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A Comparative Study on Seismic Analysis of National Building Code of Nepal, India, Bangladesh and China

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Abstract

The use of modern technologies in Civil Engineering is increasing in recent years. Due to the different aesthetic needs of people, the building of different shapes and sizes is in practice. Such building structure is more susceptible to seismic force. Numerous methods have been followed to reduce the severe effects. The shape of a building is one such method which changes the structural behavior. The objective of this research is to compare seismic properties of the seismic region of Nepal using Nepal, India, Bangladesh and China building codes provision for the same building structure with variations in the shape of a structure. Four different shapes of buildings are considered in the study and a comparison is made between different shapes of buildings against the effect of lateral loads due to the earthquake. Computer-Aided Design (CAD) is carried out to perform the relative comparison between different country building codes provision and focus on the effect due to building shape variation. In this study, countries along the Himalayan arc are chosen for a review of different seismic codes. A model RC building of four different shapes located in Nepal is analyzed by using Nepal Buildings Code (NBC 105, 1994), Indian Code (IS 1893-1, 2016), Bangladesh Code (BNBC 1993: 2014), and China Code (GB 50011: 2010). The responses of the building under the parameters like Response Spectrum Curve, base shear, time period, and absolute displacement are compared for all four codes. Based on the design base shear, China code showed a higher value compared with other codes because the design horizontal seismic force coefficient, base shear, and absolute displacement of China code are maximum than other codes. On varying the shape of a structure for base shear estimation, a similar pattern is observed. Hence, it can be concluded that shape has a negligible effect on the base shear of the structure.

Subject Areas

Civil Engineering

Keywords

Base Shear, Seismic Analysis, Displacement, Seismic Design Provision, Comparative Study

1. Introduction

Earthquake is a great challenge in the field of civil engineering, which causes severe damage and suffering to the human being such as collapsing many structures, trapping or killing persons, blockage of transport systems, animal hazards, etc. However, as designers, civil engineers play a key role in minimizing damage through proper structural design and making a useful decision by understanding earthquakes, behavior of building materials and reinforced concrete structures [1]. Since Nepal lies on active seismic belts and is vulnerable to earthquakes; the determination of earthquake forces on a structure by static analysis has gained popularity in Nepal and also in other countries due to the simplicity of the method. During the analysis using different software and country codes, all other loads seem constant but earthquake load varies [2] [3]. To calculate the earthquake load, generally, NBC and Indian standard seismic codes are followed in Nepal. These codes use different return periods which gives different base shears, drift and axial force for the same structure [4] [5] [6]. The selection of appropriate codes based on safety and economic factor is crucial in construction. Thus, this research aims to compare the specification of seismic design forces between NBC and other earthquake codes of different countries including India, Bangladesh, and China.

Seismic building codes are guidelines for the design and construction of buildings and civil engineering works in seismic areas. The reason is to protect human lives from the worst conditions that occur during an earthquake, to limit damage and to sustain operations of important structures for civil protection. Different codes use different load and material factors (or strength reduction factors) to design the members, and therefore the strength actually provided in the different codes may not correspond to the same pattern as the design base shear. Furthermore, as noted above, the drift may govern the design in many cases, resulting in further discrepancies in the actually provided strength [7] [8] [9]. The study area for this research is the seismic region of Nepal. The country lies above the border of the active Eurasian and Indian tectonic plates, and this is the main reason for earthquakes to occur at different intervals in Nepal. Nepal is surrounded by China in the north, India in the other direction and Bangladesh as a neighboring country. The codes of these countries also include the seismic region of Nepal and hence can be used to estimate and compare the seismic parameters of Nepal as well. A comparative study among different codes for single symmetric and asymmetric structures has already been studied [4]. However, there is no previous study that focuses on the effect of building shape variation using country code of Nepal, India, Bangladesh and China. Therefore, the main objectives of this research are:

1) To compare analysis output in terms of response spectrum curve, seismic coefficient, storey drift, and base shear;

2) Code comparison on response to an earthquake, with the effect of building shape variation (rectangular, L-shape, box, and octagonal).

