and ground motions. Fragility curve can be developed for both specific component of system or class of component of system, it will also provide the chance of exceeding a state of given damage as a function of parameters of engineering demand that illustrate ground motion. It also can be stated as a graph of intensity measure (IM on X axis) versus % of damage on Y axis. This work consider damage major (DM) for the the maximum inter-story drift ratio of the structure and intensity measure (IM) of 5% damped first mode spectral acceleration (Rony, 2016).

The fragility curve can be obtained by using nonlinear analysis such as IDA and POA. Previous researches shows that incremental dynamic analysis (IDA) is mostly used as initial stage to develop fragility curve than pushover analysis (POA). For instance, Vona generate the fragility curve for the analysis of response of the structures of the moment resisting concrete frame (MRCF) by using two method of analysis, NSA and NDA. From this analysis NDA method is the popular method. The collapse performance of the three structural models of 6, 12 and18 was estimated as an RC-MRF with variable story heights. The fragility curve was used to develop the estimation with the consideration of interaction of soil structure as a parameter of seismic uncertainty. The analysis of seismic efficiency of asymmetric steel structure isolated with Triple Concave Friction Pendulum (TCFP) acting as a bearing seismic element. IDA analysis is performed under the effect of 45 sets of seismic record to develop Fragility Curve. To consider the damage possibility, damage state of HAZUS were used (Kassem, Nazri, &Farsangi, 2020).

Probability of damage to buildings is described by fragility curves. Building fragility curves are lognormal functions. It explains the possibility of surpassing damage state to the structure and non-structure. It also provides the information about median spectral response estimates for instance, spectral displacement. The degree of damage among slight, moderate, extensive and complete damage states are distributed by the Fragility Curves. For different value of spectral response, the cumulative possibilities of reaching or surpassing the damage states are calculated from discrete damage-state probabilities. The fragility curve is based on

median value of the demand parameter of damage such as spectral movement, which corresponds with the threshold of the damage state and the differences related to that damage state (Kumar, Raju, &Garikipati, 2016).

B. Ground Motion Intensity Measure

Time history is a common way to describe ground motion. The classification of time history can be done in three parameters; acceleration, velocity, displacement time history. From that parameter, one parameter can be directly recorded where, other parameters can be calculated by differentiating or integrating based on the first parameter that is directly recorded (Maniyar & Khare, 2011).

The relation between the ground motion and damage of the structure can be done by using ground motion parameter called as Intensity Measure (IM). The development of different intensity measure of ground motion is done, from which every intensity measure could explains the different characteristics of the ground motion. The guidance to use particular IM for seismic analysis provides the extent of measure corresponding damage to the structural component of the system. The intensity measurement is selected as per the method of derivation of fragility function. On the basis of practicability, efficiency, effectiveness, sufficiency, robustness and computability the precise intensity measure are defined (Pitilakis, Crowley, & Kaynia, 2014).

C. Time History Analysis

From the time history analysis, maximum displacement at the top of the building was determined as the demand of the building for PGA.

The main reason behind the shaking intensity at different location is earthquake. Due to that the damage on the different building on different location is also different. Hence there is a necessity of construction of earthquake resistance building with the consideration of particular intensity of shaking instead of magnitude of an earthquake. Same magnitude of earthquake have different intensity, therefore the damaging effect on different region is not similar. So the study of variation of the intensity and its response behavior of multistoried RCC building in terms of lateral displacement and base shear is important. Understanding how buildings with similar layouts will respond in different earthquake intensities is critical. To investigate seismic response, Different method of seismic analysis of the structure needs to be carried out (Duggal, 2010).

D. Damage Measures and Performance Levels

In order to resist the potential ground motions minimum provision for the design and construction of structures are provided by the national building codes and standards. However, the expected performance of the structure is not clear on the building codes. Which has direct and indirect effect on the estimation of potential loss of lives and property during the earthquake event. The development of performance based design codes is coming forward to address the quantative and comprehensive structural damage due to earthquake. The codes considers the design elements, evaluation and construction of buildings and structures with the best seismic performances that match user expectation (SEAOC 1995; FEMA356 2000). Performance level refers to maximum damage desired for a structure resulting from a specific earthquake. According to SEAOC, the four performance level is as follow.

Fully Operational: The structure has been continuously used with minimal structural and nonstructural damage.

