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NBC 105: 2019 SEISMIC DESIGN OF BUILDINGS IN NEPAL: NEW PROVISIONS IN THE CODE

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Abstract

The NBC 105: 2019 Seismic Design of Buildings in Nepal is the revised version of the original code for seismic design first published in 1994. The code has never been reviewed and updated since then till the moment. Recognizing the development in research and technology and new knowledge learnt from various large earthquakes in last 25 years, the Government of Nepal decided to initiate the first revision of the seismic design code. The objective of this revised standard is to provide designers with general procedures and criteria for the structural design of buildings prevalent in Nepal. This paper presents the basic features of the revision and the principles adopted in the standard.

A new seismic hazard map of Nepal was proposed at the outset based on probabilistic format. Accordingly the PGA values for various locations of Nepal were revised. The performance requirements have been introduced precisely in terms of collapse prevention and damage limitation; there is a further recommendation to verify the performance requirements checking the ultimate limit state and serviceability limit state. It is proposed to check life safety and damage limitation performance requirements. Two different spectra are proposed for seismic coefficient method and modal response spectrum method. Four types of sub soil category are proposed. Very soft soil category is added in addition to previous three categories. This new soil category represents a very deep soft soil found in Kathmandu valley. Research has indicated that hard soil should have greater acceleration demand at smaller periods. This issue is rarely addressed in design codes internationally and the revised version of the NBC 105 is one of the first codes to accommodate this in practice.

The revised code, retaining the linear analysis, introduces the non-linear methods of analysis. The empirical formulae for determination of fundamental translation period have been revised. Other principal changes include the importance classes and importance factors, load combinations and load factors. The Performance factor (K), which was used in the earlier version to obtain seismic coefficient, does not reflect the modern seismic design philosophy of reducing the elastic seismic forces. The response reduction factors (Ductility factor, $R\mu$ and Overstrength factor, Ω) are introduced. The horizontal base shear coefficient will be determined separately for ultimate limit state and serviceability limit state. The horizontal design spectrum for the modal response spectrum method has been given different for ultimate limit state and for serviceability limit state. A separate section on structural irregularity has been added. The revised code now requires checking the inter-story drift for both serviceability limit state and ultimate limit state.

The standard has been developed in a new format considering the recent development in the research and technology as well as the lessons from the recent earthquakes. The whole document has been spread over 10 sections with 2 annexes separately for ductile detailing of structural concrete and structural steel.

Keywords: NBC 105, ultimate limit state; serviceability limit state; ductility factor; overstrength factor; building code; parts/ components

1. Introduction

The first National Nepal Building Code NNBC 105: 1994 Seismic Design of Buildings in Nepal [1] was developed and published in 1994. Considerable changes have taken place in last 25 years. A substantial advancement in the knowledge related with seismic resistant design of buildings and structures during the period, changes in the living style influencing the type of buildings in Nepal, changes in seismic design provisions in building codes of different countries in last 25 years, and the lessons learnt from the large earthquakes in the recent years are the major reasons for need for revision of the seismic code. Since the beginning of the new millennium many large earthquakes, such as, the earthquakes of Gujarat (2001 January), Sumatra-Andaman (2004 December), Kashmir-Kohistan (2005 October), China (2007), followed by Sendai earthquake (March 2011), and the Sikkim earthquake (September 2011). The Gorkha earthquake of 2015 April 25 followed by a series of aftershocks in Nepal has witnessed the tremendous loss of lives and properties in the country. These losses and damages in structures indicate the high seismic risk of the country and imply the need to develop, improve and update the existing documents on building codes to mitigate the seismic risk in the country. The Department of Urban Development and Building Construction, Ministry of Urban Development, Government of Nepal, through the Central Level Project Implementation Unit (CLPIU), Earthquake Emergency Assistance Project, financed by the Asian Development Bank (ADB) initiated the revision of the earlier version of the National Building Code NNBC 105: 1994. Later the revision of the seismic code was coordinated by the CLPIU (Building), under the National Reconstruction Authority (NRA).

The building codes with the seismic provisions are used for earthquake resistant structures. The seismic provisions are formulated to reduce the seismic risk and to mitigate the effects of the earthquake hazard. The seismic codes and the provisions are naturally different from country to country depending upon the seismic activity, the exposure of the society, technology of construction and the socio-economic conditions.

