



Ministry of Urban Development
Department of Urban Development and Building Construction

DUDBC Webinar Series No.6

A Discussion on the Revised National Building Code NBC 105:2020

Technical Aspects of the Revision

Presented by :
SDE. Manoj Nakarmi

Organized by: NRCBT, DUDBC

Supported by: Building Code and Byelaws Section, DUDBC

Contents

- ☐ Background
- ☐ Implementation Aspects
- ☐ Contents of NBC 105:2020
- ☐ Comparison with NBC 105:1994

Background

- With the experiences of past earthquakes(1988 Udaypur) NBC 105: 1994 was formulated.
- Basic code to establish **earthquake demand** and analysis & design **procedures & criteria** for earthquake resistant design in Nepal
- Experiences of Gorkha Earthquake, development in research and technology, worldwide update of seismic codes in Neighbouring countries (India) and learning from design & construction practices - Need for update felt
- Under Earthquake Risk Reduction Recovery Preparedness (ERRRP) Program launched by MoUD ,**study for updating** the NNBC including the NNBC 105: 1994 at the end of the year 2008 and **set of recommendations** was submitted to the Government of Nepal on April 10, 2009 by MULTI Disciplinary Consultants (P) Ltd., K.D. Associates (P) Ltd. & Khwopa Engineering College, (2009).
- “**Scoping Document for the Code Revision**” by DUDBC in September 2014.

Background

- Under ADB supported Earthquake Emergency Assistance Project(EEAP),CLPIU on behalf of DUDBC initiated the revision mobilizing team of national & international experts
Working Group (WG) consisted of four individual experts:
 - Senior Structural Engineer as a team leader: Prof. Dr. Prem Nath Maskey
 - Structural Engineer: Dr. Santosh Shrestha
 - Geotechnical Engineer: Dr. Surendra Tamrakar / Dr. Indra Acharya
 - Seismologist : Dr. Deepak Chamlagai
 Structural Engineer **International Expert: Prof. Dr. Rajesh Dhakal**
Working Group consisting of Engineers from CLPIU and DUDBC to assist the team in the revision process.
 Seismology sub-committee formed under the leadership of Dr. Sudhir Rajaure, DDG, DMG.
Building Code Revision Advisory Committee (BCRAC): responsible for defining methodology, TOR and work plan as well as the monitoring of the work progress of the WG.

Background

- The **Initial Inception Report** submitted on Nov. 01, 2017; revised version submitted on March 30, 2018.
- **Extensive** study, discussions & feedback
 Consultation Workshop on the Inception Report on January 02, 2018 at DUDBC.

 The Internal Workshop on NBC 105: 2019 on May 15, 2019 - more than 60 participants representing various Government, Academic, Professional Societies and Consulting Engineers.
 Series of regular Working Group meetings
 National Seminar was held on July 10, 2019.
- WG to BCRAC ,BCRAC to Building Construction Management and consolidation committee in December 2019 & recommended for approval to the council of ministers 17 December, 2019 (BS 2076/09/01)
- Approved in Aug 3,2020 & soon to be published in National Gazette.
- About 3 yrs. Of **Joint efforts** of DUDBC, MoUD & CLPIU

Implementation Aspects

Implementation means **design** compliance & **construction** compliance
 Better Technology does not necessarily mean better implementation.

Development of environment for:

- Designers/Engineers are familiar and able to design using NBC105:2020
 - Local govt. are capable of checking the design for building design permission & construction supervision
 - Local masons are trained for construction (Ductile detailing etc.)
 - Homeowners and local contractors are motivated for implementation
 - Federal govt./provincial govt. are able to monitor the implementation & feedback /directions are implemented
- Covid** situation , **mandatory immediate** implementation

Contents of NBC 105:2020

- Complete **Revision** not update
- All the topics and issues addressed in **NNBC 105: 1994** has been **retained**.
- Total of **10 Sections** and **two appendices** with Detailing on **Structural Concrete** and **Structural Steel**
- Supplemented by separate **commentary**

Contents of The NBC 105: 2020

Preface

Building Code Revision Advisory Committee (BCRAC)
Working Group
Consultants
Contributors
Summary Table of Contents

PART 1 SCOPE AND DEFINITIONS (2 sections)

Section 1 Title, Scope, Definitions and Notations
Section 2 General Principles

Contents of The NBC 105: 2020

PART 2 STRUCTURAL ANALYSES AND DESIGN (7 sections)

Section 3 Scope of Analysis (Accounting for earthquake in orthogonal directions; gross section/cracked section: stiffness calculation; reduction in Load combination case etc.)