2. Methodology

2.1. General Description of Model Study

This thesis is primarily a numerical study of the effect of building shape on the response to an earthquake. Four different shapes of buildings are considered in this study and a comparison is made between different shapes of buildings against the effect of lateral loads due to the earthquake. Building shape "**Figure 1**" and "**Figure 2**" is selected as these shapes are common in Nepal; Building shape "**Figure 3**" is selected as this shape is very useful for educational purpose that, it has high performance in noise management; and building shape "**Figure 4**" is selected for an architectural purpose that, these structures get maximum lightening. A computer-aided analysis is carried out to perform the relative comparison with a focus on the effect in different building shapes. The following figures represent the shape of a building used in the study.

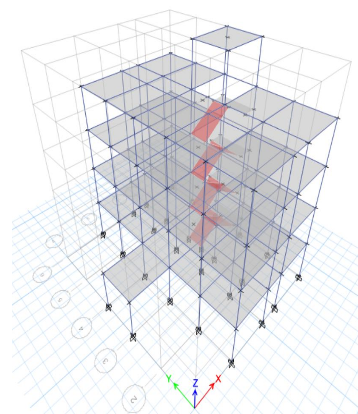

Figure 1. Rectangular shape.

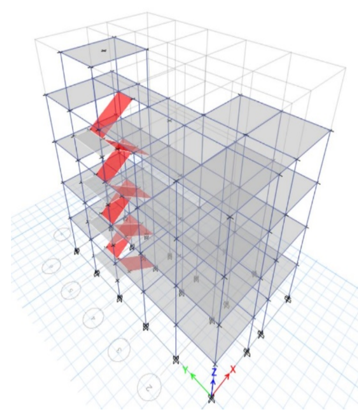

Figure 2. L-shape.

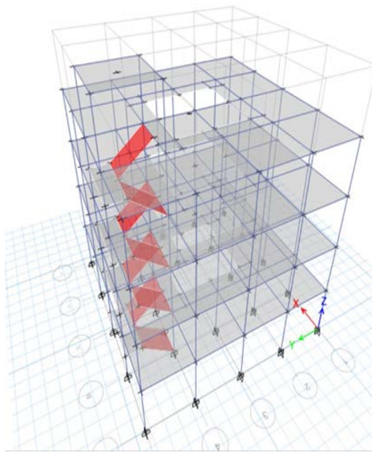

Figure 3. Box shape.

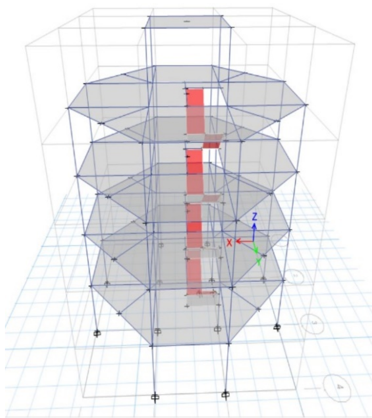

Figure 4. Octagonal shape.

2.2. General Features of Model Building

The building considered in the study is taken from the building which is in practice for the office and barrack block of Nepal Police. This structure is widely used throughout the country's police station. Building features used for the study are listed in Table 1.

2.3. Characteristic Strength of Materials

Properties of materials use for the building structure are listed in Table 2.

2.4. Loadings

Loading parameters and their standard value are listed in Table 3.

2.5. Method for Analysis

Following methods are used in the analysis of all shape of structure (rectangular. L-shape, box, and octagonal) [10]:

- Equivalent Lateral Force (Static) method;
- Response Spectrum (Dynamic) method.

Table 1. General description of the structure use in study.

Parameters	General Description
Type of building	Office Building
Structure system	RCC frame structure; Special moment resistant frame
Plinth area	Rectangle shape : 185.62 m^2 L-shape : 132.78 m^2 Octagonal shape : 110.94 m^2 Box shape : 196 m^2
No. of storey	4 (Four) storey + Stair cover
Floor to floor height	3.3 m
Types of Slab	125 mm thick; Two-way Slab, 150 mm thick staircase slab
Types of Beam	Rectangular main beam (350 mm × 450 mm) Rectangular secondary beam (225 mm × 350 mm)
Types of Column	Rectangular column(400 mm × 400 mm)

Table 2. Characteristic strength of materials.