The Nepal National Building Code NNBC 105: 1994 [2], unlike other building codes of the world, has not yet been formally reviewed and updated since it was first published in 1994. The enormous positive improvement in materials, technological development along with significant enhancement in research and scientific methods and the enormous changes in design of structures and construction practices have yet to be incorporated in the documents along with the positive feedback from the professionals from the field of design and construction. Changes in quality and increment in numbers of engineers, researchers and academic personnel in Nepal during last 25 years have been considerable.

The need for the revision of NNBC 105: 1994[2] was formally recognized through the preparation of the scoping document [3], which was formally submitted to the Department of Urban Development and Building Construction (DUDBC) in September 2014. The CLPIU (Building) had formed a Working Group (WG) consisting of different experts and other technical staff from the DUDBC was arranged to carry out the revision and updating of NNBC 105. For the overall guidance of the WG, DUDBC had constituted the Building Code Revision Advisory Committee (BCRAC) which was aimed at carrying out the task of defining methodology, TOR and work plan as well as the monitoring of the work progress of the Working Group. The BCRAC needs to forward the revised NNBC 105 to the Building Construction Management and Improvement Committee (BCMIC) for approval as required by the Building Act of Nepal.

Nepal has long been recognized as the country lying in a zone of high seismic risk. The basic reason is the neo-tectonic activities in the Himalayan region and the existing geo-technical reasons. The Government of Nepal through the Ministry of Housing and Physical Planning had initiated the process of development of National Building Codes following the Udayapur earthquake in the eastern part of Nepal in 1988 August. It had prompted the serious concerns for the seismic safety of infrastructure following the damages due to the 1988 earthquake. The Government of Nepal undertook a policy initiative jointly with UNDP and UNCHS (Habitat) Project to address the need for enhancing the current building design and construction methods. The UNDP / UNCHS and the Ministry undertook “Policy and Technical Support to Urban Sector Project” under which national housing survey, shelter sector training needs assessment, draft national housing policy formulation, draft national building code preparation etc. were undertaken.

The 'Building Act 2055' (amended in 1998) was adopted to facilitate the regulation of building design/construction practice in Nepal. It has given authority to all municipalities to implement the NNBC for providing Building Permits. The Nepal National Building Code NNBC 105: 1994 Seismic Design of Buildings in Nepal [2] is one of the total 23 building codes developed and promulgated. The design and construction of buildings to withstand the earthquake actions, and to minimize the seismic vulnerability and hence to reduce the seismic disaster risk have been the intent and purpose of the NNBC 105: 1994 Seismic Design of Buildings in Nepal [2]. The period after the publication of NNBC 105 in 1994 is especially characterized also by high population growth in the urban areas of Nepal leading to the scarce of land and growing demand for home with tremendous rise in land prices. It has called for a high demand for vertical expansion of the housing and a new culture of moderate to high rise structures requiring special attention on design and construction of these. The rising trend of higher rises of buildings is another significant aspect for urgency of updating and revision of the code on Seismic Design of Buildings in Nepal.

The revision work was carried out with the principal objective of updating the provisions of the Nepal National Building Code NNBC 105: 1994 Seismic Design of Buildings in Nepal [2] to enhance it by adopting earthquake resistant design knowledge and technology acquired through research worldwide in the last three decades.

This revised code NBC 105: 2019 [4] covers the requirements 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 buildings, low to high rise buildings, in general. Requirements of the provisions of this standard shall be applicable to buildings made of reinforced concrete, structural steel, steel concrete composite, timber and masonry.

Various codes, standards and documents related with the seismic design of the neighboring countries of the Himalayan Region [5, 6, 7, 8 and 9] and from the developed countries [10, 11, 12, 13, 14, 15 and 16] were referred to arrive at the suitable techniques and provisions applicable to Nepal.

This paper presents a summary of various aspects of the seismic design code, and emphasizes on the new provisions, such as the performance requirements, components of the response reduction factor in terms of ductility and overstrength factor and nonlinear methods of analysis.

An attempt has been made to make this code in itself a complete set, avoiding, as far as possible, the need to refer to standards of other countries. With that intent, the ductile detailing provisions for concrete and steel structure are incorporated as appendices.

2. Seismicity and Seismic Hazard Map

Estimate of the design ground motion is the most important and complicated part of the seismic design code development. Estimates of the design ground motion are necessarily controversial and uncertain. It is more important to the structural designer that this is understood than for him to attach some particular significance to any ground motion parameter used in his design. However there is a strong argument for conservatism in the assessment of ground motion input, and the use of high confidence level.