Section 4 Seismic Hazard (seismicity, MCE and DBE; strong ground motion and response spectra etc.)

Section 5 Dynamic Characteristics of Structures (Structural and dynamic characteristics of buildings, natural time period, ductility, damping, deflection and drift; response reduction factor or ductility factor for serviceability and for ultimate strength, also representing the performance based design; sub-soil characteristics; special emphasis on soil sediment characteristics of Kathmandu Valley and hence response spectra etc.)

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Contents of The NBC 105: 2020

Section 6 Equivalent Static Method (Horizontal and vertical components of strong ground motion and inertia forces; structural systems; load cases and load combination cases; Seismic coefficient and Base shear; vertical distribution of base shear etc.)

Section 7 Modal Response Spectrum Method

Section 8 Elastic time History Analysis

Section 9 Non-linear Static and Dynamic Analysis

PART 3 STRUCTURAL COMPONENTS

Section 10 Parts and Components including Non-structural Parts

Two Appendices Detailing of RCC structure and steel structure

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Provisions for comparison

- Introduction, Related Codes, Scope
- Performance requirements and verification
- Methods of analysis
- Selection of method of analysis
- Seismic Coefficient Method
- Modal Response spectrum method
- Design Methods
- Basic response Spectrum /Elastic spectra
- Seismic zone factor(Seismic Hazard map)
- Sub soil category
- Effective stiffness of cracked sections
- Time period
- Importance class and factors
- Structural Performance factor, Ductility factor, Over strength factor
- Load combinations
- Drifts and displacements
- Parts & components

Introduction

NBC 105:1994	NBC 105:2020
This Standard provides minimum requirements for the seismic design of structures which are within the scope of this Standard.	This Standard provides designers with general procedures and criteria for the structural design of buildings prevalent in the Federal Republic of Nepal considering the seismicity in the parts of the country. This document outlines analysis and design methodology that is applied in accordance with the established engineering principles .

Related Codes

NBC 105:1994	NBC 105:2020
The requirements of this section of the Nepal Building Code shall be applied in conjunction with, IS 4326 - 1976 Code of Practice for Earthquake Resistant Design and Construction of Buildings.	Rather than relying on Indian standard documents to be used in conjunction with this standard for ductile detailing, attempt has been made in this code to make it a complete set , therefore, eliminating need to refer to standards of other countries such as India. For the purpose, the ductile detailing provisions for concrete and steel structure is included as an appendix
Where conflict exists between any requirements of this Standard and IS 4326, the requirements of this Standard shall be taken.	

Scope

NBC 105:1994	NBC 105:2020
This standard sets down requirements for the general structural design and seismic design loadings for structures within any of the following categories: - All buildings having a floor area greater than 20 square meters. - Any building with a height greater than five meters. - All masonry or concrete walls greater than 1.5 meters in height. - Elevated tanks of up to 200 cubic meters capacity. Larger tanks than this should be the subject of a special study. - All buildings to which the general public have access. The requirements are not intended to apply to : - Unusual buildings or structures (eg, those with unusual configurations or risk - such as nuclear power stations, etc). - Civil engineering works (eg, bridges, dams, earth structures, etc). - Buildings or structures greater than 90 m in height.	This code covers the requirements for seismic analysis and design of various building structures to be constructed in the territory of the Federal Republic of Nepal. Type - This code is applicable to all buildings, low to high rise buildings, in general. Material - Requirements of the provisions of this standard shall be applicable to buildings made of reinforced concrete, structural steel, steel concrete composite, timber and masonry. Technology -For Base-isolated buildings as well as for buildings equipped and treated with structural control can be designed in reference with specialist literatures.