Parameters	General Descriptions
Concrete	M20
Steel grade (f_y)	Fe500
Compressive strength of brick (f_b)	17.5 N/mm^2

Table 3. Loading parameters and their standard.

Parameters	General Descriptions
Self-weight of Building	As per Software (ETABS)
Floor finish	1.5 kN/m^2
DL wall (225 mm)	10 kN/m^2
DL wall (125 mm)	5 kN/m^2
Live load floor	3 kN/m^2
Live load staircase	3 kN/m^2
Live load Roof	1.5, 0.75 kN/m^2
Partition wall load	1 kN/m^2
Earthquake Load	as per codes adopted

2.6. Seismic Analysis of Model

The following assumptions and basic characteristics were considered to model building in ETABS software:

1) Column and beam elements are modeled as line elements whereas the floor slabs and concrete walls are modeled as shell elements.

2) All the joints (Beam-Column, Column-Foundation, etc.) are considered to be rigid joints.

3) Frames are connected by means of rigid diaphragms in a horizontal plane at each floor level.

All floor loads were applied to the deck which distributes uniformly the load to the beams.

3. Results and Discussions

The model building was analyzed using four different codes and the same parameters (like same soil condition, same PGA, same building member size, material, etc.) which was present in the actual site. In this way total of 32 cases were studied: four different shapes of the building, each with a different country code (Nepal, India, Bangladesh, and China), and each building was analyzed in two different methods: static method and dynamic method (response spectrum method). Different parameters required to calculate the base shear by different countries' codes are calculated and summarized in Table 4.

3.1. Comparison Based on Response Spectrum Curve

A response spectrum curve is generated for dynamic analysis (Response spectrum method). The respective code has their respective response spectrum curve and their equation. Using those equations, the period and acceleration are generated which is used to define the response spectrum function on software. The response spectrum curve of pre-defined four different codes of practice is presented graphically in Figure 5. Bangladesh building code gives the higher value for the acceleration followed by India, China and Nepal in the decreasing order.

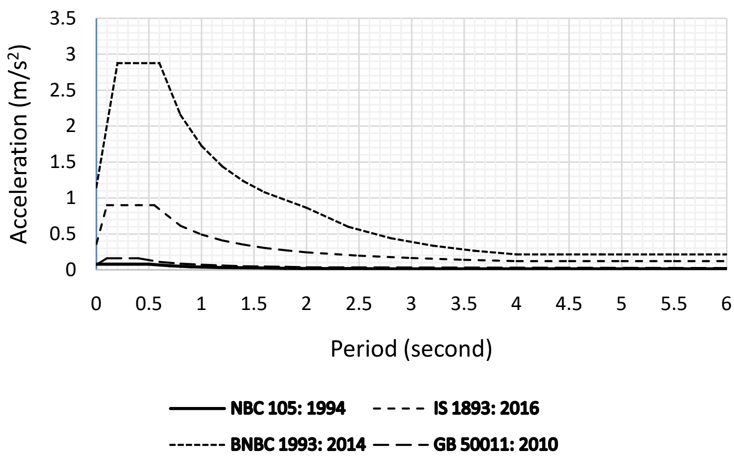

Figure 5. Comparison based on response spectrum curve.

Table 4. Code Procedure of four codes and their comparison.

Earthquake Parameters	NBC 105: 1994	IS 1893: 2016	BNBC 1993: 2014	GB 50011: 2010
Seismic Zone Factor (Z)	1	0.36	0.15	Intensity 8 0.2 to 0.3
Importance Factor (I)	1	1.2	1	$\eta = 1$
Response reduction/performance Factor (R/K)	K = 1	5	5	$\gamma = 0.9$
Soil Type	II	Medium	SC-dense or medium	For II, $T_g = 0.4$

3.2. Comparison Based on Time Period

Time period of building structure depends on the height of the structure. Different county code has a different formula to calculate the building time period. Table 5 gives the estimation of the time period of the structure. From this estimation, different standard gives different time period value due to different empirical formulae.

