Research Journal of Engineering Sciences ISSN 2278 – 9472
Vol. **8(1),** 1-9, January **(2019)** *Res. J. Engineering Sci.*

Comparative study of structural cost and seismic vulnerability of seismic resistant RC Building

Ramesh Gnawali[*], Govind R. Bhatta and Khem N. Poudyal
Nepal Engineering College, Bhaktapur, Nepal
rg.ster02@gmail.com

Available online at: www.isca.in, www.isca.me
Received 8th October 2018, revised 12th January 2019, accepted 25th January 2019

Abstract

There are many world heritage sites in Nepal. Their seismic vulnerability study is very important for their conservation. Such type of reinforced concrete frame buildings is located in the cultural site Patan Lalitpur. The seismic vulnerability of existing buildings due to different earthquake is determined in terms of fragility curves. Capacity is determined from pushover analysis as top displacement by defining formation of plastic hinges for dominant mechanism and linear dynamic response analysis is carried out using ground motion time histories of different earthquakes for response. One of the major conclusions of the study is the probability of failure, in general, of the studied reinforced concrete buildings lies between 6.16% to 56.99% for peak ground acceleration of 0.3g. Buildings of various categories are selected for the analysis by looking into number of stories, floor area, structural configuration, location and construction materials. Structural analysis is done in finite element based software SAP2000 v14. Although From the analysis it is found that total cost of the buildings are not significantly different but in existing construction major structural component of building, columns are seen unsafe, beams are over safe. It can be concluded that only cost will not increase the strength of the building but the proper design is also equally important.

Keywords: Structural cost, vulnerability, RC modelling and fragility curves.

Introduction

Assessment of seismic performance of building is to know the behaviour during the earthquake event. However, the economic losses associated with the past earthquakes were unacceptably large, as many structures were found with damage that was too costly to repair. Hence the performance assessment of buildings under earthquake loads needs a detail insight to understand the appropriateness of designed procedures[1]. In this study design is necessary for to fulfil the acceptance criteria of reinforced concrete framed buildings. For the structural engineers today the earthquake has become the threat for the safe design of the structures. Since it is difficult to predict and measure the casualties caused by the earthquake. It is even too difficult to measure the losses. Concerning the major structures building is the one of the most important structures for the human beings. In this study damage is predicted based on the basis of modal building type and loss of function and casualties[2,3]. Buildings are analyzed on the basis of their loads and their effects. In addition, the loss is occurring due to the failure of the structure[4,5].

Problem statement: Although Nepal is very severe to earthquake, there is no practice to establish damage evaluation during earthquake with doing the structural analysis. So it is difficult to predict the damage factor at present situation. There is no proper design and better supervision for construction to safe the property and people. So that it is urgent to analyse such types of buildings for to safe property and people[6].

Need of study: Almost all of the historical monuments and buildings still today in Nepal are constructed without following the codes of Practice recommended by the present engineering standards. So to make people aware of the behaviour of the structure during seismic force this study is needed. Also the study helps to make amendment of the code of Mandatory Rule of Thumb[6,7]. The people are unwaring of the possible hazards that may occur during the earthquake so this study is needed to estimate the risk of the structures. Besides, to find the safe, unsafe building with different design process and structural cost this study is essential[8,9].

Literature review: Various available literature and research reports related with the study are reviewed. In general the literature is classified into those related with safety check and structural cost comparison study[10,11].

Building structures: The research site is historical and architectural which is called Newari society. Those societal buildings are reinforced cement concrete structures. Selected residential houses can be into two categories. One is traditional and other one is modern house. Most of the traditional Newari houses are three or four stories high. Foundations of these houses are usually shallow and made out of stones. The superstructure is constructed with locally available unburned bricks and mud mortar[12,13].

The typical reinforced concrete house of the area is usually three or four stories high. These types of houses are simple rectangular, L-shape, regular grid and irregular grid.