Performance requirements and verification

NBC 105:1994	NBC 105:2020
Not explicitly defined various performance requirements. However, it is indirectly implied that a thorough use of different NBC provision will satisfy the safety requirements. There is no provision for verification of the structure in multiple limit states.	<u>Life Safety:</u> - withstand the design seismic forces without failure. <i>The design seismic force is expressed in terms of 475 years return period (reference return period) and the importance factor.</i> - to avoid damage to non-structural systems for safe evacuation <u>Damage Limitation:</u> - withstand a seismic force having a larger probability of occurrence than the design seismic forces, without the occurrence of damage which can limit the use of the structure so that structure is operational state or can be operational shortly after the earthquake. <i>The design seismic force associated with damage limitation is expressed in terms of a fraction of life safety level seismic force.</i> <u>Verification:</u> For the verification of the performance requirements of clause, following limit states shall be checked: Ultimate Limit State (ULS); Serviceability Limit State (SLS).

Methods of analysis

NBC 105:1994	NBC 105:2020
Analysis for the design earthquake actions shall be in accordance with one of the following methods : ▪ The Seismic Coefficient Method as outlined or, ▪ The Modal Response Spectrum method Analysis using numerical integration time history procedures is not covered by this Standard.	The structural analysis for design seismic actions shall be carried out using any one of the following methods: a. Equivalent Static Method (Simple & Statically determined Base shear distributed to building & responses are analyzed) b. Linear Dynamic Analysis Methods i. Modal Response Spectrum Method(Response as combination of modal responses due to input Ground motion) ii. Elastic Time History Analysis c. Non-linear Methods i. Non-linear Static Analysis ii. Non-linear Time History Analysis Linear time history analysis is added. Non-linear analysis method has been added in this revision. These methods are intended to be used for the verification of performance of existing or retrofitted structures. Need trainings.

Selection of method of analysis

NBC 105:1994	NBC 105:2020
For structures of up to 40 m in height the Seismic Coefficient Method may be used. For all other structures the Modal Response Spectrum Method shall be used. Modal Spectrum Method should be used for : i. Buildings with irregular configurations ii. Buildings with abrupt changes in lateral resistance iii. Buildings with abrupt changes in lateral stiffness with height iv. Buildings with unusual shape, size or importance.	Equivalent Static Method may be used when at least one of the following criteria is satisfied: i. The height of the structure is less than or equal to 15 m. ii. The natural time period of the structure is less than 0.5 secs. iii. The structure is not categorized as irregular one and the height is less than 40 m. 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 torsionally sensitive structures.

Seismic Coefficient Method

NBC 105:1994	NBC 105:2020
Magnitude The horizontal seismic shear force acting at the base of the structure, in the direction being considered, shall be: $V = C_d * W_t$ A linear triangular distribution along the height of the building as follows: $F_i = V * W_i h_i / \sum W_i h_i$	Magnitude The horizontal seismic base shear, V, acting at the base of the structure, in the direction being considered, shall be calculated as: $V = C_d(T_1) * W$ A distribution based on the time period of the building is proposed: $F_i = \frac{W_i h_i^k}{\sum_i^n W_i h_i^k} \times V$ k= an exponent related to the structural period as follows: - for structure having time period $T \leq 0.5 \text{ sec}$, $k=1$ - for structure having time period $T \geq 2.5 \text{ sec}$, $k=2$ - For structure having period between 0.5 sec and 2.5 sec, k shall be determined by linear interpolation between 1 and 2.

Modal Response spectrum method

NBC 105:1994	NBC 105:2020
<u>Design Spectrum</u> The design spectrum is used for the Modal Response Spectrum. The relative response of each contributing mode i shall be determined by multiplying the mode response by the value of $C(T_i)$ from 8.1.2. <u>Number of Modes to be Considered</u> A sufficient number of modes shall be considered to ensure that at least 90 % of the mass is participating in the direction under consideration. <u>Combination of Modal Effects</u> An established method shall be used for the combination of modal effects. The combination method shall take into account the effect of closely spaced modes. Modes shall be considered to be closely spaced if their frequencies are within 15 %. The <u>combined</u> modal effects shall be scaled by the modal combination factor, S, where : $S = \frac{0.9 C_d W_t}{\sum \text{combined modal base shears in the direction under consideration}}$ provided that S shall not be taken as less than 1.	1. <u>For the horizontal base shear co-efficient for each mode, $C_d(T_i)$, shall as given by:</u> $C_d(T_i) = \frac{C(T_i)}{R_{\mu} \times \Omega_u}$ 2. <u>Calculation of Base Shear for Each mode</u> $V_i = C_d(T_i) \times \gamma_i \times W$ Where γ_i is the participation factor for the i^{th} mode of vibration For each mode, the base shear shall be distributed by using $F_{ij} = \frac{\gamma_j W_j h_j^k}{\sum_i^n \gamma_i W_i h_i^k} \times V_j$ 3. <u>Number of modes to be considered</u> A sufficient number of modes shall be included in the analysis to include at least 90% of the total seismic mass in the direction under consideration. 4. <u>Combination of modal effects</u> - 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%. 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. 5. <u>Scale factor for design values of the combined response</u> When the design base shear (V_R) obtained by combining the modal base shear forces is less than the base shear (V) calculated using Equivalent Static Method; the member forces, story shear forces & base reactions obtained from the MRS method shall be multiplied by V/V_R. Where, V = Base Shear determined from Equivalent Static Method V_R = Base Shear determined from Modal Combination