The design values of ground motion parameter such as Peak Ground Acceleration (PGA) for different regions of the country are presented either in a tabular form (GB 50011-2010) [8] or attaching relevant maps like in IBC 2018 [10] in the codes. It is necessary to do the same in NNBC 105: 1994[2] also since the seismic hazard for the code was determined based on the probabilistic seismic hazard analysis. The seismic codes adopting probabilistic approach of hazard estimation use the hazard levels in terms of Maximum Considered/Capable Earthquake (MCE) as in NEHRP [11] and IBC [10], and Design Basis Earthquake (DBE) as in ATC [15] and UBC 1997 [12]. The MCE and DBE represent 2% probability of exceedence in 50 years with a return period of 2500 years and 10% probability of exceedence in 50 years with a return period of 475 years respectively.

Following the Gorkha Earthquake of 2015 April 25 it was understood that there was strong modification of the ground motion as there is strong shaking at long period causing severe damage to tall buildings in the Kathmandu Valley. It was realised that the seismicity considered in the existing NBC 105: 1994 [2] may be unable to account for seismic demand in future large earthquakes in Nepal, and a revision of the existing seismic hazard was required. As there are many new data and findings on Nepal's seismicity patterns, geometry of seismogenic faults and geodetic data, more precise probabilistic seismic hazard assessment was felt necessary for revising the seismic code of Nepal.

2.1 Seismic Hazard Map of Nepal

The seismic hazard map of Nepal (Fig.1) is the result of the probabilistic seismic hazard analysis (PSHA) that had been carried out for the entire territory of Nepal based on the latest seismo-tectonic data including all the recorded earthquakes in historical seismicity of Nepal and the surrounding region [2]. All the earthquake source regions, including subduction zones, shallow seismic sources on Earth's plates, as well as the sources of identified active faults are included in arriving at the seismic hazard map. The results of the PSHA are depicted in the map of Nepal as contour lines of peak ground acceleration (PGA) with 475 years of return period or 10% probability of exceedence in 50 years. The probabilistic seismic hazard analysis was carried out considering recent seismogenic sources and the neo-tectonic process in the region.

2.1.1 Elastic Site Spectra for Horizontal Loading

The Elastic site spectra for horizontal loading is determined using equation (1).

$$C(T) = C_h(T)\, Z\, I \tag{1}$$

Where,

$C_h(T)$ = Spectral Shape factor

Z = Seismic Zoning factor

I = Importance factor

2.1.2 Spectral Shape Factor, $C_h(T)$

A standard elastic site spectrum consistent with the modern seismic engineering is introduced. Two different spectra are proposed for seismic coefficient method and modal response spectrum method.

The spectral shape factor functions given in Fig. 2 shall be used for Equivalent Static Method and those in Fig. 3 shall be used for Modal Response Spectrum Method and Nonlinear Time History Analysis.