3.3. Comparison Based on Base Shear Coefficient

Design Horizontal seismic force coefficient parameter is mainly dependent on the time period of the structure. Time period depends on the height of structure [5]. In this study height of structure is the same for all models hence time period is also the same for all structures. So, design horizontal seismic force coefficient is the same for all shapes of structure in their respective code. From the Comparison of Base Shear Coefficient, it is found that Base Shear coefficient varies from 0.08 to 0.11. Design horizontal seismic coefficient is maximum as per Chinese code because of maximum acceleration coefficient and by Indian code, coincidently seismic coefficient for Nepal and Bangladesh code is an equal and minimum value among four codes which is presented in Table 6.

3.4. Comparison Based on Design Base Shear Force

Design base shear has a vital role in the seismic analysis as it influences all the analysis parameters of the structure. The comparison of the design base share is also the major objective of this study. In this section, the base shear force obtained from static and dynamic methods is compared along with the comparison between manually calculated and software-derived base shear [11].

In this analysis, as shown in Table 7, maximum base shear is obtained from Chinese code standards and minimum from Bangladesh and Nepalese code standards. In dynamic analysis with scale factor one, as shown in Table 7; maximum base shear is given by Bangladesh building code. Here scale factor to increase dynamic load is greater than one for Nepal, India and China but less than one for Bangladesh building code. Thus, for the structure used in this study, it's not mandatory for dynamic analysis as per Bangladesh building code. Structure doesn't meet the requirements for dynamic analysis as per Bangladesh building code. Hence, only static analysis is sufficient as per Bangladesh Building Code.

Based on Table 8, the base shear calculated manually is slightly more than calculated from ETABS. When the base shear is calculated manually only seismic weight of building is taken into account but when base shear is calculated using software, seismic weight along with their shape, base dimension, stiffness of structure, etc., are also taken into account. These cause variation between the two procedures.

Base shear for the rectangular shape model is calculated by using three procedures *i.e.* manually, by using ETABS and by using SAP which is presented in Table 9. The base shear obtained from SAP is maximum than the other two procedures. The difference between manually and ETABS estimated data lies between 0 to 1.99 percent such that the result obtained from ETABS is less than manually calculated value for base shear. The difference between manually calculated and SAP (for rectangular shape only) estimated data lies between 0 to 6.08 percent such that the value of base shear given by SAP is more than manually calculated base shear.

Table 5. Comparison on building time period.

Parameters	NBC 105	IS 1893	BNBC 1993	GB-50011
Building Time Period	$T = 0.06H^{\frac{a}{4}}$	$T = 0.075H^{0.75}$.	$T = C_t(h_n)^m$	0.1 * No of storey
Different shape Building with same Height (Time Period)	0.491	0.614	0.581	0.5

Table 6. Comparison on base shear coefficient.

Parameters	NBC 105	IS 1893	BNBC 1993	GB-50011
Design Horizontal seismic force coefficient	CZIK	$Ah = \frac{ZISa}{2Rg}$	$S_a = \frac{ZIC}{R}$	$\alpha = \left(\frac{Tg}{T}\right)^{\gamma} \eta 2 \alpha \max$
Different shape Building with same Height	0.08	0.103	0.08	0.11

Table 7. Comparison based on design base shear.

Model cases	NBC 105:1994		IS 1893:2016		BNBC 1993:2014		GB 50011:2010	
	Static	Dynamic	Static	Dynamic	Static	Dynamic	Static	Dynamic
Rectangle	819.1	60.0	1112.2	644.3	819.1	2039.9	1139.1	712.0
L-shape	640.6	41.8	869.3	478.8	640.5	1518.1	890.7	530.0
Octagonal	607.7	48.0	855.5	565.1	607.7	1732.5	845.1	604.2
Box	812.7	42.2	1097.0	812.6	812.6	1360.9	1130.1	552.6

Table 8. Comparison of base shear estimated manually and ETABS.