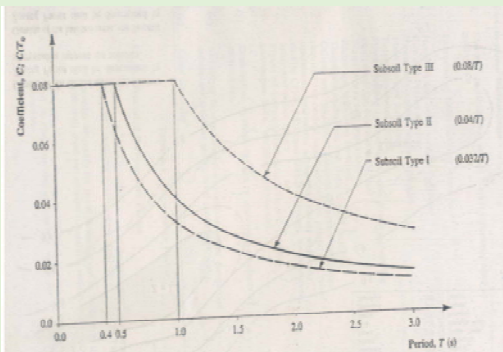
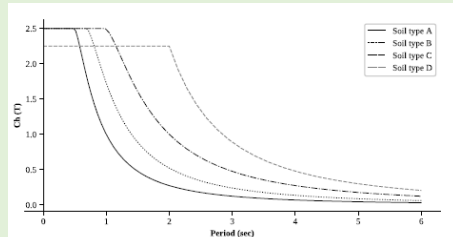
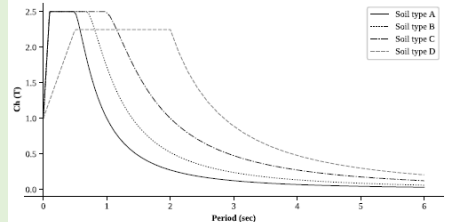
Design Methods

NBC 105:1994	NBC 105:2020
Two design methods has been specified: The Working Stress Method (elastic method), or, the Limit State Method	Only limit state method is considered in this revised standard.

Basic response Spectrum / Elastic spectra

NBC 105:1994	NBC 105:2020
A spectrum based on pseudo coefficient of 0.08 and spectral shape factor similar to IS 1893: 1984/ Seed is used. Same spectrum is used for both seismic coefficient method and modal response spectrum method. <i>Response Spectrum :Plot of maximum response of SDOF versus fundamental time period for a given damping</i>	A standard elastic site spectrum consistent to modern seismic engineering is introduced. Two different spectrum is proposed for seismic coefficient method and modal response spectrum method.

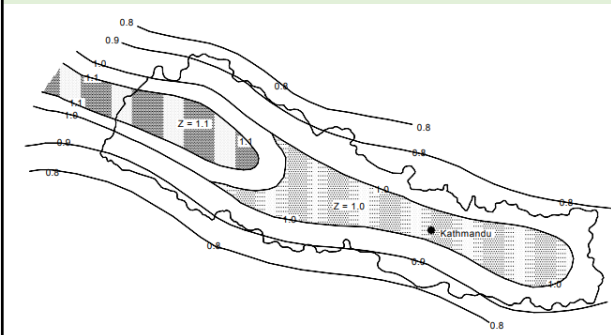
Basic response Spectra

NBC 105:1994	NBC 105:2020
 Figure 9.1 : BASIC SEISMIC COEFFICIENT, C BASIC RESPONSE SPECTRUM, $C(T_s)$	 Figure 4-1 Spectral Shape Factor, $C_h(T)$ for Equivalent Static Method  Figure 4-2 Spectral Shape Factor, $C_h(T)$ for Modal Response Spectrum Method, Nonlinear Time History Analysis, Vertical Loading and Parts and Components

Seismic zone factor(Seismic Hazard map)

