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Seismic Behaviour of Buildings as per NBC 105:1994, NBC 105:2020 and IS 1893:2016

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Abstract

A comparative study is performed between different RC Buildings as per Nepalese (Nepal National Building Code,NBC) and Indian (Indian Standard, IS) previously existing and revised standards with consideration of several design compliances. NBC 105:1994 was revised to NBC 105:2020 and also IS 1893:2002 to IS 1893:2016 which are used for RC building in current study.This paper presents the analysis of low-rise RC building of three storey and staircase cover. For the analysis Various response parameters are used using linear and non-linear static and linear dynamic approaches.The result obtained from the NBC 105:2020 was greater than the other codal provisions based on dynamic properties (time period, response reduction factor, overstrength, ductility) and seismic response (drift, displacement & base shear). The value of Base shear is higher by 104%, 116% and 157% in NBC 105:2020 than the other codal provisions NBC 105:2020 SLS, IS 1893:2002 and NBC 105:1994. The performance verification overestimate the value of performance limit state due to the due to the adaptation of latest seismic index in the estimation of the seismic hazard in NBC 105:2020.

Keywords

Nepal National Building Code (NBC), Indian Standard (IS), Seismic Analysis, Ultimate Limit State (ULS), Serviceability Limit State (SLS)

1. Introduction

RC buildings construction practice started around many decades ago as an alternative to traditional unreinforced masonry practice which doesn't satisfy the integrity and ductility criteria. As the national seismic codes are important to address the safety of buildings and occupants. It is noted that many buildings codes have some relationships and the differentiation lines can be easily drawn among the seismic codes too. Building code comparison especially in terms of seismic provisions have gained considerable momentum in the case of active seismic regions and help to form a most effective and economical building design. Nepal is a seismic prone zone and seismic activities are very frequent occur which is caused by the continental collision of Indian plates and Eurasian plates. The tectonic zone of Nepal is distinct and complicated with variance in topography and geology making it covered with major seismic activities in the past as 1988 A.D. and most recent of 2015 A.D. After major seismic event of 1988 A.D., Nepal National Building Code (NBC) in 1994 AD was formulated by Department of Urban Development and Building Construction (DUDBC). In 25th April 2015, a moment of magnitude Mw 7.8 earthquake struck at 11:56 local time followed by several strong aftershocks hits central and eastern part of the country. This earthquake with numerous aftershocks causes about 9000 deaths and more than 22,000 injured and a huge loss of lives and economy. Although, major seismic events occur within the country the use of the NBC 105:1994 still occurs. The code was still not revised since a long time although Indian code has been revised and question is been arise for the use of code. As there is introduction of NBC, there is use of IS code with no restriction on any policy level since the boundary of Nepal and India is along three directions with similar soil profile and tectonic environment. Considering the progressive study in the field of earthquake resistant design the revision of Indian Standard code IS 1893:2016 was developed. Considering the above facts, a draft of the new updated code has been proposed as NBC 105:2019 and finally NBC 105:2020 was implemented. In IS 1893:2016 and NBC 105:2020 major changes have been incorporated which should be well understood by practicing Engineers. So, an attempt is done to study the updated compliances codes and compare with the existing ones. Hence, the study is performed to compare the codal provisions with a numerical model created in ETABS.

2. Literature Review

This research focused on the comparison of seismic design codes, Nepal building code (NBC) and Indian standard (IS) both revised and existing in analysis and design aspect for the RC building structures with consideration of several design compliances. The results of the study show that the response of building is greater from the revised NBC 105:2019 as compared to other studied codal provisions. Longitudinal rebar percentage and the period of vibration is higher than the existing ones since the reduced stiffness as it considered crack section in both revised IS 1893:2016 and NBC 105:2019 [9].

In this research study it deals with the NBC 105:2019 Seismic Design of Buildings in Nepal which is the revised version of the original code NBC 105:1994. As there is various development in research and technology and new knowledge was learned from various large earthquakes in last 25 years, the Nepal A new seismic hazard map of Nepal was proposed at the based on probabilistic approach. The PGA values for various locations of Nepal were updated. The performance requirements have been inserted in terms of collapse prevention and damage limitation and there need to verify the performance requirements checking in terms of ultimate limit state and serviceability limit state. In this code two different spectra are proposed for seismic coefficient method and modal response spectrum method. The response reduction factors (Ductility factor and Overstrength factor) are introduced. The horizontal base shear coefficient will be is determined separately for ultimate limit state and serviceability limit state. The horizontal design spectrum for the modal response spectrum method is different for ultimate limit state and for serviceability limit state. This also includes to check the inter-story drift for both serviceability limit state and ultimate limit state [6].

Based on static and dynamic research of two-story and four-story RC buildings, this paper addresses the impact of the new code on seismic load estimation for low rise RC buildings. IS 1893:2002, IS 1893:2016, NBC 105:1994 and NBC 105:2020 were used in the study. The response of the buildings from the application of the four codes was compared based on numerous criteria such as time period, base shear, drifts, and story forces. The structural reaction of the structure under the new NBC 105:2020 is 60 percent to 65 percent higher than the NBC 105:1994, according to a comparison of the results based on several factors [7].