Categorization of building: Different parameters are used for categorize the building. This make easy to analyze the building and compare with the each category as shown in Table-1.

Table-1: Analyze the building and compare with the each category.

Types	Numbers
Raw brick mud masonry	67
Stone mud masonry	31
Burn brick mud masonry	259
Stone cement masonry	64
Brick cement masonry	130
Frame structure	359
Others	5

Material properties: A survey is conducted in ward no 12 of Lalitpur, Patan, an oldest society of Patan. Survey of about 885 buildings existed in area is done by Lalitpur Municipality. This table shows the types of building according to material used for construction as shown in Figure-1.

Methodology

The vulnerability analysis of the existing building which is historically important for their future prevents. Loss due to earthquake is deals about the people, property of partial or total loss. From the above table, it indicates that three hundred fifty-nine of the buildings are reinforced concrete buildings. So it is predominant over masonry buildings. Hence proper design is given more priority[14,15]. In this research process at the first selection of area. After selection of area, buildings are categories in the different section. Then one sample building is taken from each category. Each sample building is model by using sap 2000. The flow chart of the methodology is given below in Figure-2.

Building Modelling: Some common and few general buildings are selected for the detail modelling. Then the selected models are analysed by using structural software SAP 2000. One of the sample building by using Kobe's data and its calculated values of different parameters is as shown in Figure-3, Table-2, Table-3 and Table-4.

Results and discussion

The probability of failure is analyzed on the basis of peak ground acceleration 0.3g to the El Centro, Chamauli, Kobe and Lalitpur and finally they are found (18.35% to 53.52%), (11.84% to 48.03%), (6.16% to 15.58%) and (6.92% to57.0%) respectively for same PGA. The probability of failure due to seismic input Lalitpur is highest and that of Kobe is lowest generally for PGA 1.0g of different earthquakes, most of the buildings have the probability of failure greater than 90%. It is found that beams designed as per drawing and as per mandatory rule of thumb are over-safe than that from proper design. When the safety of the column are observed and compared with each other among the methods applied in the research it is seen that column design as per drawing and as per MRT are unsafe then that for proper design and the cost of steel for column are compared with each other among three methods, It is higher from proper design than from MRT and DWG. It is because the columns designed from MRT and DWG are unsafe than the columns designed properly.