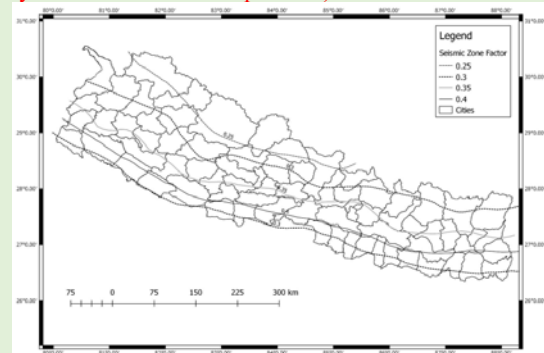
NBC 105:1994

Normalized values of zoning factor is used. The zoning factor has a minimum value of 0.8 and maximum value of 1.1 with a reference value of 1. (more empirical)



NBC 105:2020

Specific values representing the fraction of acceleration due to gravity (g) is proposed. The Seismic Zoning Factor (Z) represents the peak ground acceleration (PGA) for 475 year return period. Z :0.25g - 0.4g. (more Scientific & dynamic) (Citywise tabulated & interpolation)



Sub soil category

NBC 105:1994

Three types of sub soil category is provided:

- I -Rock or stiff soil sites
- II- Medium soil sites
- III- Soft soil sites

NBC 105:2020

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 (eg Kathmandu, laitpur,Bhaktapur, Madhyapur Thimi, Kageswori Manohara, Tokha)

Effective stiffness of cracked sections

NBC 105:1994	NBC 105:2020															
Such provision is not explicitly provided in the code.	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 from Table 3-1. <table><tr><th>No.</th><th>Component</th><th>Flexural Stiffness</th></tr><tr><td>1</td><td>Beam</td><td>$0.35 E_c I_g$</td></tr><tr><td>2</td><td>Columns</td><td>$0.70 E_c I_g$</td></tr><tr><td>3</td><td>Wall—cracked</td><td>$0.50 E_c I_g$</td></tr><tr><td>4</td><td>Wall—uncracked</td><td>$0.80 E_c I_g$</td></tr></table> For steel structures, the gross stiffness values shall be used.	No.	Component	Flexural Stiffness	1	Beam	$0.35 E_c I_g$	2	Columns	$0.70 E_c I_g$	3	Wall—cracked	$0.50 E_c I_g$	4	Wall—uncracked	$0.80 E_c I_g$
No.	Component	Flexural Stiffness														
1	Beam	$0.35 E_c I_g$														
2	Columns	$0.70 E_c I_g$														
3	Wall—cracked	$0.50 E_c I_g$														
4	Wall—uncracked	$0.80 E_c I_g$														

Time period

NBC 105:1994	NBC 105:2020
Rayleigh Method as well as empirical method of time period estimation is used. Empirical method of time period estimation is given for concrete, steel and infilled wall buildings. $T_i = 2\pi \sqrt{\sum W_i d_i^2 / g \sum F_i d_i} \quad 7.1$ (a) For framed structures with no rigid elements limiting the deflection : $T_1 = 0.085 H^{0.75}$ for steel frames $T_1 = 0.06 H^{0.75}$ for concrete frames (b) For other structures : $T_1 = \frac{0.09 H}{\sqrt{D'}}$ If T_1 calculated using these equations is greater than 120 percent of that finally calculated using Equation 7.1, the seismic forces shall be re-assessed.	Rayleigh Method as well as empirical method of time period estimation is used. Empirical method of time period estimation is expanded to include concrete, steel, eccentric braced frame and structural wall buildings. As the empirical methods gives 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 Rayleigh method. $T_1 = 2\pi \sqrt{\frac{\sum_{i=1}^n (W_i d_i^2)}{g \sum_{i=1}^n (F_i d_i)}} \quad 5.1(1)$ $T_1 = k_s H^{0.75} \quad 5.1(2)$ Where, k_s = 0.075 for Moment resisting concrete frame = 0.085 for Moment resisting structural steel frame = 0.075 for Eccentrically braced structural steel frame = 0.05 for all other structural systems Where, H = Height of the building from foundation or from top of a rigid basement.