A history of seismic code development in Nepal, India, Japan, and the European code. NBC, IS, Japanese code BSLJ, and Euro code EC were compared in terms of base shear and fundamental natural period. Ground conditions, seismicity, construction technology, and the degree of seismic code development are all varied. EC and IS codes are recommended for usage in Nepal. When EC is employed in designs, it achieves the highest frequency of the four codes. Because NBC and IS produce the same basic period, a comparison of base shear shows that IS code has higher base shear than NBC. This may lead to variation in design of lateral load resisting system. This study set out to provide the account and comparison between four seismic codes. (Prajwal Giri, Anand Dev Bhatt, Dipendra Gautam and Hemchandra Chaulagain)

The comparative analysis of G+21 RC building for different soil category of NBC 105:1994 and IS 1893:2016 is computed. The seismic coefficient method shows higher base shear, displacement and reinforcement demand than the model response spectrum analysis. For soil type I and II, IS 1893:2016 gives higher base shear, displacement and drift than NBC 105:1994. For soil type III NBC 105:1994 give higher base shear, displacement and drift than IS 1893:2016. IS 1893:2016 gives higher reinforcement demand than NBC 105:1994 [4].

Structures in megacities are in great danger due to faulty and inexperienced design and construction. Structure designers are sometimes more concerned with constructing various load resistant members without understanding their necessity or performance in the structure. Different construction configurations may also result in significant variations in the capacity of the same structure. Nonlinear static pushover analysis provides a more accurate picture of structure performance during seismic events. This comprehensive study evaluates and compares the performance of bare, different infill percentage level, different configuration of soft story and Shear wall consisting building structures with each other, and then, based on the findings, suggests which building structures to use. Above all, the findings could be used to summarize a better understanding of the effects of pushover analysis. According to pushover concerned codes, masonry walls are represented by equivalent strut. The performances of structures are evaluated for various loading conditions using performance point, base shear, top displacement, story drift, and stages of number of hinges form [10].

3. Overview of Codal Provisions

For the overview of the codal provisions NBC 105:1994, NBC 105:2020 and IS 1893:2016. Each seismic code has its own set of analyzing parameters.

3.1 NBC 105:1994

NBC 105:1994 was developed on the basis of a probabilistic seismic hazard analysis with respect to Nepal's 150 km border. As per NBC 105:1994 it is not recommended for analyzing unusual structures such as power plants, bridges, dams, and structures taller than 90 meters. Seismic analysis is based on both the Working Stress Method (elastic method) and the Limit State Method, but in the case of RC buildings, the limit state design is preferred. It suggests using the basic seismic coefficient or modal response spectrum for each of the three subsoil types, Subsoil type-I, Subsoil type-II, and Subsoil type-III. The subsoil type is explained using representative undrained shear strength for cohesive soils and representative standard penetration resistance (SPT) values for cohesionless soils. The basic seismic coefficient (C) and the basic response spectrum C (Ti) for three types of subsoils per NBC are represented in Fig.1.

The structures having height more than 40 m height is analyzed with model response spectrum method but up to 40 m, seismic coefficient method is applied. There is no provision of time history analysis included in the code. The seismic weight at each level, Wi, shall be taken as the sum of the dead loads and the seismic live loads between the mid-heights of adjacent storeys. Seismic live load is based on the design live load as (a) up to 3 kPa 25 percentage is used of design live load (b) above 3 kPa and vehicle garages 50 percentage is used of design live load (c). For roofs nil. The approximate period of vibration for mode of buildings for the seismic coefficient method is based on the height of the building as shown in Table 6. For both seismic coefficient method (1) and response spectrum method (2), the horizontal seismic force coefficient is obtained as:

$$Cd = C\,ZIK \tag{1}$$

$$Cd\,(Ti) = C\,(Ti)\,ZIK \tag{2}$$

where, Cd is the lateral seismic force coefficient; C is the basic seismic coefficient for the translational period in the direction under consideration; Z is seismic zoning factor; I is the importance factor for buildings; K is structural performance factor; and C(Ti) is the ordinate of the basic response spectrum. The inter-story drift is limited to 0.01 when the inter-story drift to height of story ratio is considered and the maximum value of inter-story drift is limited to 60 mm. To calculate the horizontal seismic base forces in the following equations:

$$V = Cd\,Wt \tag{3}$$

where,
Wt is total gravity load above the lateral restraint;
Cd is the design horizontal seismic force coefficient

On the other hand, in the case of response spectrum analysis, the participation of at least 90 percentage of the total mass is considered.

