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Comparative Study of Behaviour of Buildings using NBC 105:2020 and IS 1893:2016 based on Horizontal Irregularities

Suchana Rijal[1*], Pujan Tharu[2], Sanskar Shrestha[3], Saurav Poudel[4], Krishna Ghimire[5]

[1,2,3,4] *Department of Civil Engineering Pokhara Engineering College, Pokhara, Nepal*

[5] *Assistant Professor, Department of Civil Engineering, Pokhara Engineering College, Pokhara, Nepal*

**Corresponding email:* krishnaghimire040@gmail.com

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Abstract

Seismic performance of structures is highly influenced by building configuration and the design code adopted. Irregular buildings, especially those with L-, C- and E-shaped plans, are known to exhibit complex dynamic behavior compared to regular-shaped structures. This study focuses on evaluating the seismic response of such irregular configurations using two widely adopted design standards: NBC 105:2020 (Nepal) and IS 1893:2016 (India). A comparative analysis was conducted through equivalent static method using ETABS software, assessing key parameters such as lateral displacement, inter-storey drift, and torsional irregularity. Four different building models—regular, L-shaped, C-shaped, and E-shaped—were analyzed under identical loading, material, and geometric conditions. The results revealed that irregular buildings consistently exhibited higher lateral displacement and drift, particularly at the re-entrant corners where stress concentrations were most severe. Among the codes, NBC 105:2020 produced notably higher drift values in all configurations compared to IS 1893:2016, indicating a more conservative approach. Torsional irregularities were also more pronounced in L- and C-shaped buildings under NBC, due to its stricter consideration of eccentricity and mass irregularity. Overall, the study highlights the critical impact of both structural configuration and seismic code selection on the response of buildings. It is concluded that while NBC 105:2020 provides a higher margin of safety, especially for irregular buildings, careful consideration of building geometry during the design phase remains essential for seismic resilience. The findings underscore the need for enhanced code-specific design provisions for irregular structures in high-seismic zones.

Keywords: Code comparison, horizontal irregularities, base shear, drift, torsion, displacement

1. Introduction

Seismic forces significantly impact the safety and performance of buildings, especially in earthquake-prone countries like Nepal and India. One of the key factors influencing seismic response is horizontal irregularity, which includes non-uniform building shapes in plan such as L-shaped, U-shaped, and E-shaped structures. These irregular configurations cause uneven distribution of stiffness and mass, which results in stress concentrations and enhanced torsional effects during ground motion (Agarwal and Shrikhande, 2010). To address these concerns, national seismic design codes such as NBC 105:2020 in Nepal and IS 1893 (Part 1):2016 in India provide criteria for identifying and analysing horizontal irregularities. Both codes define types of plan irregularities, including torsional irregularity, re-entrant corners, diaphragm discontinuities, and non-parallel lateral force-resisting systems. For torsional irregularity, both codes state that it exists when the maximum storey displacement at one end exceeds 1.5 times the minimum displacement at the other end of the same storey (NBC 105:2020 and IS 1893:2016).

Previous studies highlight that buildings with horizontal irregularities often experience higher seismic demand compared to regular buildings. According to Adhikari et al. (2020), L- and U-shaped buildings show significantly increased lateral displacement and torsional response. Goyal and Choudhury (2019) emphasized that torsional effects are especially critical when such buildings are analysed using simplified methods like the equivalent static approach. Sharma and Khandelwal (2017) found that NBC 105:2020 generally leads to higher base shear and more conservative designs than IS 1893, due to differences in seismic zoning and design assumptions. Despite these observations, limited research has been conducted that directly compares NBC 105:2020 and IS 1893:2016 in the context of horizontally irregular structures under a consistent modelling approach.

Although seismic codes like NBC 105:2020 and IS 1893:2016 discourage the use of horizontally irregular buildings due to their poor seismic performance, such irregular forms are still commonly used in practice for functional or architectural reasons. This mismatch between codal intent and construction practice can compromise structural safety.
Moreover, the two codes differ in their treatment of irregularities, which may lead to variations in design and seismic response. There is limited comparative analysis of how these codes address horizontal irregularities in terms of drift, displacement, and torsion. The main objective of the research is to compare seismic codes NBC 105:2020 and IS 1893:2016 based on horizontal irregularities. This study aims to fill that gap by analysing and comparing the behaviour of irregular buildings under both codes.