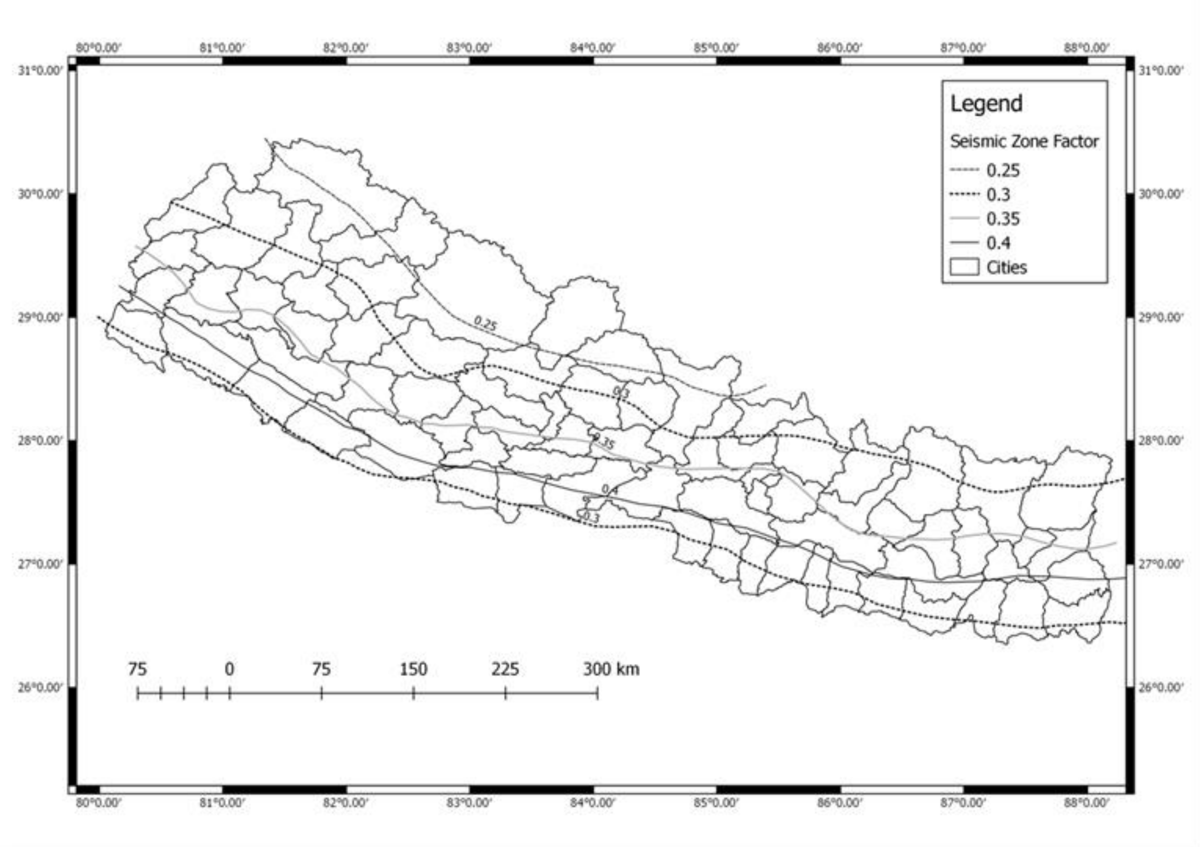

Fig. 1- Seismic Zoning Map of Nepal

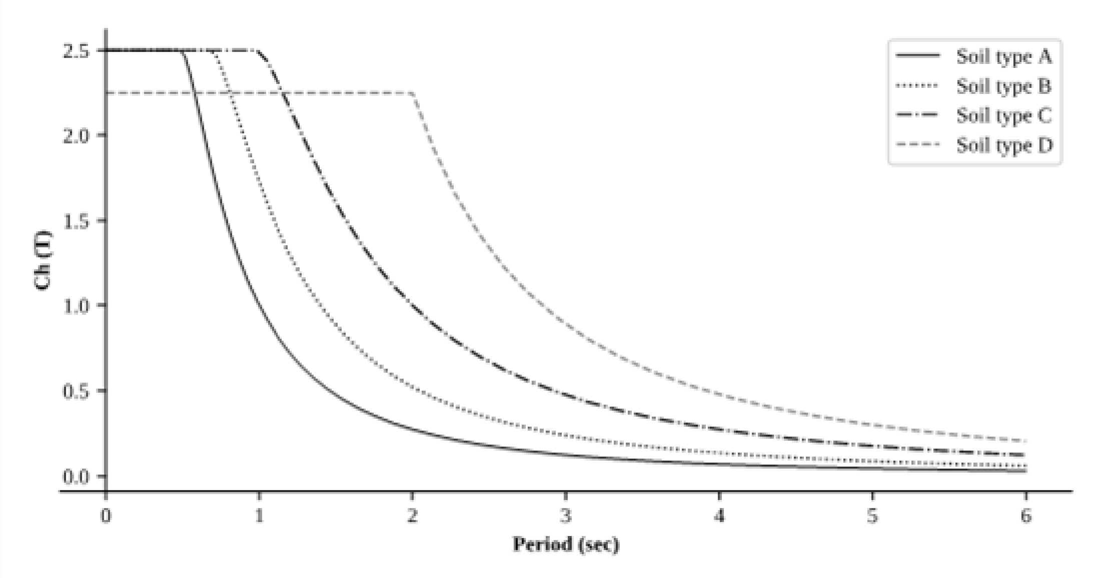

Fig. 2- Spectral Shape Factor, $C_h(T)$ for Equivalent Static Method

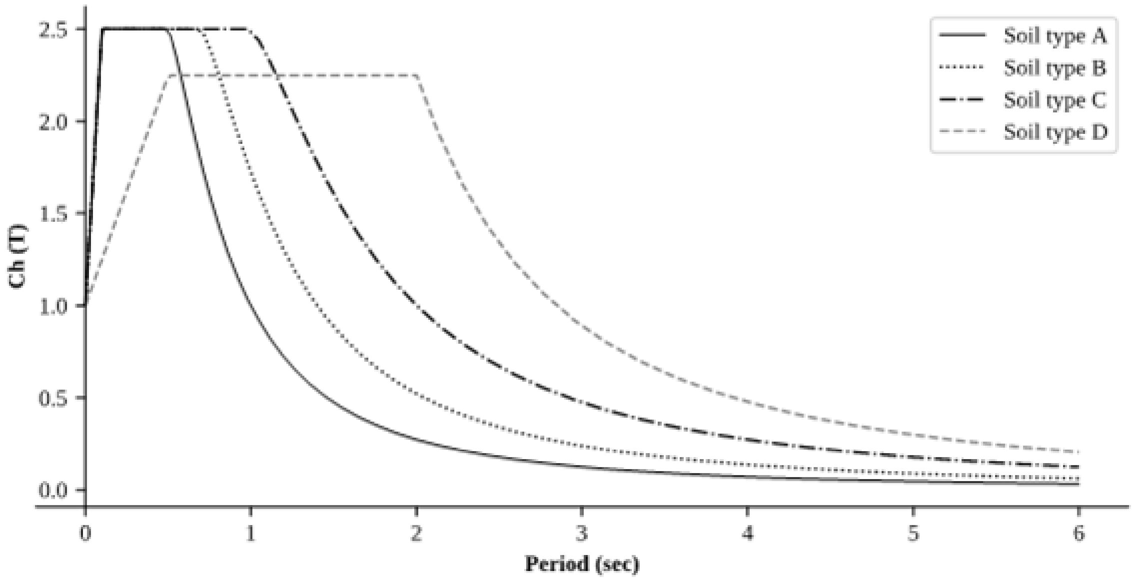

Fig. 3- Spectral Shape Factor, $C_h(T)$ for Modal Response Spectrum Method, Nonlinear Time History Analysis , Vertical Loading and Parts and Components

2.1.3 Sub soil category

Altogether four types of sub soil category is proposed. Very soft soil category is added in addition to previous three categories. This new soil category represents a very soft soil found in Kathmandu valley core where there is deep deposit of clay. The soil types are as follows:

a. Stiff or hard soil sites
b. Medium soil sites
c. Soft soil sites
d. Very soft soil sites

2.1.4 Seismic Zoning factor

Seismic zoning factor specifies the value representing the fraction of the acceleration due to gravity (g) is proposed. The Seismic Zoning Factor (Z) represents the peak ground acceleration (PGA) for 475 year return period. The minimum zoning factor is 0.25g and maximum zoning factor is 0.4g.

2.1.5 Important classes and importance factors

Structures to be deisgned are classified into three importance clases, and correspondingly three factors of importance, namely, 1.0, 1.25 and 1.5 are recommended, depending upon the consequence of structures' loss of function.

2.2 Elastic site spectra for serviceability limit state

The elastic site spectra for serviceability limit state is given by

$$C_S(T) = 0.20\ C(T) \quad (1)$$

Where C(T) = elastic site spectra for horizontal loading.

2.3 Elastic spectra for vertical loading