3.2 IS 1893:2016

IS 1893:2016 was designed based on deterministic hazard analysis with respect to recorded time history data. It is the sixth revision adopted by Bureau of Indian Standard for Earthquake Resistant Design of Structures (BIS 2016). The design response spectra curve is extended to 6s while a constant value is depicted after 4 s. The effect of infill masonry is also included in the analysis of frame buildings in the revised version. The effect of vertical earthquake shaking is considered when the structure is located in seismic zone IV or V, structure have plan or vertical irregularities, rested on soft soils, bridges, long spans and having horizontal overhangs of structure members. For the calculation of seismic force, it considers equivalent static and dynamic analysis method. It recommends the use of the basic seismic coefficient or modal response spectrum as per three subsoil types, Subsoil type-I, Subsoil type-II, and Subsoil type-III as Hard, Medium and Soft soils. The design horizontal seismic coefficient (Ah) for three types of subsoils per IS are represented in Fig.2

Linear dynamic analysis is performed to obtain the design lateral force for all building, other than regular buildings lower than 15m in seismic zone II. Dynamic analysis may be performed by either the Time History Method or the Response Method. On either of the method, design base shear estimated shall not be less than the design base shears calculated using a fundamental period, Ta. The seismic weight at each level, Wi, shall be taken as the sum of the dead loads and the seismic live loads between the mid-heights of adjacent storeys. Seismic live load is based on the imposed load as (a) up to 3 kPa 25 percentage is used of imposed load (b) above 3 kPa 50 percentage is used of imposed load. The approximate period of vibration for mode of buildings for the seismic coefficient method is based on the height of the building as shown in Table 6. The design horizontal seismic coefficient (Ah) is calculated as:

$$A_h = \frac{ZIS_a}{2Rg} \tag{4}$$

where, Sa/g is the average response acceleration coefficient and is the ordinate of the basic response spectrum; Z is seismic zoning factor; I is the importance factor for buildings; R is response reduction factor. The inter-story drift is limited to 0.04 when the inter-story drift to height of story ratio is considered and the maximum value of inter-story drift is limited to 50 mm. To calculate the design seismic base forces in the following equations:

$$V_B = A_h\, W \tag{5}$$

where,
Ah is design horizontal seismic coefficient;
W is the seismic weight of the building

Response spectrum method may be performed for any building using the design acceleration spectrum using equation of Ah or by a site-specific design acceleration spectrum. The number of modes Nm to be used in the analysis for earthquake shaking along a considered direction, should be such that the sum of total modal masses of these modes considered is at least 90 percent of the total seismic mass. Peak response quantities (member forces, displacements, story shears, and base reactions) may be combined as per Complete Quadratic (CQC) method.

3.3 NBC 105:2020

The principal objective of revising national building code NBC 105:1994 Seismic Design of Buildings in Nepal to update it by endorse earthquake resistant design knowledge and technology acquired through out worldwide by the different countries. This codal provision covers the required parameters for seismic analysis and design of various building structures to be constructed in the territory of the Federal Republic of Nepal. This code is applicable to all type of building structures, low to high rise buildings, in general. This code is applicable to buildings made of reinforced concrete, structural steel, steel concrete composite, timber and masonry. A new seismic hazard map of Nepal is introduced based on probabilistic approach. The PGA values for selected cities/municipalities of Nepal were revised.

The performance requirement is introduced in terms of collapse prevention and damage limitation and also used to verify the performance requirements checking in terms of ultimate limit state and serviceability limit state. Hence, the main aim is to check life safety and damage limitation performance requirements. Four types of site sub soil category are used. Very soft soil category is added in addition to previous NBC 105:1994. This new soil category represents a very deep soft soil found in Kathmandu valley. This code introduces the non-linear methods of analysis. The empirical formulae for determination of fundamental translation period is revised and Rayleigh method is introduced. The calculated period of vibration is multiplied by amplification factor 1.25 and tabulated in Table 6. The structural performance factor is calculated by interpolation. The importance factors, load combinations for both the parallel and non-parallel and load factors are revised. The response reduction factors (Ductility factorand Overstrength factor) are introduced. Two different spectra are used for seismic coefficient method and modal response spectrum method. The horizontal base shear coefficient will be determined separately for ultimate limit state and serviceability limit state and shown in Figure 3.

$$Cd(T1) = (C(T1))/((R)(Wu)) \tag{6}$$

$$Cd(T1) = (Cs(1))/Ws \tag{7}$$

Where,
Cd(T1) = Elastic Site Spectra for Ultimate Limit State
Cs (T1)) = Elastic Site Spectra for Serviceability Limit State
R= Ductility Factor
Ωu = Over strength Factor for Ultimate Limit State
Ωs = Over strength Factor for Serviceability Limit State
The horizontal seismic base shear at the base of the structure in the direction is calculated as:

$$V = Cd(T1)W \tag{8}$$

Where,
Cd(T1) = Horizontal base shear coefficient
W = Seismic Weight of the structure

The Vertical Distribution of Seismic Forces induced at each level 'i' shall be calculated as:

??? (9)

Where,
Wi = seismic weight of the structure assigned to level 'i';
hi= height (m) from the base to level 'i';
n= total number of floors/levels
V= horizontal seismic base shear

The horizontal design spectrum for the modal response spectrum method is also different for ultimate limit state and for serviceability limit state. A separate section on structural irregularity has been added. This code includes checking the inter-story drift for both ultimate limit state and serviceability limit state as 0.025 and 0.006.