Operational: In most cases, the structure can resume most of its operations immediately after the earthquake occurs.

Life Safe: Moderate structural damage. Repair is possible but not economical.

Near Collapse: Structural collapse is prevented despite severe damage to the structure.

It is important for the engineers and clients to select the desired performance level of the structure under earthquake conditions based on reliability in structural predictions with sufficient assurance; that is, performance-based design; such performance level would have definite impact on the design and construction of the structure (Yasser & Ashraf, 2016).

E. Schmidt Hammer Test

The hammer can be used in different position such as vertical, horizontal and any intermediate angle, where the hammer should be perpendicular to the surface during testing. Due to the action of gravity on the mass, the position of the mass in the hammer affects the rebound number. As a result, the smaller reading value of rebound number is expected on the floor than soffit. However, inclined and vertical surface has intermediate results. The higher value of rebound number indicates the high value of compressive strength and low rebound number represent low compressive strength.

A non-destructive test device, the Schmidt hammer is used to determine the surface hardness and penetration resistance of concrete. Rebound of a hammer depends on the strength of concrete used so it helps to found the grade of concrete used in matepani gompa.

F. Rapid Visual Assessment

Rapid Visual Screening is a method that doesn't require structural calculations to be performed. The damageability grading system is used in this method, in which, the evaluator identifies the primary structural lateral load-resisting system and specifies the attributes of the building that modify the performance of ground motion expected for this lateral load-resisting system along with non-structural components. The tasks such as inspection, collection of data and decision making process are generally carried out at the building site, which could take couple of hours depending on the size of the site

G. Conceptual Framework

Structural analysis of reinforced concrete framed buildings is conducted using the time history analysis method. Dynamic responses under earthquake loading are evaluated by using linear or nonlinear time-history analyses.

The seismic performance of building of Nepal after earthquake was conducted by Varum et al. in 2018. The conclusion of the study was the damage to the RC buildings that were not properly design to resist seismic force is severe damage leading to partial or complete collapse. The damage is due to the vertical irregularities during construction which causes differences in stiffness and subsequent soft story mechanism, which is related to non-engineered structures. However, the tall RC buildings designed with proper engineering practice also suffer from significant

nonstructural damage such as damage in masonry infill walls. The reason behind the damage to the URM building which are collapsed during the earthquake are could be due to poor material quality and lack of construction process or knowledge which could improve the quality of structural behavior during seismic event (Varum, Dumaru, & Barbosa, 2018).

The test conducted by Miyamoto and H kit in 2018 was by using two sets of fragility curves. From that damage probability matrix was developed. For one set of matrix, six story frame structure is considered while for other sets, 16 story frame wall structure was chosen. Macedonian design code was used to design the sample structures. In developing a new earthquake intensity-damage relationship, special consideration was given to the conditions of the local seismic hazards. As per the theart methods, the modeling of nonlinear behavior of the element of the structure was completed. The condition of damage was defined as five damage state. From the analytical research, the determination of each damage state corresponding to the global damage index was carried out. The two sets of fragility curves and probability of damage matrix were defined from the 240 synthetic time history of nonlinear dynamic analysis of simple structure[3].

The analysis of seismic assessment was done by Korkmaz by using fragility analysis in 2008. The probabilistic characterization of the demand was established by performing correlation of demand and capacity in different aspect. This paper is based on evaluation of structural seismic behavior by using probabilistic seismic analysis. For this different methodology such as Monte Carlo Simulation and analytical based analysis is used to compare the results of sample RC frame structure [4].

Using the maximum inter-storey drift ratio as a damage parameter, Ozer and Erberik constructed seismic fragility curves for different reinforced concrete moment resisting frame structures in 2008. Using non-linear time history analysis, the four damage states in Turkey are considered as poor, medium, and good depending on the design of the structure. The parameters used for this analysis are the number of stories of the building, structural deficiency, and the level of seismic intensity that have direct impact on fragility of the structure. With the addition of number of stories and reduction of quality of material of structure results in incremental structural damage [5].