Model cases	NBC 105:1994		IS 1893:2016		BNBC 1993:2014		GB 50011:2010	
	Manually	Software	Manually	Software	Manually	Software	Manually	Software
Rectangle	834.2	819.1	1126.2	1112.2	834.2	819.1	1136.6	1139.1
L-shape	653.4	640.6	882.0	869.3	653.4	640.5	898.4	890.7
Octagonal	614.8	607.7	830.0	855.5	614.8	607.7	845.3	845.0
Box	826.6	812.7	1115.9	1097.1	826.6	812.6	1147.0	1130.1

Table 9. Comparison of base shear estimated Manually, ETABS and SAP.

Codes	Manually (kN)	ETABS (kN)	SAP (kN)
NBC 105:1994	834.20	819.09	866.94
IS 1893:2016	1126.18	1112.20	1171.43
BNBC 1993:2014	834.20	819.08	867.73
GB 50011:2010	1136.55	1139.09	1205.69

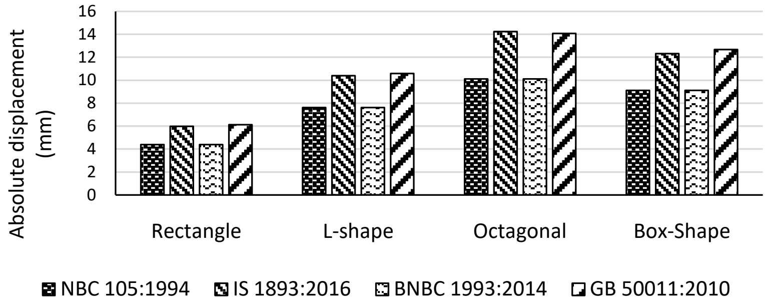

Figure 6. Graphical representation of absolute displacement in X-direction.

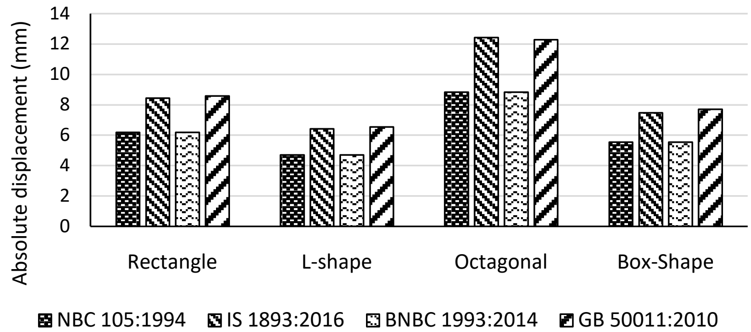

Figure 7. Graphical representation of absolute displacement in Y-direction.

3.5. Comparison Based on Absolute Displacement

The inter storey drift ratio is an important parameter to be considered in finding out the performance of a structure. Codes define the limit of the drift ratio for the performance level of the structure. For better performance of the structure minimum drift ratio is required. Storey drift ratio is linked with absolute displacement; finally, it has an effect on the performance of structure [12].

Figure 6 and Figure 7 represent drift in x- and y-direction respectively. Both direction drifts are maximum by using the lateral load obtained from the Chinese standard followed by Indian, Nepalese and Bangladesh standards in the decreasing order. The pattern of the drift is the same for all shapes of the structure.

4. Conclusions

The building has four different shapes considered in the study and a comparison is done between these buildings against the effect of lateral loads due to the earthquake. A computer-aid analysis is carried out to perform the relative comparison between building code provisions of different countries with a focus on the effect of the building shape. From a comparative study of four different codes on earthquake response analysis of RC structure which lies on the same Himalayan belt, the following conclusions are drawn:

1) Based on the design base shear, China code showed a higher value compared with other codes because the design horizontal seismic force coefficient of China code is maximum than other codes. Since NBC, IS and BNBC use response reduction but Chinese standard doesn't use a response reduction factor,

it has a maximum horizontal seismic coefficient.

2) On varying the shape of a structure for base shear, a similar pattern was observed. Hence, it can be concluded that shape has a negligible effect on the base shear of the structure.