Response spectrum method is performed as the combination of modal effects (such as story shear, moment, drift, displacements) shall be carried out using an established method such as Square Root of the Sum of the Squares (SRSS) or the Complete Quadratic Combination (CQC) method or any other generally accepted combination methods. Modes shall be considered to be closely spaced if their frequencies are within 15 percentage. For such modes, if the SRSS combination method is used, the modal action effects from any modes shall be first combined by direct summation ignoring any signs.

4. Aims and Scope

The aim of this research work is to observe and evaluate the response of the buildings and analyzed as per NBC 105:2020, NBC 105:1994 and IS 1893:2016. The primary objectives are as follows:

1. To evaluate the performance of buildings with all significance structural parameters based on the effect of variation on shape and size in response to earthquake.

2. To evaluate the performance of buildings using linear and nonlinear static analysis procedures.

5. Methodology

Five different shape and size RC residential buildings were taken in consideration for the modeling. These different buildings were analyzed and a comparison is made between different shape and size of buildings against the effect of lateral loads due to the earthquake. This research mainly deals with a numerical study of the effect of different shape and size RC building on the response to the earthquake. These structures are widely used throughout the Nepal for the residential purposes. This section includes the material property and section property used for the analysis of the structure. Building features used for the study are listed on Table 1 and building model are shown in Figure 4, 5, 6, 7 and 8.

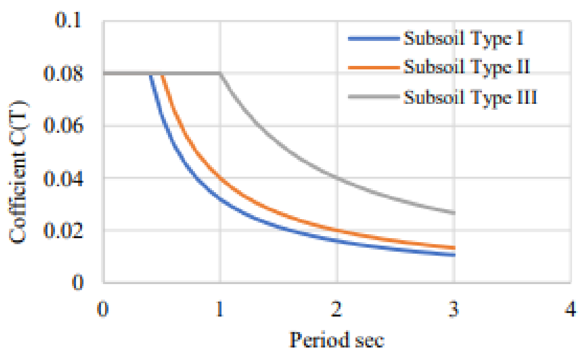

Figure 1: Building-1 Structure used for analysis

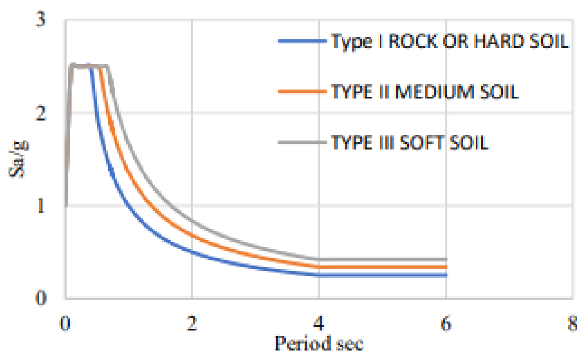

Figure 2: Building-2 Structure used for analysis

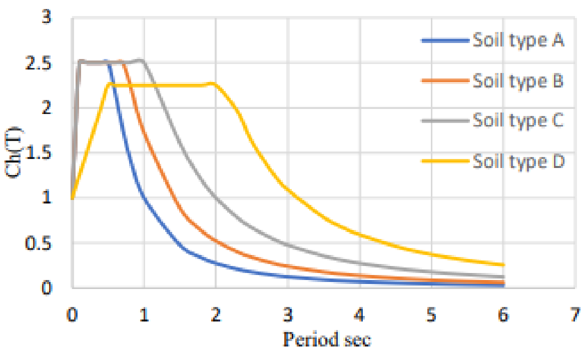

Figure 3: Building-3 Structure used for analysis

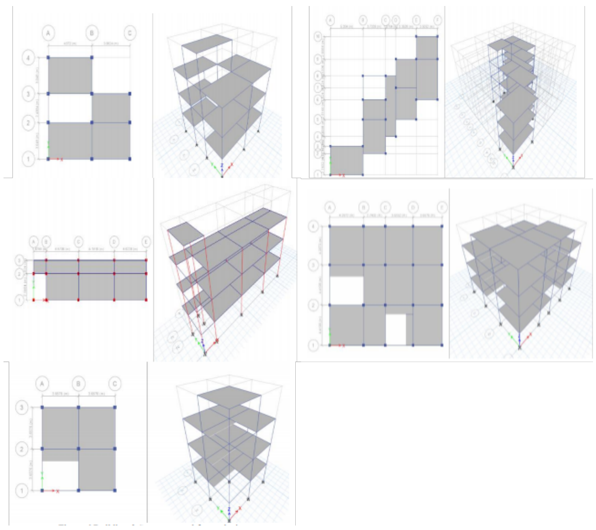

Figure 4: Building-4 Structure used for analysis

Table 1: General features of the building use in study

Type of building	Residential Building
Structure system	RCC frame structure; SMRF
Plinth area	Building-1: 77.458 m^2 Building-2: 210.613 m^2 Building-3: 58.058 m^2 Building-4: 67.980 m^2 Building-5:135.340 m^2
No. of story	3 (Three) story+ Stair cover
Floor to floor height	3 m
Types of Slab	125 mm thick; Two-way Slab, 150 mm thick staircase slab
Types of Beam	Rectangular main beam (230mm×450mm)
Types of Column	Rectangular column(300mmx300mm)
Materials	Cement, Brick, Sand, Rebar etc.
Unit weight of brick	19.2KN/m^3
Grade of Concrete	M20
Grade of Steel	Fe500
Method of analysis	Static and dynamic