The scope of the study encompasses various aspects in functional planning and structural analysis of building with NBC and IS using ETABS. The comparative analysis using NBC and IS will be for the four buildings (5 storey + staircase cover); one is the designed to be building named Regular building and others are the buildings having horizontal irregularities, i.e. L shaped building, C shaped building and E shaped building. The research uses Equivalent Static Method for analysis and it will evaluate how each code handles torsional irregularities. The soil type is considered "soil type D" for NBC and "soil type III" for IS. This research outlines the approach to utilizing different plans, for seismic analysis and comparison (NBC and IS) along with detailed design of an apartment building.
The load cases and load combinations used in the analysis were adopted from IS 1893:2016 and NBC 105:2020, ensuring that the structural evaluation reflects the seismic design provisions, safety requirements, and code-based guidelines specified by both Indian and Nepalese standards for accurate and reliable assessment of critical element forces.

The seismic load combinations were adopted from IS 1893:2016 and NBC 105:2020. As per IS 1893:2016, the structure is designed considering bidirectional seismic effects using combinations such as (ELX ± 0.3 ELY) and (ELY ± 0.3 ELX), where X and Y are orthogonal horizontal directions. These are incorporated into load combinations provided in code to capture critical loading conditions. In contrast, NBC 105:2020 specifies load combinations for both parallel and non-parallel systems likely DL + λLL ± E and other combination as mentioned in code, where the live load factor λ is taken as 0.6 for storage facilities and 0.3 for other occupancies. For non-parallel systems, directional combinations such as (EX ± 0.3EY) and (0.3EX ± EY) are considered, ensuring realistic representation of seismic action in both principal directions.

2. Materials and Methodology

2.1 Building configuration

For comparison, an identical structural model is adopted for all seismic codes, and the important characteristics of the building are presented in the table below. The study was conducted on four different building configurations—regular, L-shaped, C-shaped, and E-shaped—where each model was subjected to the same loading conditions, material properties, and geometric parameters. This consistent approach ensures that the comparison of structural responses is purely based on the effect of building shape and plan irregularity.