III.   RESEARCH METHODOLOGY
A.   Theoretical Framework
The methodology of study include a through literature review to develop the overall concept needed to meet the desired goal of the study. To get the objective of the study following methodology will be done. To accomplish the objective of the thesis work, first of all literature review of previous related work. Then collection of available drawing, material properties and earthquake data was done. After that preparation of simulation modeling of matepani gompa in SAP2000V19 has been done. Then determination of response of building in terms of displacement at different scale of PGA by time history analysis. Then generation of fragility curve at four damage state specified by HAZUS

technical manual for gompa. And after interpretation of result and conclusions were drawn. The basic aim of this research is to evaluate the seismic performance of the existing Religious buildings with developing the fragility curve.
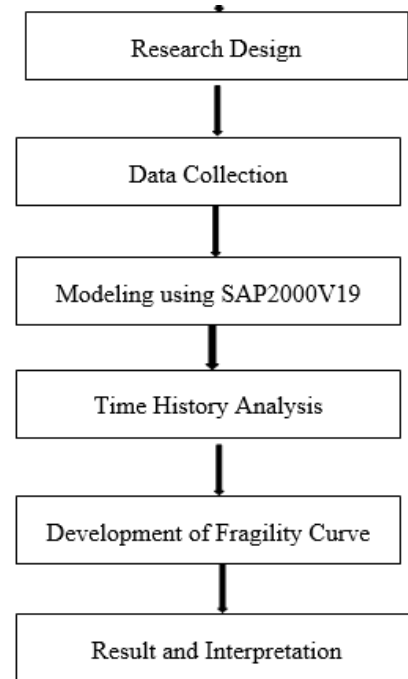

Figure 1 Flow Chart of the Study

B.   Data collection
Building Detail
Existing religious building of Pokhara valley is used for analysis. RCC four storey building is considered which named as Matepani Gompa. The building configuration is used to find the seismic behavior of building. Building analyze by a 3D space frame model. Which consisting of assemblage of slab, beam, and column elements. The buildings will be designed for gravity loads and evaluated for seismic forces. First floor plan on auto cad of Matepani Gompa is represented on Figure 2 and the dimensions shown are in feet and inches.

General detail of building
Number of model: 1
Number of Stories: 4
First storey Story Height: 5.1816m
Second storey Story Height: 4.2672m
Third and Fourth storey Story Height: 3.048m
Building frame system: RCC Frames Structure
Seismic zone: Zone V
Soil type: Soft soil
The details of Beam, Column and Slab size, reinforcement material properties are in Table 1.

TABLE 1   BUILDING SECTION PROPERTIES

Section	Size(mm)	Rebar	Grade of Concrete	Grade of Steel
Beam 1	300*405	2Ø20 3Ø16	M25.1	Fe 415
Beam 2	300*430	3Ø16	M25.1	Fe 415

		2Ø12		
Beam 3	230*355	3Ø12 2Ø12	M25.1	Fe 415
Column 1	380*380	4Ø20 4Ø16	M27.8	Fe 415
Column 2	230*230	4Ø16	M27.8	Fe 415
Column 3	380*380	4Ø25 4Ø20	M27.8	Fe 415
Column 4	300*300	4Ø20 4Ø16	M27.8	Fe 415
Column 5	300*300	8Ø20	M27.8	Fe 415
Column 6	300*300	6Ø16 2Ø12	M27.8	Fe 415
Slab	125mm thickness		M28.5	
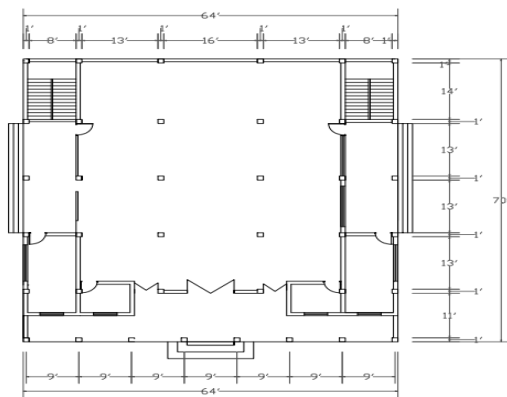
Figure 2First Floor Plan

Load Calculation

Dead load and live load are assigned and calculated as per IS875 part 1 and part 2.