The seismic loads for selected RC buildings models were calculated by following the respective codal provision NBC 105:2020, NBC 105:1994 and IS 1893:2016. The selected building models are not in regular in geometry, mass, and stiffness. The initial lateral stiffness of a building is essential to its overall response. The amount of lateral load resisted by individual building members is determined by their lateral stiffness; stiffer elements attract more force than flexible ones. Furthermore, adequate overall stiffness in a building is required to control overall lateral displacement during earthquake shaking. As a result, uniform distribution of stiffness in a building is essential to ensuring uniform distribution of lateral deformation and lateral forces across the plan and elevation of a building. As, the buildings used for the analysis are different in shape and size. Thus, the mass of the buildings is different from each other's. So, both the equivalent static method and response spectrum method are used for computation of base shear coefficient. The step by step procedure for the calculation of seismic load and its distribution among different floors as provided in NBC 105:2020, NBC 105:1994 and IS 1893:2016 are explained in the overview section and calculation is done in result section.

The research deals with the numerical modeling. For linear analysis NBC 105:2020 stipulates the use of the elastic flexural and shear stiffness properties of the cracked concrete elements through rational analysis. However, in absence of such analysis, the effective stiffness of the cracked section shall be used and the all other respective properties code is given in Table 2.

In this study, no rational analysis was made to evaluate the elastic flexural and shear stiffness properties of the cracked concrete section so effective stiffness of cracked section was used in the analysis.

The dead loads used in the calculation is used from Indian standard for computation of dead load (IS 875 (Part 1):1987) and live loads were used using Indian standard for computation of Imposed load (IS 875 (Part 2):1987). The seismic loads were calculated following as per their respective codal provisions. The detailed procedure for the calculation of seismic loads is explained in detail in overview section. The seismic load was combined with gravity load using the load combination given in NBC 105:2020 and all the load combination of respective codes is shown in Table 3.

The estimation of base shear for both the regular and irregular buildings is obtained by response spectrum analysis using the response spectra curve. The curve having the values of acceleration and times as per the respective codes. The Modal Response Spectrum Method may be used for all types of structures and the structures where Equivalent Static Method is not applicable. A three-dimensional analysis shall be performed for torsional sensitive structures. The procedure for the calculation of the base shear and other parameters using respective codes are provided in the literature review section. The design of the prototype building is performed according to IS 456:2000 for all the models. The loads considered in the analysis is as per IS 875 Part(II). The general loading parameters used in the study and their standard value are listed on the Table 4.

The structural performance of the building during an earthquake can be verified in different ways. The structural performance can be evaluated from a local level or global level structural response. The local level structural response includes component stress-strain, component rotation or curvature, story drift, and so on. Similarly, the global structural response includes the drift limit of the roof or other reference points, structural stability indices, and so on. The respective codes having different inter-story drift limit for performance verification which is shown in Table 5. The earthquake-resistance design philosophy includes that the structure should have sufficient strength and stiffness to resist moderate earthquake, damage limitation objective and structure must be detailed to ensure that the probability of collapse in a severe earthquake. Life safety objective are verified by the SLS and ULS respectively as per NBC 105:2020. The SLS for ordinary buildings is based on earthquake ground motion with a return period of 20 years. Similarly, the ULS for ordinary buildings is based on earthquake ground motions with a return period of 475 years.

The drift value for the ULS is obtained by multiplying the horizontal deflection found from the Equivalent static method or Modal response spectrum method by the Ductility factor. Similarly, the drift value for the serviceability limit state is obtained by taking equal to the deflection obtained from the Equivalent static method or Modal response method.

Table 2: Performance requirement as per respective codes

Performance limit state	Inter-story drift limitation
NBC 105:2020 (ULS)	0.025
NBC 105:2020 (SLS)	0.006
NBC 105:1994	0.0012
IS 1893:2016	0.004

Pushover analysis is a static, nonlinear procedure in which the magnitude of the lateral force is incrementally increased, maintaining the predefined distribution pattern along the height of the building. With the increase in the magnitude of the loads, weak links and failure modes of the building are found. Pushover analysis can determine the behavior of a building, including the ultimate load and the maximum inelastic deflection. Local Nonlinear effects are modeled and the structure is pushed until a collapse mechanism gets developed. At each step, the base shear and the roof displacement can be plotted to generate the pushover curve. It gives an idea of the maximum base shear that the structure was capable of resisting at the time of the earthquake. For regular buildings, it can also give a rough idea about the global stiffness of the building.
The material model used in the static Nonlinear pushover analysis is based on the procedures proposed by the documents, defining force – deformation criteria for the hinges used in the pushover analysis. Figure 2 describes the typical force-deformation relation proposed by those documents. Five points labeled A, B, C, D and E are used to define the force deflection behavior of the hinge and these points labeled A to B – Elastic state, B to IO- below immediate occupancy, IO to LS – between immediate occupancy and life safety, LS to CP- between life safety to collapse prevention, CP to C – between collapse prevention and ultimate capacity, C to D- between C and residual strength, D to E- between D and collapse ¿E – collapse.