3) From the comparison of the time period, it can be concluded that code provision time period of a building is different in different four codes and varies from 0.491 to 0.614. Based on the time period, India has a higher value while Nepal has a lower one.

4) The distribution of base shear at different floor levels is linear in Nepalese code and Chinese code but is distributed in a parabolic pattern in Indian code and in linear interpolation in Bangladesh code. Among predefined codes, IS 1893:2016 and BNBC 1993:2014 have provisions to scale up the base shear in dynamic analysis results if it is less than the static base shear. However, NBC 105:1994 and GB 50011:2010 are silent on this. In this study, the scale factor is greater than one as per India, Nepal and Chinese codes but less than one as per Bangladesh building code. So, dynamic base shear is not required to scale up according to BNBC.

5) Among the three procedures used in this study, maximum base shear is obtained from SAP analysis followed by a manual method and from ETABS analysis respectively.

6) Maximum drift for structure is given by Chinese standard followed by Indian standard, NBC and BNBC respectively.

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Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Bari, M.S. and Das, T. (2013) A Comparative Study on Seismic Analysis of Bangladesh National Building Code (BNBC) with Other Building Codes. *Journal of The Institution of Engineers* (*India*): *Series A*, **94**, 131-137. https://doi.org/10.1007/s40030-014-0053-3

[2] Dhanvijay, V., Telang, P.D. and Nair, V. (2012) Comparative Study of Different Codes in Seismic Assessment. *International Research Journal of Engineering and Technology*, **2**, 1371-1381.

[3] Singh, Y. and Khose, V.N. (2015) A Comparative Study of Code Provisions for Ductile RC Frame Buildings. 15*th World Conference on Earthquake Engineering*, **4**, 3012-3021.

[4] Landingin, J., Rodrigues, H., Varum, H., Arêde, A. and Costa, A. (2014) Comparative Analysis of RC Irregular Buildings Designed According to Different Seismic Design Codes. *The Open Construction & Building Technology Journal*, **7**, 221-229. https://doi.org/10.2174/1874836801307010221

[5] IS 1893 (Part 1) (2016) IS 1893 (Criteria for Earthquake Resistant Design of Structures, Part 1: General Provisions and Buildings). Bureau of Indian Standards, New Delhi, 1893, 1-44.

[6] Department of Urban Development and Building Construction (DUDBC), Government of Nepal, Ministry of Physical Planning and Works (1994) Nepal National Building Code NBC 105:1994 Seismic Design of Buildings in Nepal. Nepal National Building Code, No. 10.

[7] Tamrakar, A. and Chen, S. (2017) Comparison of the Seismic Design Code for Buildings of Nepal with the Chinese, European and American Seismic Design Codes. *The Thirtieth KKHTCNN Symposium on Civil Engineering*, Taiwan, 2-4 November 2017.

[8] Nahhas, T.M. (2017) A Comparison of Saudi Building Code with 1997 UBC for Provisions of Modal Response Spectrum Analysis Using a Real Building. *Open Journal of Earthquake Research*, **6**, 98-116. https://doi.org/10.4236/ojer.2017.62006

[9] Aryal, E.A. and Dhungana, E.S. (2020) Comparative Analysis of NBC with IS Code for RC Structures. International Research Journal of Engineering and Technology, **6**, 2113-2117.

[10] Bureau of Indian Standards New Delhi (2002) Criteria for Earthquake Resistant Design of Structures—General Provisions and Buildings Part-1. Bureau of Indian Standards, New Delhi, Part 1, 1-39.

[11] Itti, S.V., Pathade, P.A. and Karadi, R.B. (2012) A Comparative Study on Seismic Provisions Made in Indian and International Building Codes for RC Buildings. Vol. 3. https://www.sefindia.org/forum/files/a_comparative_study_on_seismic_provisions_made_in_indian_and_international_building_codes_for_rc_buildings_107.pdf

[12] Luo, K.H. and Wang, Y.Y. (2012) Researches about the Conversion Relationships among the Parameters of Ground Motions in the Seismic Design Codes of China, America and Europe. 15*th World Conference on Earthquake Engineering*, **36**, 103-107.