Where consideration of vertical seismic forces is required, the design vertical seismic coefficient shall be taken as 2/3 of the horizontal seismic coefficient.

3. Performance Requirements and Verification

The existing NBC 105: 1994 [2] did not explicitly define various performance requirements. However, it is indirectly implied that a thorough use of different NBC provisions will satisfy the safety requirements.

The revised NBC 105: 2019 [4] includes the provision for the performance requirements and verifications. Structures designed and built in seismic regions are supposed to fulfil the following fundamental performance requirements:

3.1 Life Safety

The structure shall be designed and constructed to withstand the design seismic forces without local or global failure that, thus retaining its structural integrity, stability against overturning and a residual load bearing capacity after the earthquake. Further, it is also necessary to avoid damage to non-structural systems which are essential for safe evacuation from the structure. The design seismic force is expressed in terms of 475 years return period (reference return period) and the importance factor.

3.2 Damage Limitation

The structure shall be designed and constructed to withstand a seismic force having a larger probability of occurrence than the design seismic forces, without the occurrence of damage and the associated limitations of use of the structure. The critical facilities need to be operational state or be in a state which can be returned to fully operational state shortly after the earthquake (within minutes to hours). The design seismic force associated with damage limitation is expressed in terms of a fraction of life safety level seismic force.