Unit weight of masonry brick = 19 KN/m³

Live load in roof accessible =1.5 KN/m²

Live load in roof inaccessible =0.75 KN/m²

Live load on Staircase and hall room = 3 KN/m²

Live load in small room = 2 KN/m³

Load calculation of Brick masonry wall:

Brick masonry wall 230mm thick of first floor = 18.11KN/m

Brick masonry wall 230mm thick of second floor = 14.92KN/m

Brick masonry wall 110mm thick of second floor = 7.58KN/m

Brick masonry wall 230mm thick of third and fourth floor = 10.65KN/m

Brick masonry wall 110mm thick of third and fourth floor = 5.4KN/m

Brick masonry parapet wall 230mm thick =3.93KN/m

Schmidt Hammer Test

The concrete test hammer is used to measure the surface hardness of any concrete mass. The compressive strength of nearby concrete mass is determined by results of test made with the instrument. The test is nondestructive therefore it is a simple, speedy and convenient method. The digital concrete test hammer D-7000 is used to test compressive strength of concrete mass.

C. Modeling of Structure

For the modeling of the matepani gompa, the finite element analysis software SAP2000V19 is used to create 3D model and run for all analyses. The software can identify the geometric nonlinear behavior of structure under static or dynamic loadings, considering both geometric nonlinearity and inelastic material.

Matepani Gompa is belonging to Pokhara area is considered. The building was modeled in SAP2000V19 and subjected to earthquake loadings. For any given earthquake load, gompa may undergo certain deformation. Buildings in reality during earthquake may experience several types of damages, but in this study the damage was idealized as the maximum top displacement of the buildings. Model on SAP2000 of Matepani Gompa are represented on Figures 3.
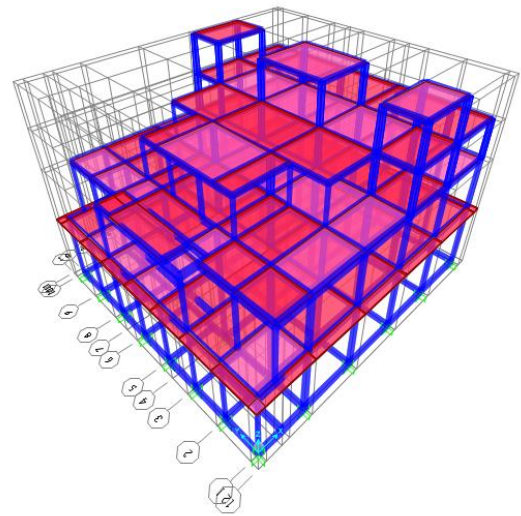

Figure 3   3D Model on SAP2000 of Matepani Gompa

D. Rapid Visual Assessment

In rural areas as well as in urban areas, the RVS methodology can be implemented. The reliability of RVS is more in urban areas than the rural areas due to the difference in construction practice. Hence the RVS methodology shall be used for non-governmental or non-standard construction with adequate precaution in rural areas. The RVS method should be only used for buildings. For the structure other than building such as bridge, detail evaluation method should be done. The weak forms of non-engineered buildings in urban areas which are vulnerable to very low seismic event are also excluded from RVS procedure for the estimation of vulnerability [6].

The estimated probable damage based on RVS score is illustrated below. There are numerous factors that depend on actual damage, which are not included in the process of RVS. Therefore the table shown below should be used as a reference to estimate the simplified vulnerability assessment of the buildings. It can also demonstrate the requirement of renovation and retrofitting of the vulnerable building where comprehensive assessment of the vulnerability cannot be carried out [6].

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TABLE 2 EXPECTED DAMAGE LEVEL AS FUNCTION OF RVS SCORE (FEMA, 2015)

RVA Score	Damage Potential
S < 0.3	High probability of Grade 5, Very high probability of Grade 4
0.3 < S < 0.7	High probability of Grade 5, Very high probability of Grade 3
0.7 < S < 2.0	High probability of Grade 5, Very high probability of Grade 2
2.0 < S < 3.0	High probability of Grade 5, Very high probability of Grade 1
S >3.0	Probability of Grade 1 damage

The Basic score for the building typologies of the study area = 2.6

Score modifier for the building typologies of the study area = -2.2

The Final score for the building typologies of the study area= 0.4

Classifications of damage grade of RCC Building using EMS [7]:

Grade 1: Negligible to slight damage

Grade 2: Moderate damage

Grade 3: Substantial to heavy damage

Grade 4: Very heavy damage

Grade 5: Destruction

E. Structure Analysis of the Structure

Ground Motion Data

For conduction linear time history analysis different ground motion data is required. In this research work the three selected Accelerogram had been scaled to the required PGA and then nonlinear time history analysis of the Buildings for the scaled Accelerogram had been conducted.