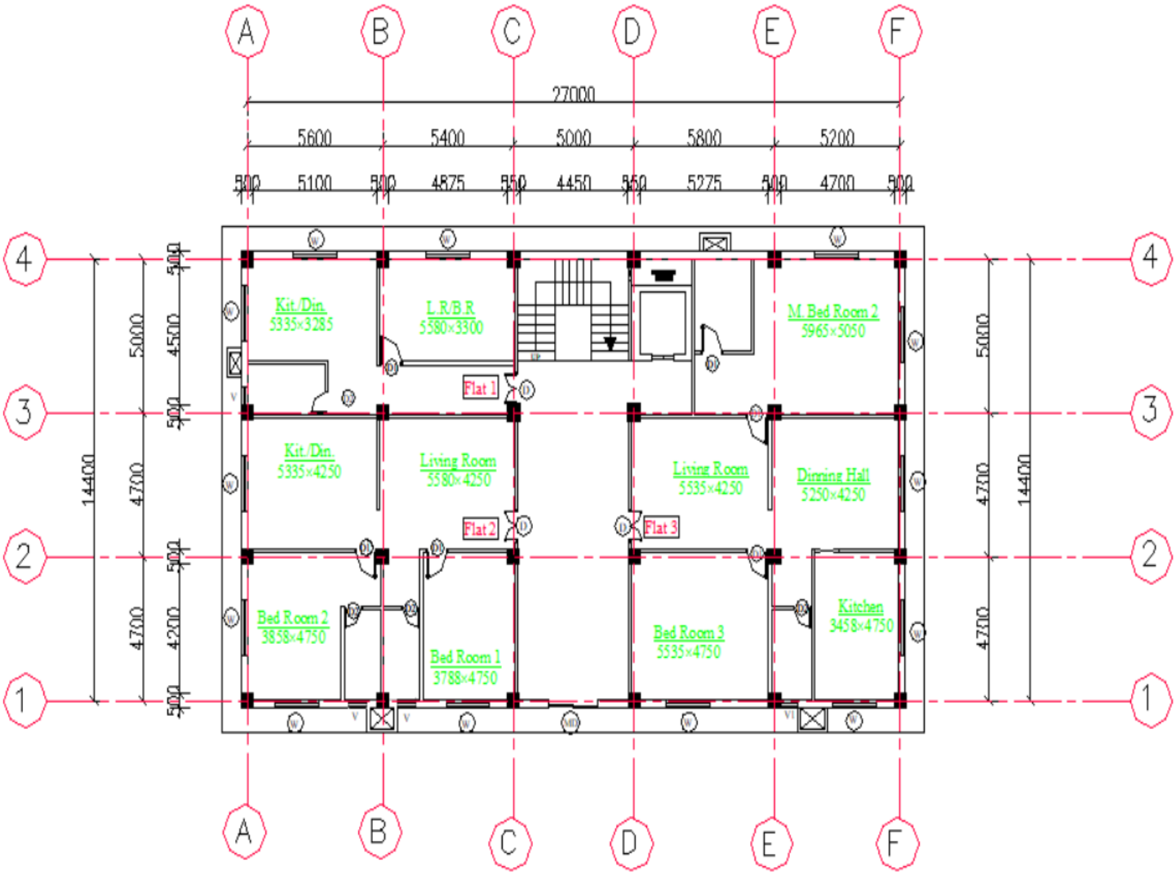

Figure 1: Architectural Drawing of Ground Floor.

Table 1: Description of Building (NBC 206:2015, Architectural Design Requirements).

Parameters	Details
Types of Building	Apartment Building
Category of Building	Mid-Rise Building
Structural System	RCC Frame Structures; SMRF
Number of Story	5 (G + 4 + Staircase Cover)
No. of Bays in X Direction	5 nos. of Bays
No. of Bays in Y Direction	3 nos. of Bays
Plint Area	429.93 Sq m
Floor Height	3.0 m
Size of Building	Length = 27000 mm, Breadth = 14400 mm
Grade of Concrete	M25 for Beam, Column and M20 for Slab
Grade of Steel	Fe 500

2.2 Material

Table 2: Parameters used for the design of models (IS 456:2000, Indian Standard Code of Practice for Plain and Reinforced Cement Concrete)

Description	Section/Constant	Units
Parameters	Data	Unit
Column size	500X500	mm X mm
Main Beam size	300X500	mm X mm
Slab thickness	125	mm
Shear wall	200	mm
Specific weight of concrete	25	KN/m^3
Unit weight of Brick	19.0	KN/m^3
Modulus of elasticity of concrete	25000	MPa

2.3 Modelling of Buildings

Modelling is done using ETABS 2000 Vs. 24.0, using the finite element model of a building. Modelling is done as per the architectural drawing, and the changes are made later as per the structural requirements. Special attention is given while modelling the building in ETABS as a very small and unnecessary section may cause the failure of the whole structure which is undesirable.

The structure is a mid-rise apartment building with RCC frame construction using a Special Moment Resisting Frame (SMRF) system. It has a total of 5 stories (Ground + 4 floors + staircase cover). The building layout consists of 5 bays along the X direction and 3 bays along the Y direction. The building was modeled and analyzed using the Equivalent Static Method according to both Nepal (NBC 105:2020) and Indian (IS 1893:2016) seismic codes. After the initial analysis of the regular building, additional building configurations—C-shaped, E-shaped, and L-shaped plans—were created to study the effects of plan irregularity on seismic response. The analysis is done following Equivalent static method (ESM)