Table 3: Force-Displacement Curve in Push over Analysis, Image Source: http://research gate

			IS 1893:2016	NBC 105:1994	NBC 105:2020
Effective Stiffness (RC)	Beams	Flexure	$0.35E_c I_g$	$E_c I_g$	$0.35E_c I_g$
		Shear	$E_c A_w$	$E_c A_w$	$0.4 E_c A_w$
	Columns	Flexure	$0.7 E_c I_g$	$E_c I_g$	$0.7 E_c I_g$
		Shear	$E_c A_w$	$E_c A_w$	$0.4 E_c A_w$

6. Results and Discussion

The response of the building is analyzed by using linear static and linear dynamic approaches for the different codal provisions. The response parameters under comparison were response spectrum curve, base shear, time period of vibration, maximum displacement, inter story drift, eccentricity. Response-spectrum analysis (RSA) helps to understand the dynamic behavior by measuring spectral acceleration as a function of structural period as per the height of the building and level of damping.

The prediction of displacements and member forces in structural systems is one of the computational benefits of using the response spectrum method of seismic analysis. Using smooth design spectra that are the average of several earthquake motions, the method calculates only the maximum values of displacements and member forces in each mode. The response spectrum curve of pre-defined three different code of practice is presented graphically in Figure 10. NBC 105:2020 and IS 1893:2016 building code gives the same value for the acceleration followed by NBC 105:1994 in the decreasing order. As, the design acceleration coefficient for the different types of soil depends upon the peak ground acceleration corresponding to time period of structures in IS 1893:2016 and in case of NBC 105:2020 lower and upper time period, peak ground acceleration and coefficient that controls the descending branch.

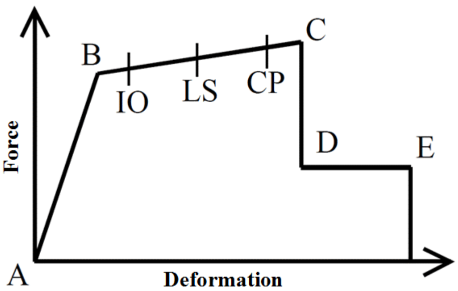

Figure 5: Comparison based on Response Spectrum Curvee

Time period of the structure depends on stiffness and on the mass of the structure. With increase in height of structure the time period is higher showing the flexibility of the structure. Usually several codal provisions provides the fundamental period of vibration (approximate) which depends upon the height of the structure. The estimated time period doesn't depend upon the shape and size of the structure. For the analysis for torsional effects, the applied torsion at each level is based on the eccentricity allowed for providing the severe effect on lateral force resisting elements.

The design horizontal base shear coefficient parameter mainly dependent on the time period of the structure as the time period of the structure depends on the height of building to be analysis. Here we consider same height of the structure for all five model hence time period is also same for all structure as per their respective code. So, design horizontal seismic force coefficient is same for different structure in their respective code. From the Comparison of Base Shear Coefficient, it is found that Base Shear coefficient varies from 0.08 to 0.125. Hence, the design horizontal seismic coefficient is maximum as per NBC 105:2020 ULS because of consideration of latest hazard index followed by NBC 105:2020 SLS, IS 1893:2106 and NBC 105:1994 minimum value among four codes since the response reduction factor for NBC 105:20220 ULS is only 6 and NBC 105:20220 ULS is 1.25 while the response reduction (2R) considered in IS 1893:2016 is 10 which is presented in Table 6.

The effect of these base shear coefficients on the design result, however, cannot be judged solely on the value of the base shear coefficient values. Because the load combination used in NBC 105:2020 differs significantly from that used in NBC 105:1994 and IS 1893:2016. When the seismic load is combined with the gravity load, NBC 105:2020 considers only one factor, whereas the other two codes assume a factor of up to 1.5. The base shear coefficient has a direct effect on the lateral deformation caused by lateral loading in the direction of the earthquake attack, which is used as a performance verification method in the respective codes. So, due to the differences in load combinations used, the base shear coefficient alone may not affect the design output results. However, the design procedure such as capacity design may affect the result; however, the base shear coefficient directly affects the amount of lateral deformation induced by the design level of earthquake loading.

Design base shear has a vital role in the seismic analysis as it influences all the analysis parameter 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 are compared along with the comparison between manually calculated and software derived base shear. In the analysis as shown in figure 11, maximum static base shear is obtained from NBC 105:2020 ULS followed by NBC 105:2020 SLS and IS 1893:2016 and minimum from NBC 105:1994.

In dynamic analysis with scale factor greater than one, as shown in figure 12, maximum base shear is given by NBC 105:2020 ULS followed by NBC 105:2020 SLS and IS 1893:2016 and minimum from NBC 105:1994. Here scale factor is to increase dynamic load is greater than one for all respective code. Thus, for the structure used in my study it is compulsory for dynamic analysis for all respective codes. In dynamic analysis the value of the base shear is make equal to the value of static base shear by increasing scale factor from the EQ and RS value.