3.3 Verification:

For the verification of the abovementioned performance requirements, the ultimate limit state as well as the serviceability limit state shall be checked. The serviceability limit state is introduced to ensure that the building remains essentially elastic in a specified level of minor/moderate shaking. It represents a level of force within the structure below which there is a high degree of assurance that the structure can continue to be used as originally intended without repair.

4. Methods of Analysis

The structural analysis for design seismic actions shall be carried out using any one of the following methods:

a) Equivalent Static Method

b) Linear Dynamic Analysis Methods

   i. Modal Response Spectrum Method

   ii. Elastic Time History Analysis

c) Non-linear Methods

   i. Non-linear Static Analysis

   ii. Non-linear Time History Analysis

These methods are intended, in general, for the verification of performance of existing or strengthened structures.

The Equivalent Static Method is recommended for use when:

i. the height of the structure is less than or equal to 15 m. or
ii. the natural time period of the structure is less than 0.5 sec. or
iii. the structure is not categorized as irregular one and the height is less than 40 m.

The modal response spectrum method may be used for all types of structures and the structures where equivalent static method is not applicable.

The elastic time history analysis has been introduced and it may be used for all types of structures to verify that the specific response parameters are within the limits of acceptability assumed during design.

While retaining the linear analysis methods, the non-linear methods, namely, the non-linear analysis and the non-linear dynamic analysis are also introduced in the code. These two methods are used basically to verify the performance of existing or retrofitted structures. These methods are also intended for verifying the limits of acceptability assumed during design.

4.1. Horizontal Base Shear Coefficient

The horizontal base shear coefficient is determined for ultimate limit state and serviceability limit state separately.

For the ultimate limit state, the horizontal base shear coefficient (design coefficient), $C_d(T_1)$, shall be given by:

$$C_d(T_1) = \frac{C(T_1)}{R\mu \text{ x } \Omega u} \quad (2)$$

Where,
$C(T_1)$ = Elastic Site Spectra, Rμ = Ductility Factor and **Ω**u = Over strength Factor for ULS.

For the serviceability limit state, the horizontal base shear coefficient (design coefficient), Cd(T_1), shall be given by:

$$C_d(T_1) = \frac{Cs(T_1)}{\Omega s} \quad (3)$$

Where,

$C_s(T_1)$ = Elastic Site Spectra determined for Serviceability Limit State and **Ω**s = Over strength Factor for SLS

4.2 Horizontal Seismic Base Shear

The horizontal seismic base shear, V, acting at the base of the structure, in the direction being considered, shall be calculated as:

$$V = C_d\,(T_1)\,W \quad (4)$$

Where,

$C_d\,(T_1)$ = Horizontal base shear coefficient and W = Seismic Weight of the structure.

The vertical distribution of seismic forces is determined using equation (5)

$$F_i = \frac{W_i h_i^k}{\sum_i^n W_i h_i^k} \text{ x } V \quad (5)$$

Where,

F_i is the lateral seismic force induced at each level 'i' ;

W_i = seismic weight of the structure assigned to level 'i';

h_i= height (m) from the base to level 'i';

n= total number of floors/levels

V= horizontal seismic base shear calculated

k= an exponent related to the structural period as follows:

- for structure having time period T≤0.5sec, k=1
- for structure having time period T≥2.5sec, k=2
- for structure having period between 0.5 sec and 2.5 sec, k shall be determined by linear interpolation between 1 and 2.

4.3 Dynamic Analysis

The estimation of base shear for irregular buildings is obtained by response spectrum analysis using the response spectra. The ordinate value in the spectra is multiplied by the ratio of importance factor and seismic reduction factor.

4.4 Design Methods

In the earlier version of the code, two design methods had been specified, namely, the Working Stress Method (elastic method), or, the Limit State Method. However, only limit state method is considered in this revised version of the NBC 105: 2019 [4].

There must be a valid logical reason for need of limit state method of design for reinforced concrete design and recommending working stress method for other structural materials. At this juncture of improvement, it will be preferable to explore the design methods available and recommended in other codes and adopt the design method most appropriate for the country. In general, most of the countries have adopted limit state method or strength method replacing working stress method for concrete as well as steel, the two principle structural materials.

4.5 Effective stiffness of cracked sections

A rational analysis shall be performed in arriving at the elastic flexural and shear stiffness properties of cracked concrete and masonry elements. In absence of such analysis, the effective stiffness of cracked sections shall be taken as given in Table 1.