The predominant frequency of EL Centro earthquake, Chamoli earthquake, Kobe earthquake and Gorkha earthquake are 2.66 Hz, 1.17 Hz, 0.59 Hz and 0.265 Hz.[8]

TABLE 3 PGA(G) OF ACCELEROGRAM USED FOR TIME HISTORY ANALYSIS

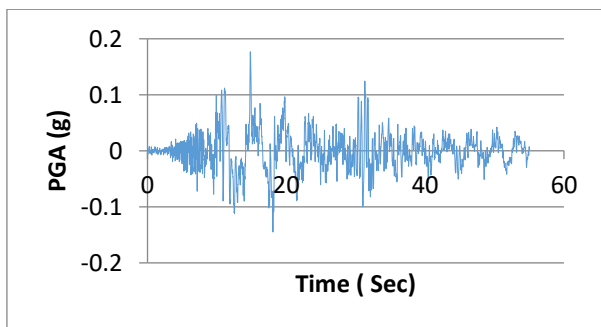| S.N.	Accelerogram Name	PGA (g)
1	Gorkha	0.177
2	Kobe	0.3447
3	Chamoli	0.4356
4	El Centro	0.3188

Figure 4 Time History Graph of Gorkha recorded at Kantipath Station (Department of Mines and Geology, 2017)
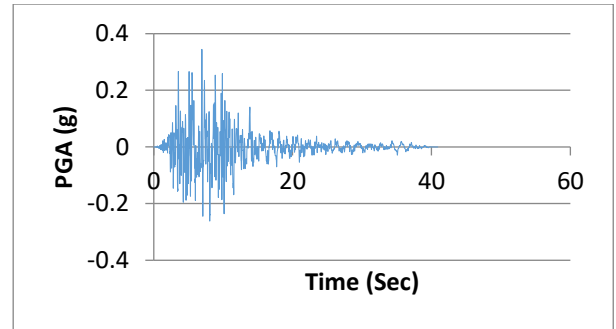

Figure 5 Time History Graph of KOBE (PEER Ground Motion Database)
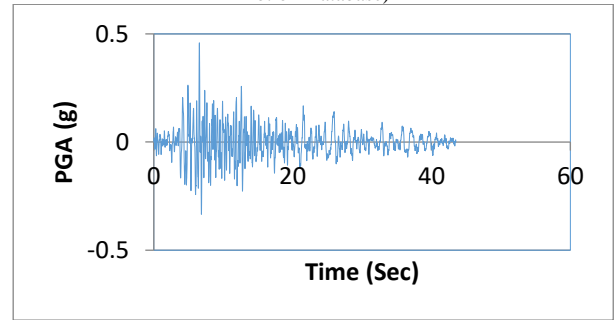

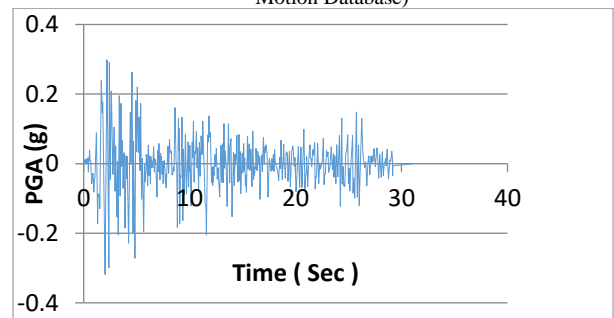Figure 6 Time History Graph of Chamoli (PEER Ground Motion Database)

Figure 7 Time History Graph of El Centro (PEER Ground Motion Database)

Time History Analysis

Linear time history analysis was conducted to determine building response. The demand for the building for the PGA was determined as the maximum displacement at the top of the building as obtained from time history analysis. On the basis of the displacement values Fragility Curve is to be plotted to determine the seismic vulnerability of the building.

Fragility Analysis

Fragility curve in this study were constructed to correlate the cumulative probability of failure P(f), with increasing value of demand displacement(Sd) based on obtaining the best fitted log-normal distribution function of equation, which was defined by the median and standard deviation parameters Sc and β respectively.[9]

$$P(f) = \phi \left[\frac{ln\left(\frac{Sd}{Sc}\right)}{\beta} \right]$$

Where,

ϕ = the normal cumulative distribution function.

Sd = demand displacement of the building.

Sc = capacity displacement of the building.