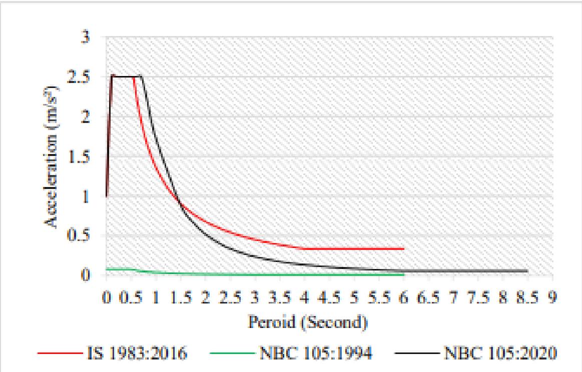

Figure 6: Graphical representation of static base Shear from ETABS

Table 4: Graphical representation of dynamic base Shear from ETABS

SN	Earthquake Parameters	IS 1893:2016	NBC 105:1994	NBC 105:2020 For ULS	NBC 105:2020 For SLS
1	Seismic Zone Factor (Z)	0.36	1	0.3	0.3
2	Importance Factor(I)	1.2	1	1	1
3	Response reduction / performance Factor(R/K)	5	1	1.0521	1.0521
4	Soil Type	Medium II	Medium II	Medium B	Medium B
5	Time Period from Rayleigh Method			$T_1 = 2\pi\sqrt{\frac{\sum_{i=1}^{n}(W_i d_i^2)}{g\sum_{i=1}^{n}(F_i d_i)}}$	
		For building 1 model		T_x =0.8065	$T_y = 0.8143$
6	Time Period of Building(T) Sec	$T = 0.075H^{0.75}$	$T = 0.06H^{0.75}$	$T = 1.25 * 0.075H^{0.75}$	$T = 1.25 * 0.075H^{0.75}$
		0.483	0.386	0.6043	0.6043
7	Response Spectrum Coefficient/ Spectral shape factor	$\frac{S_a}{g}=\frac{1.36}{T}$	$C=\frac{0.04}{T}$	$C_h(T)$	$C_h(T)$
		2.5	0.08	2.5	2.5
8	Elastic Site Spectra			$C(T)= C_h(T)ZI$	$C_s(T) = 0.20\ C(T)$
				0.75	0.15
9	Design horizontal seismic coefficient	$A_h = \frac{ZIS_a}{2Rg}$	$C_d = CZIK$	$C_{du}(T) = \frac{C(T)}{R_\mu * \Omega_u}$	$C_{ds}(T) = \frac{C_s(T)}{R_s * \Omega_s}$
		0.108	0.08	0.125	0.12
10	Eccentricity allowed	0.05	0.1	0.1	
11	Design base shear (KN)	Bldg-1: 377 Bldg-2: 789 Bldg-3: 391 Bldg-4: 319 Bldg-5: 501	Bldg-1: 297 Bldg-2: 584 Bldg-3: 289 Bldg-4: 236 Bldg-5: 371	Bldg-1: 439 Bldg-2: 920 Bldg-3: 454 Bldg-4: 370 Bldg-5: 585	Bldg-1:422 Bldg-2:833 Bldg-3:436 Bldg-4:356 Bldg-5:561

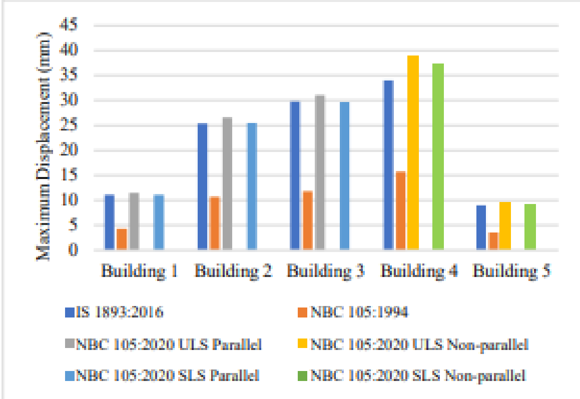

Figure 7: Representation of Pushover Analysis of Building-3 model

Also, here from figure 13 graphical representation of the base shear which is calculated manually and figure 11 graphical representation of base shear using ETABS, normally the value of base shear calculated manually is more than calculated from ETABS since the pattern of difference between the manually and ETABS calculated base shear is nearly same.

The result of performance assessment using nonlinear static procedures shows that all the building models satisfies the performance limit state. This result shows that the building-3 model have sufficient capacity to resist the given hazard and achieve the earthquake resistance design objective of damage limitation and life safety.

7. Conclusions

A study is performed between different RC Building Nepalese (Nepal National Building Code, NBC) and Indian (Indian Standard Code, ISC) previously existing and revised standards with consideration of several design compliances. NBC 105:1994 was revised to NBC 105:2020 and also IS 1893:2002 to IS 1893:2016 which are used for RC building in current study. After the interpretation and through observation of the results, some conclusions are found out. However, the conclusion made here does not represent in a broad sense because only limited building was used in this study. The building selected here was a low-rise RC building of three stories plus staircase cover that lie on soil type 'B'. The design basis of Indian Standard Codes for seismic hazard analysis is deterministic approach whereas Nepal Building Code is based on probabilistic and impact are studied. Seismic Demand (MCE, DBE and PGA), Dynamic properties (time period, response reduction factor, overstrength, torsional irregularity) and Seismic response (drift, displacement and base shear) from the four codes were compared in this study using linear static, linear dynamic and non-linear analysis approaches.