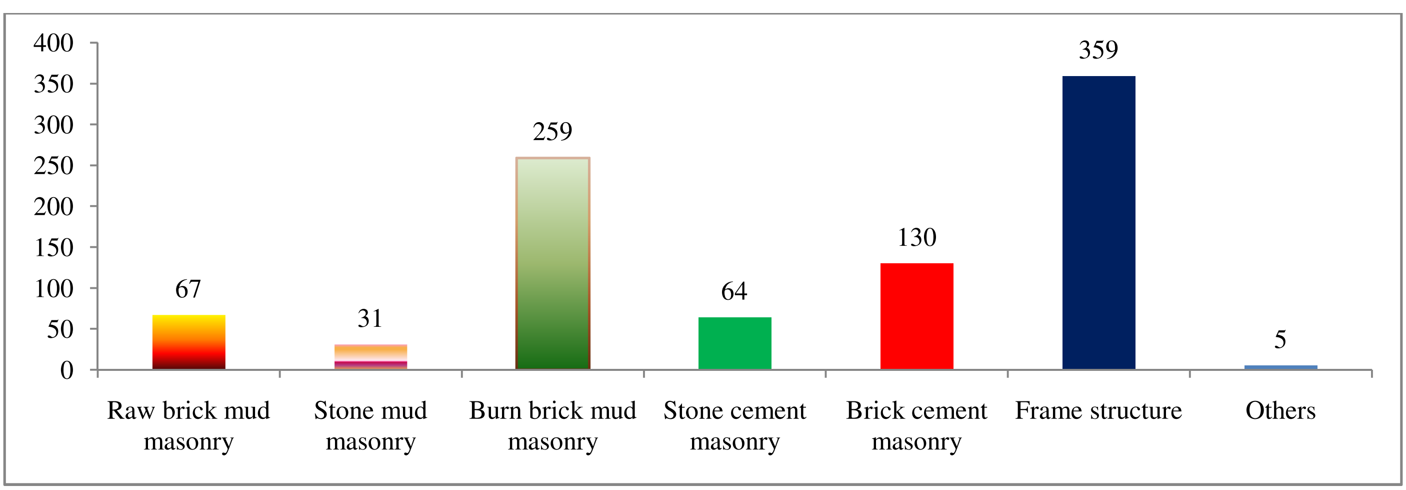

Figure-1: Types of building according to material used for construction.

Survey of buildings in selected area
(Review of the literature related to the vulnerability analysis of the existing buildings)

⇓

Categorization of buildings
(During survey check list format was used to note the data for each building in the survey area)

⇓

Selection of representative building

⇓

Computer modelling
(Capacity of building is determined by pushover analysis setting certain limit state)

⇓

Response of the building is determined by linear time history analysis and
Comparison of area of steel and cost of steel for beam and column from design output

⇓

The output of analysis is obtained in terms of storey displacements
Then analytical fragility curves are developed from the probabilistic seismic response model and capacity calculated for defined damage states
And also
Comparison of safety of building in three methods (as per design, as per drawing and as per mrt)

Figure-2: Methodology.

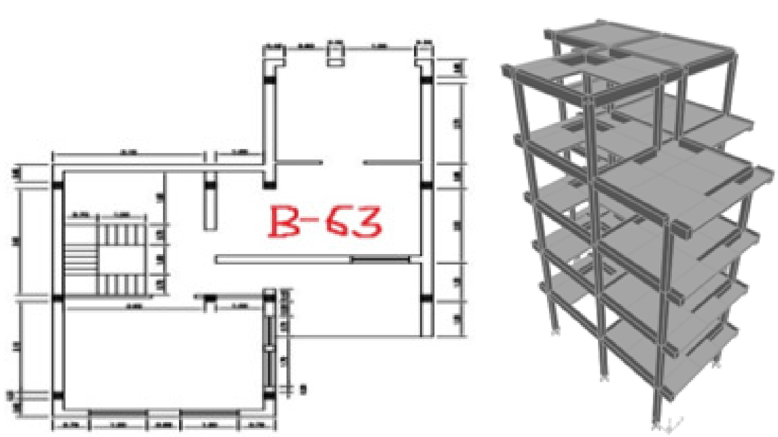

Figure-3: Calculated values of different parameters.

Table-2: Sample building by using Kobe's data.

Building B63				
PGA 0.3g				
Storey level	Height (m)	Displacement (mm)	Drift ratio (%)	Base shear(KN)
Ground	0	0	0	754.76
First	2.7	15.01	0.556	
Second	5.4	30.13	0.56	
Third	8.1	42.17	0.446	
Fourth	10.8	53.59	0.423	
Fifth	13.5	58.5	0.182	
PGA 0.45g				
Storey level	Height (m)	Displacement (mm)	Drift ratio (%)	Base shear(KN)
Ground	0	0	0	1150.23
First	2.7	22.52	0.834	
Second	5.4	45.2	0.84	
Third	8.1	63.26	0.669	
Fourth	10.8	80.39	0.634	
Fifth	13.5	87.76	0.273	
PGA 0.6g				
Storey level	Height (m)	Displacement (mm)	Drift ratio (%)	Base shear(KN)
ground	0	0	0	1509.6
First	2.7	30.02	1.112	
Second	5.4	60.27	1.12	
Third	8.1	84.34	0.891	
Fourth	10.8	107.19	0.846	
Fifth	13.5	117.01	0.364	
PGA 1.0g				
Storey level	Height (m)	Displacement (mm)	Drift ratio (%)	Base shear(KN)
Ground	0	0	0	2116
First	2.7	50.04	1.853	
Second	5.4	100.44	1.867	
Third	8.1	140.57	1.486	
Fourth	10.8	178.66	1.411	
Fifth	13.5	195.03	0.606	

Table-3: Sample building by using Kobe's data.