β = the standard deviation of the natural logarithm of spectral displacement of damage state.

Demand displacement is taken from the output data of time history analysis in SAP2000 and capacity displacement is taken from the HAZUS technical manual. The damage states of structure in the analysis are adopted as recommended in HAZUS. Four damage state namely Slight, Moderate, Extensive and Complete are recommended for analysis. Structural limit states are expressed in terms of spectral displacement. It is further assumed that the total variability of each equivalent PGA structural damage state, β is modeled bye the combination of two contributors to damage variability, uncertainty in the damage state = 0.4 and variability in response = 0.5. β is log standard deviation that represent the total uncertainty. It is simply the square root sum of the square combination of individual variability terms which is equivalent to 0.64.[10]

The four damage states were used as the capacity of the building [11], as follows:

(1) Slight Damage, Capacity = 0.7dy
(2) Moderate Damage, Capacity = 1.5dy
(3) Extensive Damage, Capacity = 0.5(dy+du)
(4) Complete Damage, Capacity = du

Where,

dy = Yield Displacement = 0.26 inch

du = Ultimate Displacement = 1.946 inch

C3M = Concrete Frame with Unreinforced Masonry Infill Wall Building having roof height greater then 50 feet and less then 120 feet

IV. RESULTS AND DISCUSSIONS

A. Fragility Analysis

The demand displacement of religious building (matepani gompa) for various PGA values of different earthquake are estimated by time history analysis. The results of fragility analysis are graphically shown in Figure 8 to Figure 11, which showed the probability of failure with respect to varying intensities of earthquake (PGA) at different damage state namely slight, moderate, extensive and complete. Fragility curve were been generated at four different earthquake namely El Centro, Kobe, Chamoli and Gorkha earthquake to consider multitude scenario of earthquakes of different amplitude. From the analysis of model fundamental frequency for matepani gompa was 1.02036 Hz.

TABLE 4   CODE BUILDING CAPACITY CURVE-MODERATE CODE SEISMIC DESIGN LEVEL (HAZUS, 2004)

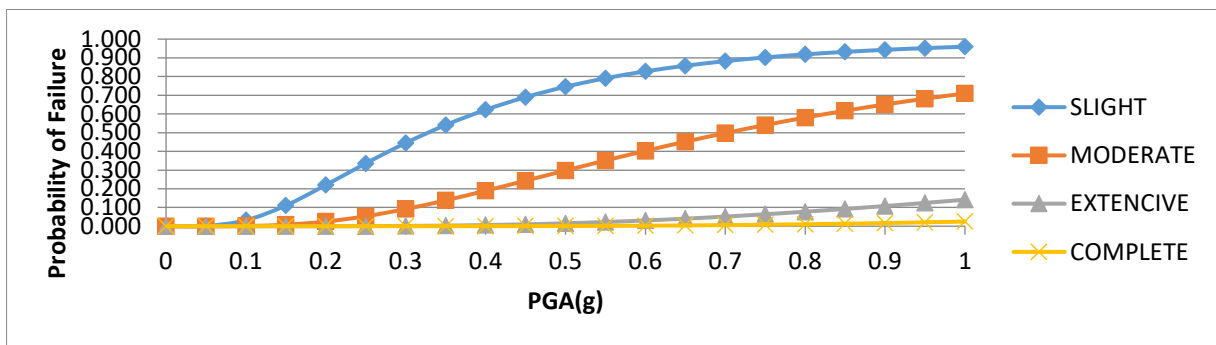| Building Type	Yield Capacity Point		Ultimate Capacity Point	
	Dy (in)	Ay (g)	Dy (in)	Ay (g)
C3L	0.12	0.100	1.349	0.225
C3M	0.26	0.083	1.946	0.188
C3H	0.735	0.063	4.134	0.143