Importance class and factors

NBC 105:1994

Class	I
I: Ordinary Structures	1.0
II: Essential facilities which needs to be functional after earthquake, monumental structures and places of assembly Buildings where large mass gathers For Example: Schools, colleges, cinemas, shopping malls, hospitals	1.5
III: Distribution facilities for gas or petroleum products in urban areas; Structures for the support or containment of dangerous substances	2.0

NBC 105:2020

Class	I
I: Ordinary Structures	1.0
II: Buildings where large mass gathers For Example: Schools, colleges, cinemas, shopping malls	1.25
III: Essential facilities which needs to be operable aftermath of earthquake. For example: hospitals, fire stations, police headquarters, power stations	1.5

Structural Performance factor, Ductility factor, Over strength factor

NBC 105:1994

In contrast to the other modern seismic codes, this is a multiplication factor used to arrive at the design seismic coefficient.

$$C_d = C \times Z \times I \times K$$

where,

C= Basic Seismic coefficient

Z= Seismic Zone factor

I = Importance Factor

K= Structural performance factor

NBC 105:2020

K factor approach does not reflect the modern seismic design philosophy of reducing the elastic seismic forces and rely on the nonlinear behavior of the structures to resist the seismic forces. To make consistent with **modern seismic design philosophy**, response reduction factors (Ductility factor, R_μ and Overstrength factor, Ω_s) is introduced as follows:

$$C_d(T_1) = \frac{C(T_1)}{R_\mu \times \Omega_s} \text{ for ultimate limit state}$$

$$C_d(T_1) = \frac{C_s(T_1)}{\Omega_s} \text{ for serviceability limit state}$$

Ductility: Capacity of structure to undergo large inelastic deformations without significant loss of strength.

Ductility factor, R_μ : The ratio of ultimate displacement demand to yield displacement demand.

Overstrength factor Ω_s : The ratio of first significant yield strength of structure to the design base shear of the structure.

Load combinations

NBC 105:1994	NBC 105:2020
Design Load Combinations for the Working Stress Method:	For parallel systems $1.2DL + 1.5LL$ $DL + \lambda LL \pm E$ For non-parallel systems $1.2DL + 1.5LL$ $DL + \lambda LL \pm (E_x \pm 0.3E_y)$ $DL + \lambda LL \pm (0.3E_x \pm E_y)$
DL + LL + E	
0.7 DL + E	
DL + SL + E	
Design Load Combinations for the Limit State Method	Where, $\lambda = 0.6$ for storage facilities $= 0.3$ for other usage Load combination for dead and live load has been introduced.
DL + 1.3 LL + 1.25 E	
0.9 DL + 1.25 E	
DL + 1.3 SL + 1.25 E	Factor of 1.25 in earthquake load combination is now removed. <i>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 elastic force level implies a reduction of expected ductility requirement.</i> Dead and live load factor in the load combination involving earthquake load has been made consistent with the calculation of seismic weight.

Drifts and displacements

NBC 105:1994	NBC 105:2020
The design lateral deformations shall be taken as the deformations resulting from the application of the forces or design spectrum as specified in 10 or 11 respectively, multiplied by the factor 5/K.	<u>Ultimate limit state</u> The design horizontal deflections shall be determined by multiplying the horizontal deflection found from Equivalent Static Method or Modal Response Spectrum Method by the Ductility factor (R_w).
<u>Inter-Storey Deflections</u> The ratio of the inter-storey deflection to the corresponding storey height shall not exceed 0.010 nor shall the inter-storey deflection exceed 60 mm (refer also to 12.6.2).	<u>Serviceability limit state</u> 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.
	<u>Inter-Story Deflections</u> The ratio of the inter-story deflection to the corresponding story height shall not exceed: 0.025 at ultimate limit state 0.006 at serviceability limit state The deflections shall be obtained by using the effective stiffness properties of the components as given in 3.4.

Parts & components

NBC 105:1994	NBC 105:2020
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. <u>Design Forces</u> All elements and components shall be designed for a seismic force F_p, in any direction given by : $F_p = C_p (1.0 + h_i / H) K_p W_p$ C_p is taken equal to C_d $F_p = C_p P K_p W_p$ Where, P= structural response factor K_p= component seismic performance factor W_p = weight of element, component or item of the equipment	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. <u>Design Forces</u> 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): $F_p = Z \left(1 + \frac{h_p}{H} \right) \frac{a_p}{\mu_p} I_p W_p$ where, Z = seismic zoning factor a_p= component amplification factor μ_p = Component ductility factor I_p =Component importance factor W_p= component weight h_p = height of attachment of the component H = total height of structure

Thank you