PGA (g)	Max drift ratio (%)	Top displacement (mm)
0	0	0
0.3	0.56	58.5
0.45	0.84	87.76
0.6	1.12	117.01
1	1.87	195.03

Table-4: Sample building by using Kobe's data.

Building B63									
PGA	Top displacement (mm)					Probability of failure			
	Capacity	Demand							
		El Centro	Chamauli	Kobe	Lalitpura	El Centro	Chamauli	Kobe	Lalitpura
0	111.8	0	0	0	0	0	0	0	0
0.05	111.8	21.45	13.83	9.75	20.17	0.0049	0.0005	0.0001	0.0037
0.1	111.8	40.82	27.66	19.5	40.34	0.0577	0.0145	0.0032	0.0556
0.15	111.8	60.19	41.49	29.25	60.5	0.1667	0.0607	0.0181	0.1687
0.2	111.8	79.56	55.31	39	80.67	0.2975	0.1358	0.0499	0.3051
0.25	111.8	98.94	69.14	48.75	100.84	0.4243	0.2264	0.0974	0.436
0.3	111.8	118.31	82.97	58.5	121.01	0.5352	0.3206	0.1558	0.5492
0.35	111.8	137.68	96.8	68.26	141.17	0.6275	0.4109	0.2203	0.6423
0.4	111.8	157.05	110.63	78.01	161.34	0.7023	0.4934	0.2869	0.7167
0.45	111.8	176.43	124.46	87.76	181.51	0.762	0.5665	0.3526	0.7755
0.5	111.8	195.8	138.29	97.51	201.68	0.8094	0.6301	0.4154	0.8217
0.55	111.8	215.17	152.11	107.26	221.84	0.8468	0.6848	0.4742	0.8579
0.6	111.8	234.54	165.94	117.01	242.01	0.8765	0.7314	0.5284	0.8862
0.65	111.8	253.92	179.77	126.76	262.18	0.9	0.771	0.5778	0.9085
0.7	111.8	273.29	193.6	136.52	282.35	0.9187	0.8045	0.6225	0.9261
0.75	111.8	292.66	207.43	146.27	302.51	0.9337	0.8329	0.6627	0.9401
0.8	111.8	312.03	221.26	156.02	322.68	0.9456	0.8569	0.6987	0.9512
0.85	111.8	331.41	235.08	165.77	342.85	0.9552	0.8772	0.7309	0.96
0.9	111.8	350.78	248.91	175.52	363.02	0.963	0.8945	0.7595	0.9671
0.95	111.8	370.15	262.74	185.27	383.18	0.9693	0.9091	0.785	0.9729
1	111.8	389.52	276.57	195.03	403.35	0.9744	0.9215	0.8077	0.9775