Figure 8   Fragility Curve of Matepani Gompa for Various Damage State at EL Centro Earthquake
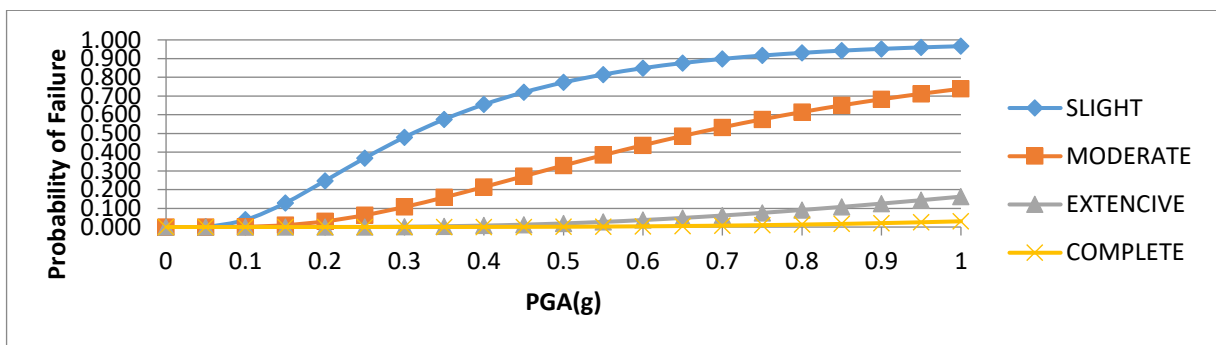

Figure 9   Fragility Curve of Matepani Gompa for Various Damage State at Kobe Earthquake
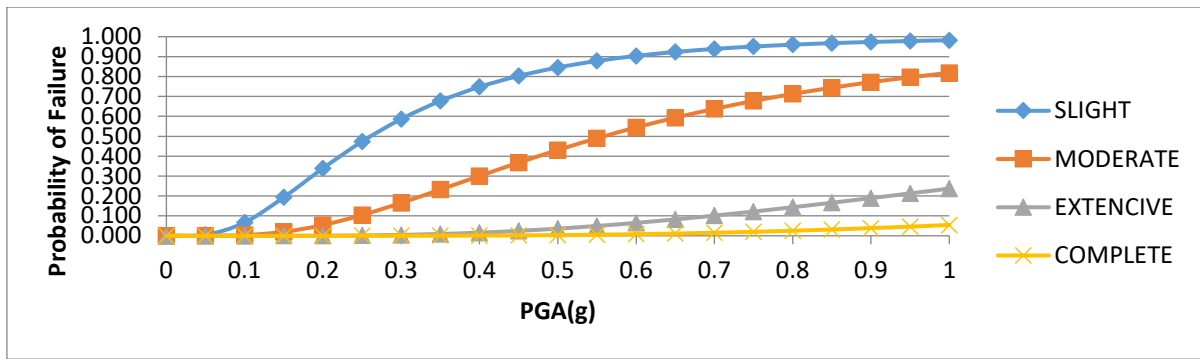
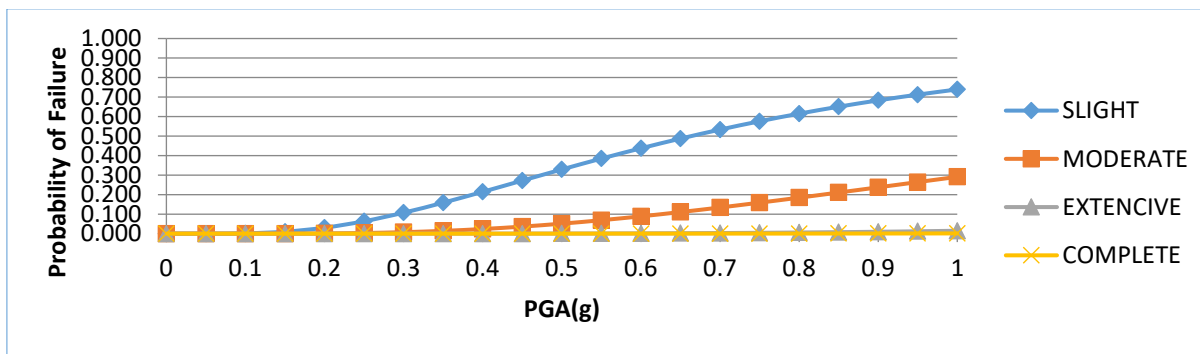*Figure 10   Fragility Curve of Matepani Gompa for Various Damage State at Chamoli Earthquake*

Figure 11   Fragility Curve of Matepani Gompa for Various Damage State at Gorkha Earthquake

B. Discussion

It has been found that, the expected peak ground acceleration (PGA) for 10 % and 5% probability of exceedance in 50 years (return period 475 years) was obtained between 0.22-0.50g and 0.30-0.64g, respectively in Nepal.[12]

Therefore, probability of failure of the building was observed at the PGA value of 0.45g. Probability of failure of building at different damage state during various earthquake scenarios was determined from fragility analysis of the building. The results in order to compare are tabulated on Table 5.