The conclusions of this study are listed below:

1. From the response analysis different parameters were observed to be estimated greater from the NBC 105:2020 as compared to other studied codal provisions. The major reason behind this is the adoption of the latest seismic index in estimation of the seismic hazard.

2. Based on the different shape and size of residential buildings from static and dynamic base shear, different pattern was observed. Hence, it can be concluded that shape and size have effects on the base shear of the structure.

3. The time period of vibration estimated by the NBC 105:2020 is higher than IS 1893:2016 and NBC 105:1994 since it includes effective stiffness of cracked sections (flexural and shear) and amplification factor. 4. The distribution of base shear at different floor levels is linear in NBC 105:1994 but distributed is in parabolic pattern in IS 1893:2016 and linear interpolation in NBC 105:2020. As per given codal provision IS 1893:2016, NBC 105:2020 shows to scaled up the base shear in dynamic analysis result if it is less than the static base shear. However, NBC 105:1994 does not provide any provision on this scale factor. In this study, scale factor is greater than 1 as per all codes used. So, dynamic base shear is required to scale up according to all the codes used.

5. The value of Base shear is higher by 104%, 116% and 157% using compared codes NBC 105:2020 ULS to NBC 105:2020 SLS, IS 1893:2016 and NBC 105:1994. Similarly, the value of inter story drift is higher by 4%, 4% and 150% using compared NBC 105:2020 ULS to NBC 105:2020 SLS, IS 1893:2016 and NBC 105:1994.

6. In some of the buildings as per respective codal provision the process for performance verification of the buildings using linear analysis procedures overestimate the value of performance limit state.

8. Recommendations

1. This study is based on the different shape and size of residential building. As per the conclusion in most building structure the value of performance verification is beyond the limit in all codes so the size of the beam and column need to be increased.

2. By increasing the size of the beam and column the percentage of the reinforcement is also increased. The cost of the construction of the residential building increased from the economical point of view.

3. Hence, the base shear coefficient should be reduced to a certain portion by using performance factor without compromising the performance requirements, so that economy in the building construction can be achieved at the same time the performance objectives of damage limitation and life safety can be achieved.

References

[1] NBC 105:1994. National Building Code of Nepal, Seismic Design of Buildings in Nepal

[2] NBC 105:2020. National Building Code of Nepal, Seismic Design of Buildings in Nepal

[3] Standards, B. of I. (2016). IS 1893:2016 - Indian Standard Criteria for Earthquake Resistant Design of Structures, Part 1 - General Provisions and Buildings. Bureau of Indian Standards (Vol. 1893).

[4] Pandit, P., and Vasudev, M., (2019) "Comparative Analysis of NBC 105:1994 And Is 1893:2016 Seismic Codes With G+21 Rc Building", International Research Journal of Engineering and Technology (IRJET), Vol. 6, No. 11, PP. 1995-2000

[5] Aryal, A., and Dhungana, S., (2020) "Comparative Analysis of NBC With Is Code for Rc Structures" International Research Journal of Engineering and Technology (IRJET), Vol. 6, No. 24, PP. 2113-2117

[6] Maskey, P., Dhakal, R., Tamrakar, M., Bista, M., Ojha, S., Gautam, B., Acharya, I., and Chamlagain, D., (2020) "NBC 105:2019 Seismic Design of Buildings in Nepal: New Provisions in the Code" 17th World Conference on Earthquake Engineering, 17WCEE, 2b-0036

[7] Shrestha, J., Paudel, N., Koirala, B., Giri, B., and Lamichhane, A., (2021) "Impact of Revised Code NBC 105 on Assessment and Design of Low Rise Reinforced Concrete Buildings in Nepal" Journal of Institute of Engineering, Vol. 16, No. 1, PP. 1-5

[8] Lamichhane, K., Lamichhane, G., Ghimire and Adhikari, K.,(2021) "Analysis of Irregular Structure with Addition of Shear Walls as Per Nepal Building Code (NBC 105:2020)" International Journal of Engineering Research and Technology (IJERT), Vol. 10, No. 03, PP. 608-612

[9] Bhusal, B., and Paudel, S., (2021) "Comparative study of existing and revised codal provisions adopted in Nepal for analysis and design of Reinforced concrete

structure" International Journal of Advanced Engineering and Management. Vol 6, No. 1 PP. 16-24

[10] Yousuf Dinar, Y., Hossain, M., Biswas, R. and Rana, M., (2014) "Descriptive Study of Pushover Analysis in RCC Structures of Rigid Joint" IOSR Journal of Mechanical and Civil Engineering . Vol 11, No. 1 PP. 60-68

[11] Garlock, M., Richard Sause, R. and Ricles, J., (2004) " Design and Behavior of Post-tensioned Steel Moment Frames" 13th World Conference on Earthquake Engineering., No. 2560