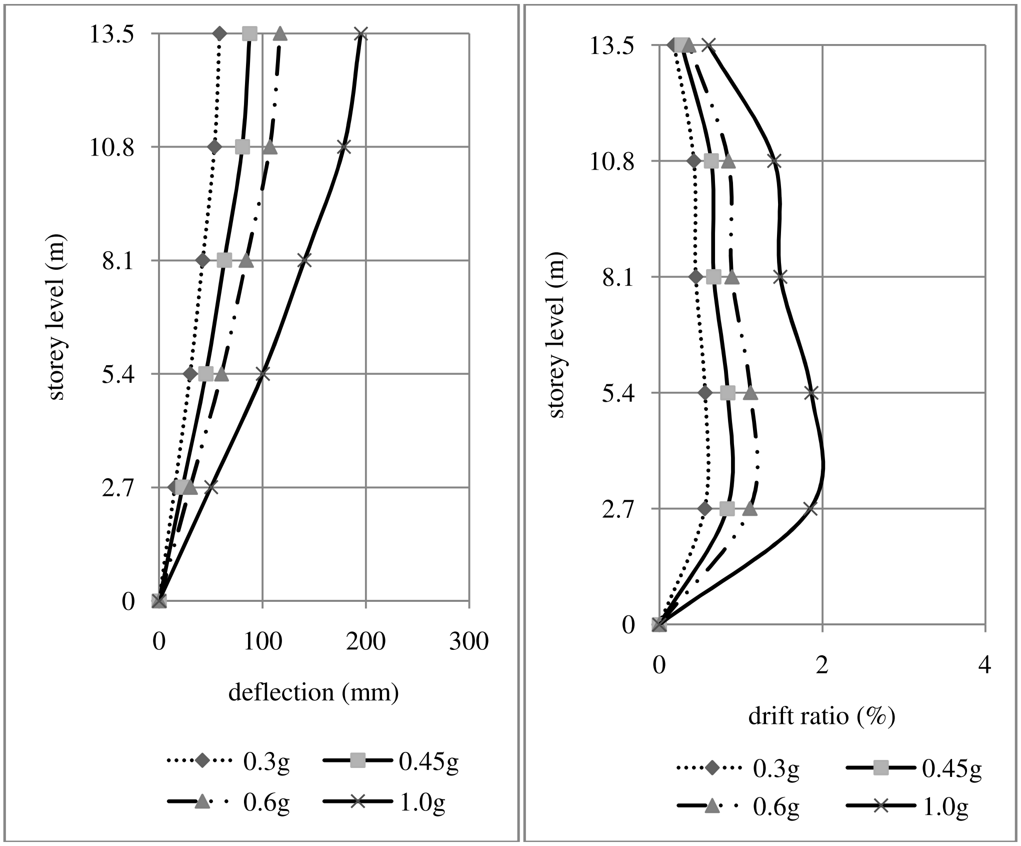

Figure-4: Sample responses plotted.