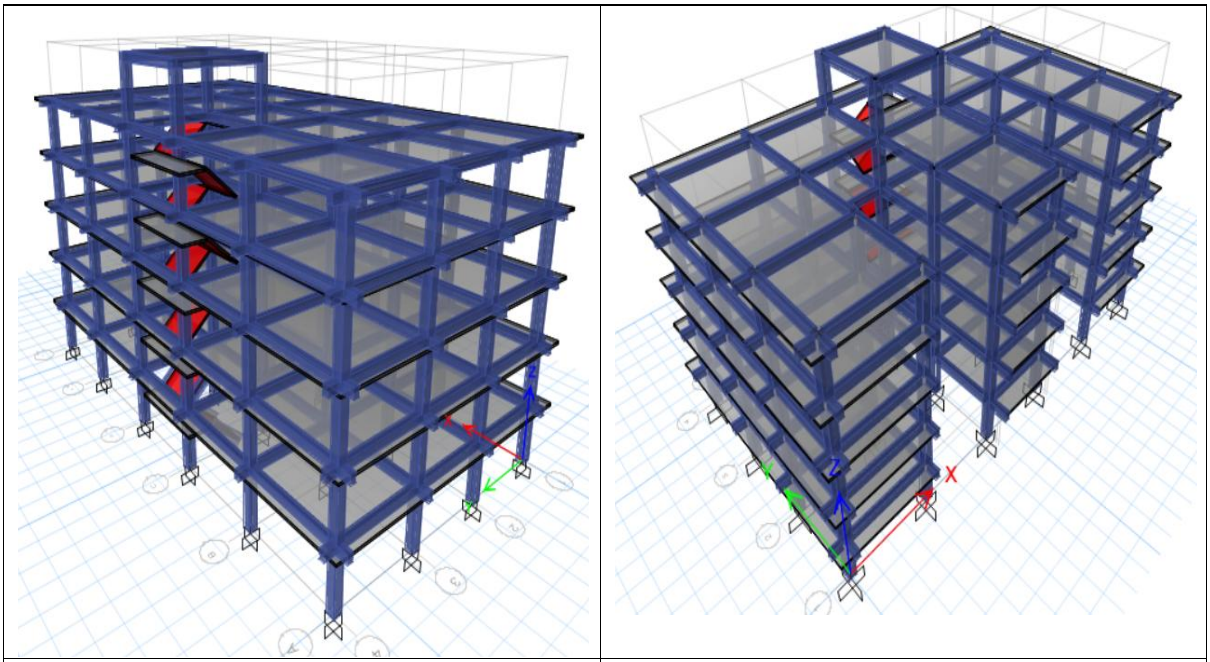

Figure 2 a: Regular Shape Building

Figure 2 b: E Shape Building

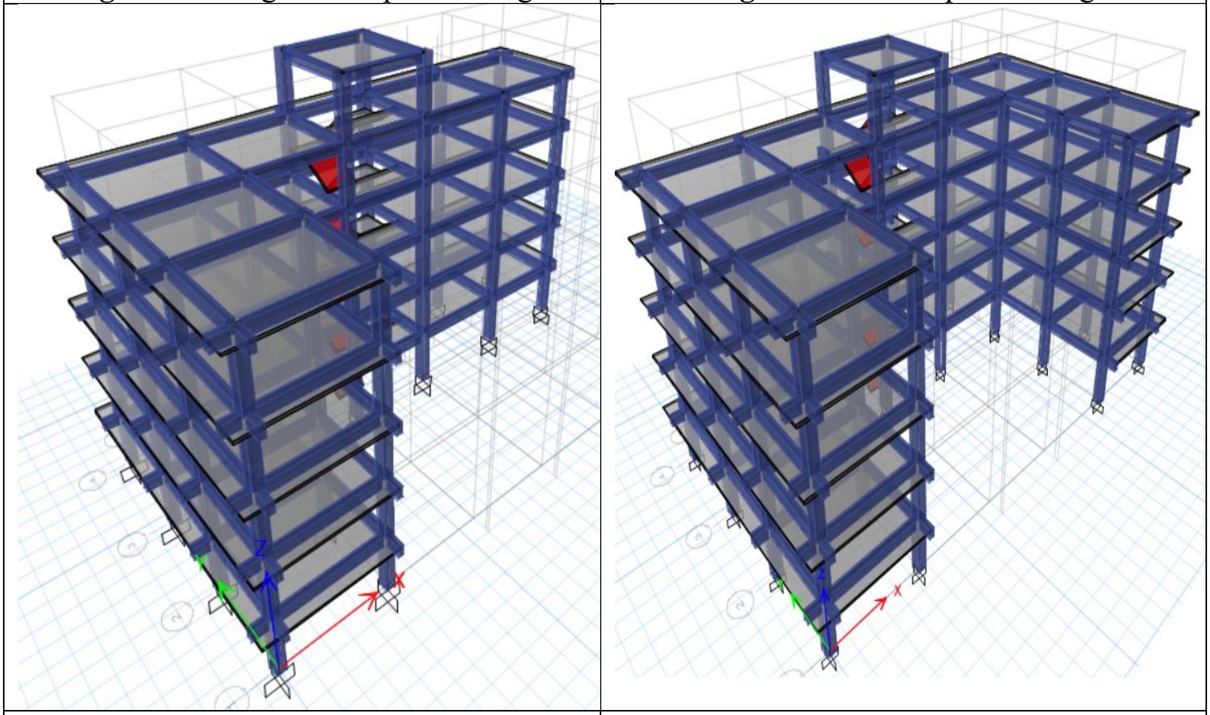

Figure 2 c: L Shape Building

Figure 2 d: C Shape Building

Figure 2: Different sides Extrude view of building from ETABS.