TABLE 5   PROBABILITY OF FAILURE OF MATEPANI GOMPA

Earthquake	Probability of Failure at PGA = 0.45g in percentage				Damage State
	Slight	Moderate	Extensive	Complete	
EL Centro	69	24.3	1	0.1	Slight
Chamoli	80	36.7	2.5	0.2	Slight
Kobe	72	27.2	1.3	0.1	Slight
Gorkha	27.2	3.6	0	0	Slight

From Table 5, For EL Centro earthquake, it was seen that the matepani gompa had 69% chance of experiencing slight damage, 24.3% chance of experiencing moderate damage, 1% chance of experiencing extensive damage and complete damage had 0.1% chance of occurrence. For Chamoli earthquake, it was seen that the gompa had 80% chance of experiencing slight damage, 36.7% chance of experiencing moderate damage, 2.5% chance of experiencing extensive damage and 0.2% chance of experiencing complete damage. For Kobe earthquake, it was seen that the gompa had 72% chance of experiencing slight damage, 27.2% chance of experiencing moderate damage, 1.3% chance of experiencing extensive damage and complete damage had 0.1% chance of occurrence. For Gorkha earthquake, it was seen that the gompa had 27.2% chance of experiencing slight

damage, 3.6% chance of experiencing moderate damage and no chance of experiencing moderate damage and complete damage. Analyzing these results, it was found that probability of failure for matepani gompa corresponds to slight damage state, as the probability of failure exceeds 50%.

It can be observed that the probabilities of damages were really low in case of Gorkha earthquake and higher in case of Chamoli earthquake. This could be somehow be explained by the frequency content of the earthquake. In case of predominant frequency of Chamoli earthquake is 1.17 Hz that was near to the range of fundamental frequency of matepani gompa (1.02036 Hz).   Therefore, higher demand was expected and hence higher probability of damage.

In case of predominant frequency of Gorkha earthquake, that was 0.256 Hz that was very less than the fundamental frequency of gompa. Therefore lower demand was expected and hence less probability of damage.

In case of predominant frequencies of El Centro and Kobe earthquakes are 2.66 Hz and 0.59 HZ respectively.

C. RVS Method Results

The results of the vulnerability assessment of the gompa by RVS methods:

According to EMS damage grade of Matepani Gompa = Grade 3.

According to FEMA 154 damage grade of Matepani Gompa = High probability of Grade 5, Very high probability of Grade 3.

The results of rapid visual assessment indicate that the damage grade of matepani gompa is grade 3.

V. CONCLUSION AND RECOMMENDATION

A. Conclusion

Field survey, data collection and documentation were undertaken as a part of the research work. The historic matepani gompa was taken for analysis and modeled in SAP2000V19. Fragility curve which define the probability of gompa sustaining slight, moderate, extensive and complete damage state due to earthquakes had been presented in this report. Four Accelerogram (El Centro, Chamoli, Kobe and Gorkha) were employed in the construction of fragility curve to take into account the multitude earthquake scenarios. These curves were useful in determining the probabilities of damage and making rational decision on retrofitting of the gompa. Moreover, these curves could also be used for the further study such as earthquake losses estimation which is helpful for earthquake preparedness plans. The major conclusions are as follows:

1. Maximum top displacement of a matepani gompa was found to be different for different earthquakes records. This variation was due to the variation in the frequency content, duration and peak amplitude of the earthquake record.

2. For 0.45 PGA, gompa was obtained different percentage of probability of failure at damage state for different earthquakes. Those earthquakes having dominating frequencies near to that of fundamental frequency of the gompa resulted in higher vulnerability.

3. The gompa was suffered from Gorkha earthquake but result from analytical method did not match with the result from RVS method. This was due to the fact that RVS method does not consider other factors on the building performance when the ground shaking is very intense.

B. Recommendations

1. The obtained result demonstrates that religious matepani gompa was found slight vulnerable was shown in fragility analysis and moderate vulnerable was shown in RVS method. So stability of soil shall be checked and foundation of gompa shall be strengthened.

2. From the RVS method, it is found that severe damage in infill wall due to lack of sill and lintel band, providing those band could increase the safety of gompa.

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