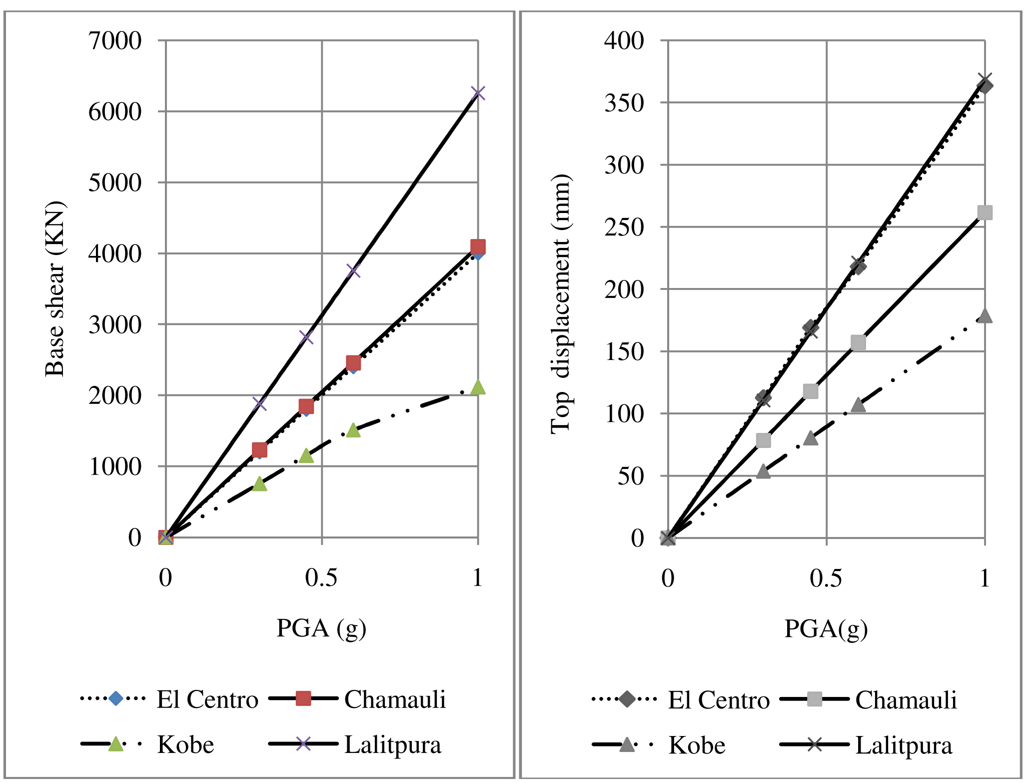

Figure-5: Earthquakes at different pick ground acceleration.

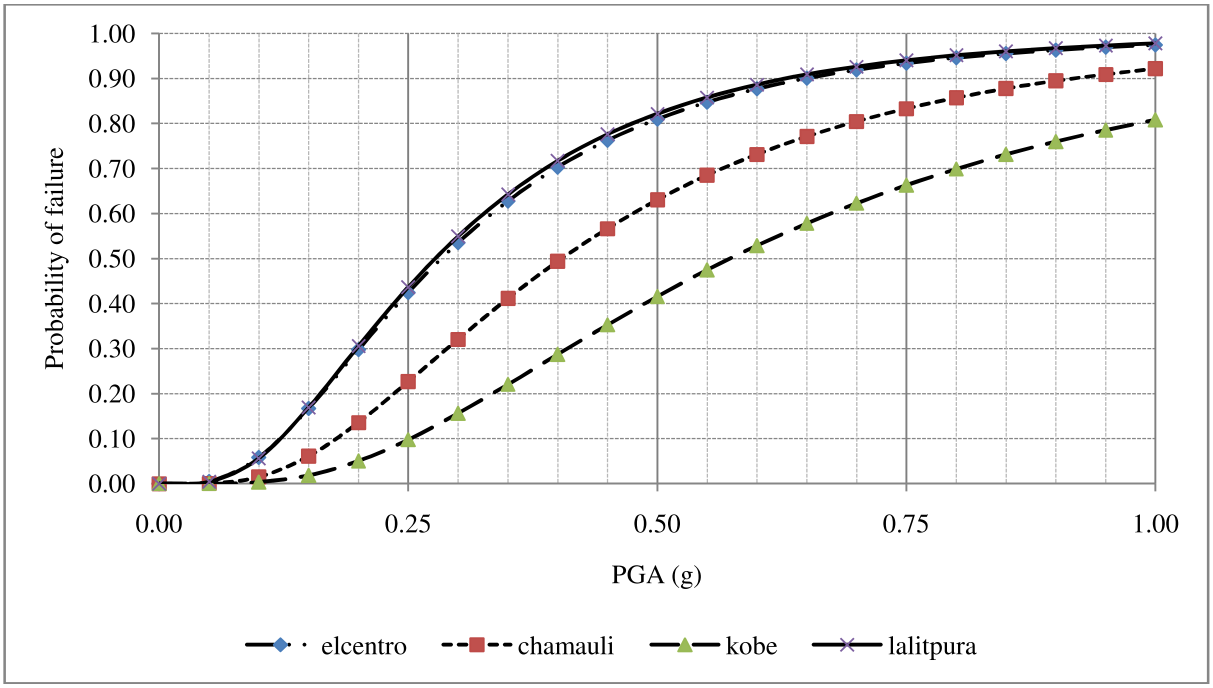

Figure-6: Cost of the buildings.