2.4 Seismic coefficient calculation:

Using NBC 105:2020, The base shear coefficient will be determined separately for ultimate limit state and serviceability limit state from the figure 4.

$$Cd(T1) = (C(T1))/((R\mu)(\Omega u)) \quad (1)$$

$$Cd(T1) = (Cs(T1))/\Omega s \quad (2)$$

Where, $Cd(T1)$ = Elastic Site Spectra for Ultimate Limit State

$Cs\ (T1))$ = Elastic Site Spectra for Serviceability Limit State

$R\mu$= 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:

$V = Cd(T1).W$

Where, $Cd(T1)$ = Horizontal base shear coefficient

The Elastic site spectra for horizontal loading shall be as given by

$$C\ (T) = Ch(T)\ Z\ I \quad (3)$$

where, $Ch(T)$ = Spectral Shape factor

According to IS 1893:2016 (Part 1), the base shear coefficient is determined based on various factors such as the seismic zone, importance of the structure, and the structural system's response.

The base shear is calculated using the formula:

$V_B = Ah.W$

where, V_B = Total base shear (in KN)

Ah = Horizontal seismic coefficient

W= Seismic weight of the structure (in KN)

$$Ah = \frac{Z.I.Sa}{2.R.g} \quad (4)$$

Z = Zone Factor

I = Importance Factor

R = Response Reduction Factor

Sa/g = Average Response Acceleration

g = Acceleration due to gravity

Table 3: According to IS 875 (Part 1): 1987 and IS 875 (Part 2): 1987 Indian Standard Code of Practice for Design Loads

Parameters	Dead Load	Units
External Brick wall Without Opening	13.25	KN/m
External Brick wall 25% Opening	9.95	KN/m
Partition Brick wall Without Opening	8.75	KN/m
Partition Brick wall With Opening	6.5	KN/m
Dead load of Floor finish for Roof	0.75	KN/m^2

Dead load of Floor finish with Granite	1.50	KN/m^2
Dead load of Floor finish with Tile	1.25	KN/m^2
Balcony and staircase,	4	KN/m^2
Kitchen and Hall	3	KN/m^2
Toilet and Bathroom	2	KN/m^2
Roof accessible	1.5	KN/m^2
Roof not accessible	0.75	KN/m^2

3. Results and Discussion

A study is performed in apartment RC Building of different configuration through different edition of National Building Code (NBC) from Nepal, and Indian Standard Code (IS) from India. The Results are interpreted in terms of base shear, displacement, torsion, drift, lateral forces.

Base Shear comparison bar chart is Shown below:

Table 4: Base Shear along X- Direction

Building	NBC SLS (KN)	NBC ULS (KN)	IS (KN)
Regular	2716.52	2842.28	2245.14
L- Shape	1561.09	1633.28	1361.97
U- Shape	2042.76	2137.34	1712.82
E- Shape	2274.32	2379.622	1927.02