Table 1 Effective stiffness of different components

S No.	Component	Flexural Stiffness	Shear Stiffness
1	Beam	$0.35\ E_c\ I_g$	$0.40\ E_c\ A_w$
2	Columns	$0.70\ E_c\ I_g$	$0.40\ E_c\ A_w$
3	Wall—cracked	$0.50\ E_c\ I_g$	$0.40\ E_c\ A_w$
4	Wall—uncracked	$0.80\ E_c\ I_g$	$0.40\ E_c\ A_w$

For steel structures, the gross stiffness values shall be used.

Load combinations for limit state method

The load combinations and the load factors have been recommended as follows:

For parallel systems:

$$1.2DL + 1.5LL \tag{6}$$

$$DL + \lambda\ LL + E \tag{7}$$

For non-parallel systems

$$1.2DL + 1.5LL \tag{8}$$

$$DL + \lambda\, LL + (E_x + 0.3E_y) \tag{9}$$

$$DL + \lambda\, LL + (0.3E_x + E_y) \tag{10}$$

Where, λ = 0.6 for storage facilities

= 0.3 for other usage

The factor of 1.25 in earthquake load combination in the earlier version is now removed. For the modern seismic design philosophy based on ductility, this approach is inappropriate. Applying a load factor to a force level that has already been reduced from the level corresponding to elastic force level implies a reduction of expected ductility requirement. Dead and live load factors in the load combination involving earthquake load have been made consistent with the calculation of seismic weight.

5 Dynamic Characteristics of structures

To determine the fundamental period of vibration of structures, Rayleigh Method as well as the empirical method are recommended. The empirical method of time period estimation is expanded to include concrete, steel, eccentric braced frame and structural wall buildings. As the empirical methods give very conservative values of time period, it is proposed to amplify this time period by 25% in such a way that this amplified time period does not exceed time period estimated from the Rayleigh method.

5.1 Ductility factor (R_μ) and Overstrength factor (Ω)

The structures including the buildings are not normally designed for elastic behavior under earthquake load, rather they are designed for a fraction of the maximum elastic forces. The design earthquake forces are arrived at by dividing the maximum elastic forces by the response reduction factor. The response reduction factor in its turn is dependent on the inelastic parameters, namely, overstrength factor, ductility factor, and the redundant factor. Arriving at the values of these factors requires precise knowledge about the load deformation behavior under earthquake excitation. Experimental results, to certain extent, help in arriving at these numbers. Most often, in the absence of enough information the provisions available in International building codes are adopted by seismic codes of different countries.

In the earlier version of the NBC 105: 1994 [2], the effect of the ductility was taken into consideration in the form of Performance Factor K. Since the K factor approach does not reflect the modern seismic design philosophy of reducing the elastic seismic forces and does not account for the nonlinear behavior of the structures to resist the seismic forces, and to be consistent with modern seismic design philosophy, response reduction factors (Ductility factor, R_μ and Overstrength factor, Ω) are introduced as follows:

$C_d(T_1) = \frac{C(T_1)}{R\mu \times \Omega u}$ for ultimate limit state

$C_d(T_1) = \frac{Cs(T_1)}{\Omega s}$ for serviceability limit state

5.2 Structural Irregularity

No explicit provision for irregularity was presented in the earlier version. In the revised version of the code a separate section on structural irregularity has been added. The following irregularities have been especially considered:

- The vertical irregularity consists of weak story, soft story, vertical geometric irregularity, in-plane discontinuity in vertical lateral force resisting element and the mass irregularity.
- The plan irregularity: torsion irregularity, re-entrant corners irregularity, diaphragm discontinuity irregularity and out of plane offset irregularity.

5.3 Drift and displacements

The design horizontal deflection for the ultimate limit state is determined by multiplying the horizontal deflection found from the equivalent static method or modal response spectrum method by the ductility factor (R_μ). The design horizontal deflection for serviceability limit state shall be taken as equal to the horizontal deflections calculated either by equivalent static method or modal response spectrum methods.

5.4 Inter-Story Deflections

The ratio of the the inter-story deflection to the corresponding story height shall not exceed 0.025 at the ultimate limit state and 0.006 at the serviceability limit state.

5.5 Parts and Components

This section specifies the minimum design requirements for non-structural components of architectural, mechanical and electrical systems, their support and connections. All elements, components or equipment shall be positively connected to the structure to resist the specified seismic loads.