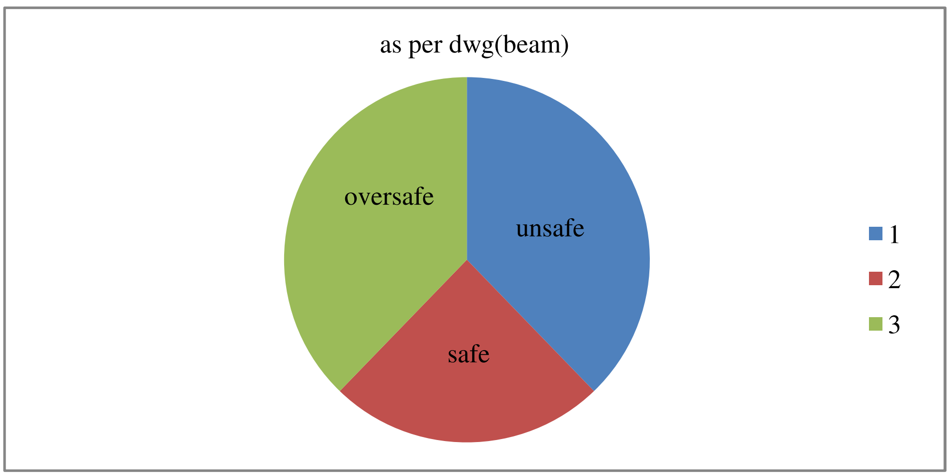

Figure-7: Cost of the buildings.

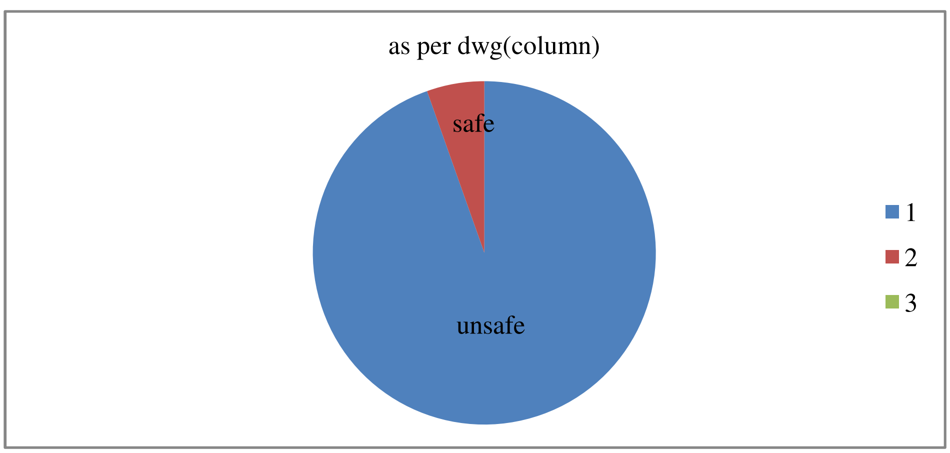

Figure-8: Cost of the buildings.

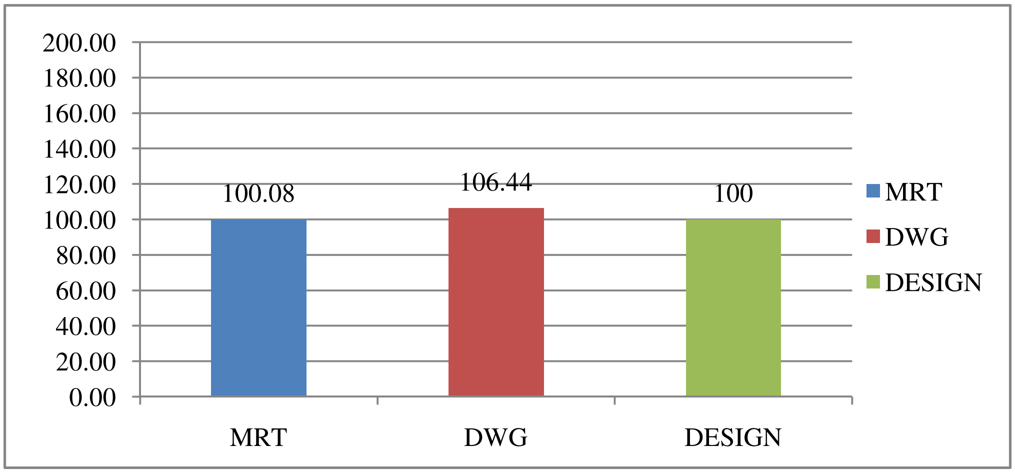

Figure-9: Percentage of total structural cost.