A new equation format consistent with response reduction factor is proposed. All elements and components shall be designed for a design seismic force (F_p):

$$F_P = Z\left(1 + \frac{h_p}{H}\right)\frac{a_p}{\mu_p} I_p W_p \tag{11}$$

C_p in earlier version of NBC 105: 1994 is replaced by Z. Similarly, K_p is replaced by a_p and μ_p where a_p is component amplification factor and μ_p is ductility factor of parts and components.

Component amplification factor (a_p) is determined based on absolute difference between the natural periods of the building and the component $|T_1\text{-}T_p|$ and varies in the range of 1 to 2.5.

Component ductility factor (μ_p) represents the ductility and energy dissipation capacity of the components and its connections. Its value varies from 1.5 to 2.5.

Component Importance factor (I_p) is also introduced in the new equation. Its value varies from 1 to 1.5 based on whether the component is ordinary or components that needs to be operational after earthquake, hazardous components or components that are required to function for life safety after earthquake.

8. Conclusion

The new provisions developed and included in the revised versión of the national seismic design code of Nepal NBC 105 are summarised in this paper. The enhanced versión of the seismic code makes the code more effective in terms of acceptability, simplicity in application, and clarity in each clause. The revised code has retained the probabilistic format of occurrence of the earthquake and incorporates two levels of earthquakes – earthquakes with return periods of 2475 years and 475 years as the MCE and DBE. The seismic hazard zoning map for Nepal in terms of peak ground acceleration (PGA) (as a fraction of gravity) for the return period of 475 years has been presented. Two response spectra developed based on the result of the probabilistic seismic hazard analysis; one for equivalent static method and another for the dynamic analysis, are incorporated in the code. The importance class and factors are revised to reflect the effect of ductility provisions, and nonlinear static and nonlinear dynamic analyses, apart from retaining the seismic coefficient method and response spectrum method as the main methods. The commentary to the NBC 105: 2019 facilitates in understanding the clauses and rationale of the code provisions.

References

[1] Chamlagain, Deepak (2019), "Probabilistic Seismic Hazard Mapping for Nepal", Report submitted to Central Level Project Implementation Unit EEAP, National Reconstruction Project, Babarmahal, Kathmandu, Nepal, 2075.

[2] NBC 105: 1994 (2004) Nepal National Building Code Seismic Design of Buildings in Nepal, HMG of Nepal, Ministry of Physical Planning and Works, DUDBC, Kathmandu, Nepal, 2060.

[3] Maskey, P. N., (2014), "Final Report on Preparation of Scoping Document and TOR for Revision of Nepal Building Code 105:1994, Seismic Design of Buildings in Nepal", Government of Nepal, Ministry of Urban Development, Department of Urban Development and Building Construction, Kathmandu, September 2014.

[4] NBC 105: 2019 (2019) Nepal National Building Code Seismic Design of Buildings in Nepal, HMG of Nepal, Central Level Project Implementation Unit (Building), National Reconstruction Authority, Babar Mahal, Kathmandu, NEPAL, 2076.

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

[6] IS 4326: 1993 Indian Standard Code of Practice for Earthquake Resistant Design and Construction of Buildings, Bureau of Indian Standards, New Delhi, India.

[7] BNBC 2014 (2015) Bangladesh National Building Code, HBRI, Govt. of Bangladesh.

[8] GB 50011-2010 (2010) Code for Seismic Design of Buildings, National Standard of the People's Republic of China, Beijing, PRC.

[9] Building Code of Pakistan Seismic Provisions (2008) Government of Pakistan Ministry of Housing and Works.

[10] IBC 2015 International Building Code, International Code Council, USA.

[11] NEHRP 2003 (2003) Recommended Provisions for the Development of Seismic Regulations for New Buildings, Building Seismic Safety Council, Federal Emergency Management Agency, USA.

[12] UBC 1997 (1997) Uniform Building Code, INTERNATIONAL Conference on Building Officials, Whittier, California, USA.

[13] ASCE 7-15 (2016), "Minimum Design Loads for Buildings and Other Structures" Reston, Virginia: American Society of Civil Engineers. 2016.

[14] Standards New Zealand (2016), "Structural design actions - Part 5: Earthquake actions - New Zealand" Standards New Zealand, Wellington.

[15] ENV 1998-1-1: 1994 Euro code 8 Design Provisions for Earthquake Resistance of Structures General ru1es - Seismic actions and general requirements for structures ENV1998-1-2: 1994

[16] ATC 3-06 (1978) Tentative Provision for the Development of the Seismic Regulations for Building, Applied Technology Council, USA.