Conclusion

The response of the existing building structures to different earthquake time histories in terms of story displacements are found out. The obtained sample responses are plotted in Figure-4. Earthquake loading is given in the form of ground motion histories with varying level of peak ground acceleration. Fragility curves for the different level of earthquakes are shown in Figure-5 at different pick ground acceleration. Seismic vulnerability of the existing buildings can be quantified with the help of fragility curves. These curves give important information for pre-disaster planning and loss estimation of existing building stock due to future potential earthquake disaster. The cost of the buildings from as per drawing is not significantly varying with designed one as shown in Figure-6, 7, 8 and 9. It is concluded that the proper design is urgent for safe construction of the building.

Acknowledgements

Authors would like to extend their sincere gratitude to IOE Pulchowk Campus (Nepal) and special thanks to Prof.Dr. Prem Nath Maskey and Dr. Hariram Parajuli Department of Civil Engineering IOE Pulchowk. And also grateful to faculty members of the Department of Civil Engineering, Nepal Engineering College.

References

1. Chen W.F. and Scawthorn C. (2003). Earthquake Engineering Hand Book. CRC press, Boca Raton, Florida, United States.
2. Chopra A.K. (1996). Dynamics of Structures.(3rd ed). Prentice Hall of India.
3. Clough R.W. and Penzien J. (1993). Dynamics of Structure. (2nd ed). McGraw-Hill Inc.
4. Building Seismic Safety Council (US) and Applied Technology Council (1997). NEHRP guidelines for the seismic rehabilitation of buildings. Federal Emergency Management Agency, 1.
5. FEMA 310 (1998). Handbook for the Seismic Evaluation of Buildings. Federal Emergency Management Agency, Washington, D.C.
6. NBC (2004). Illustrated guideline for construction of earthquake safe residential building. Nepal Building Code.
7. HAZUS-MH MR3 (2003). Technical Manual. Department of Homeland Security Emergency Preparedness and Response Directorate, FEMA Mitigation Division Washington, D.C.
8. Hariharan R. (2012). Dhvani a text to speech System for Indian languages. Available: http://dhvani.sourceforge.net/. Accessed on 20 February 2012.
9. Ji J.U.N., Elnashai A.S. and Kuchma D.A. (2009). Seismic fragility relationships of reinforced concrete high-rise buildings. *The Structural Design of Tall and Special Buildings*, 18(3), 259-277. DOI: 10.1002/tal.408
10. Kircher C.A., Nassar A.A., Kustu O. and Holmes W.T. (1997). Development of building damage functions for earthquake loss estimation. *Earthquake spectra*, 13(4), 663-682.
11. Kramer S.L. (1996). Geotechnical Earthquake Engineering, published by Dorling Kindersley [India] Pvt. Ltd. *licensees of Pearson Education in South Asia*.
12. Naqvi T., Datta T.K. and Ramana G.V. (2001). Reliability Analysis of Building Frames for Seismic Forces. *Transactions, SMiRT 16*, Washington DC.
13. Ranganathan R. (1990). Reliability Analysis and Design of Structures. TATA McGRAW-Hill Publishing Company Limited, New Delhi, India
14. Asli A. (2008). A Comparative Study on Earthquake Resistance of Reinforced Concrete and Masonry Residential Buildings in Small-Scale Cities of Turkey

(Doctoral dissertation, Ph. D. Thesis, The Graduate School of Natural and Applied Science, Middle East Technical University, Turkey).

15. Mishra Vivek Kumar and Patel Rakesh (2018). Comparative non-linear analysis of bamboo concrete column and steel reinforced concrete column under axial loading using ANSYS. *Research Journal of Engineering sciences*, 7(7), 1-4.