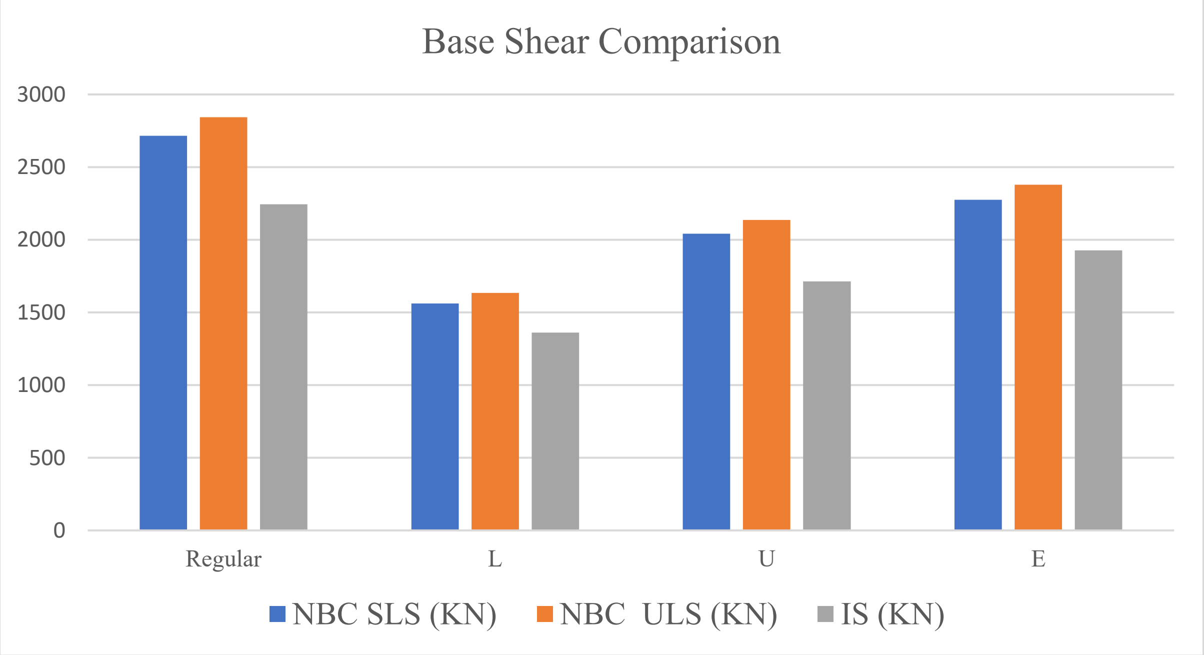

Figure 3: Base Shear in EQX Direction

The comparison of base shear values indicates that the NBC (National Building Code) produces higher base shear values for all building configurations compared to the Indian Code. The Regular-shaped building shows the highest difference, where the NBC value is 26.5% greater. Similarly, the L-shaped, C-shaped, and E-shaped buildings show increases of 19.92%, 24.78%, and 23.48%, respectively. This suggests that the NBC provisions result in more conservative base shear estimates, leading to potentially safer structural designs for different building plan irregularities than IS Code.

The story displacement are compared and presented below:

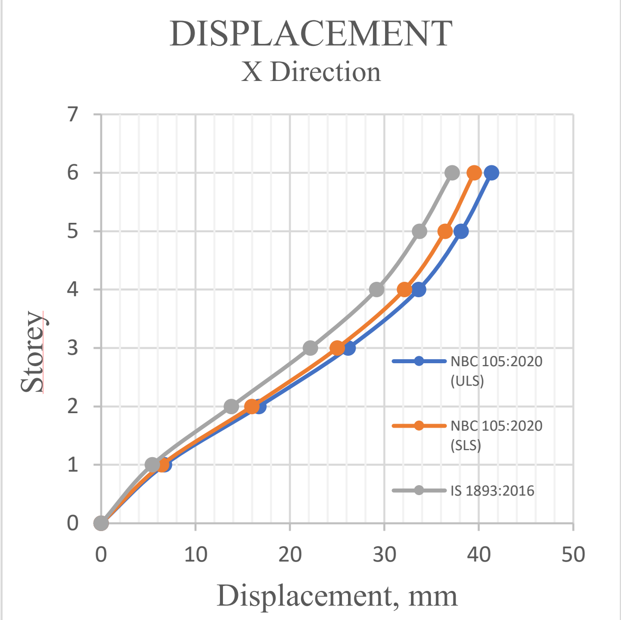

Figure 4: Displacement in X-Direction of Regular Building

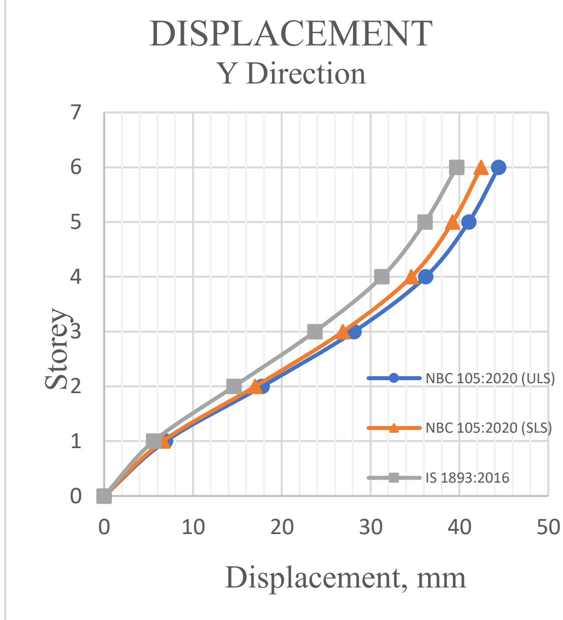

Figure 5: Displacement in X-Direction of Regular Building

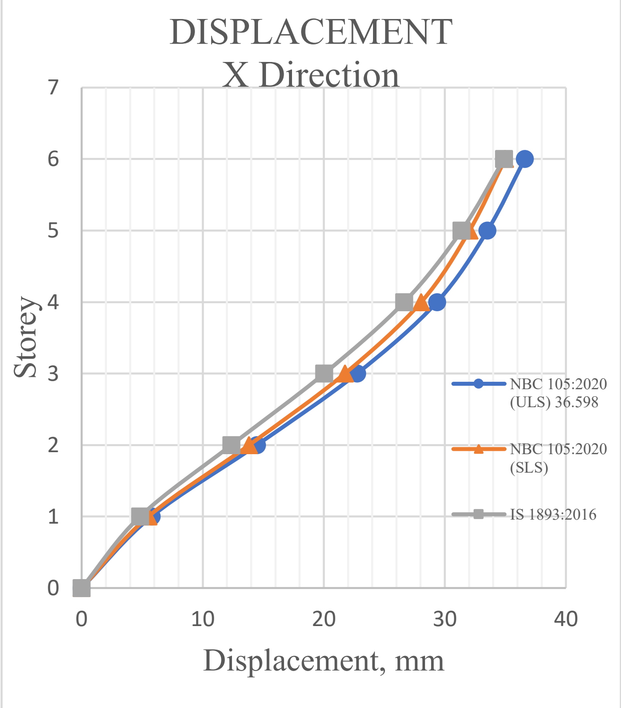

Figure 6: Displacement in X-Direction of L-shaped Building

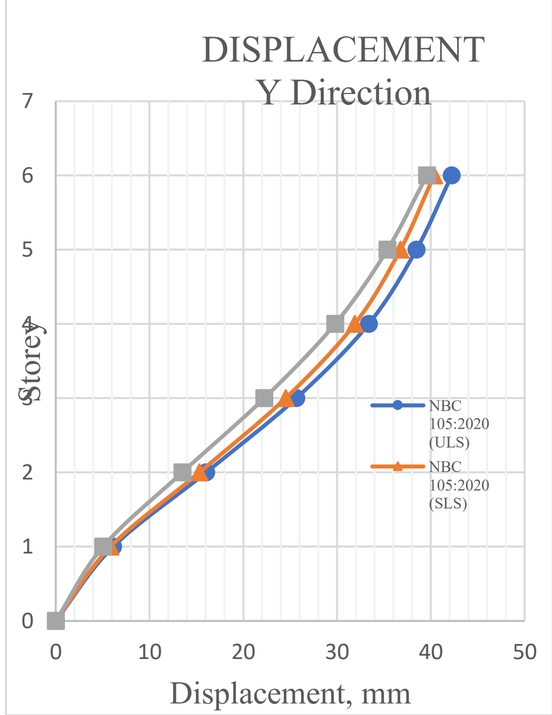

Figure 7: Displacement in Y-Direction of L- shaped Building

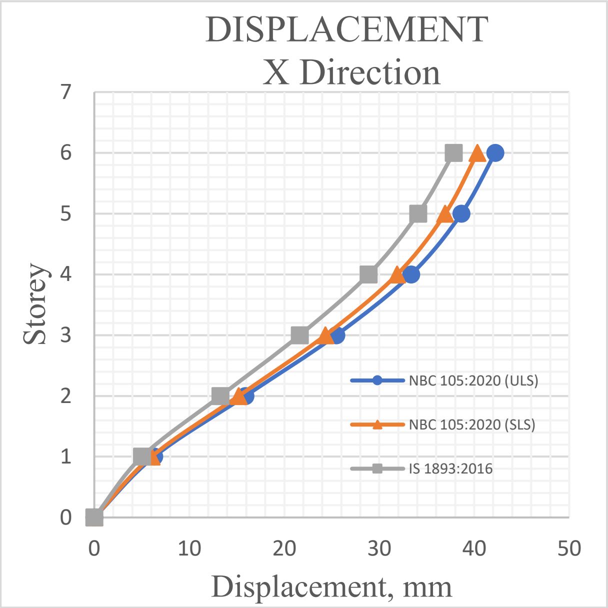

Figure 8: Displacement in X-Direction of C-shaped Building

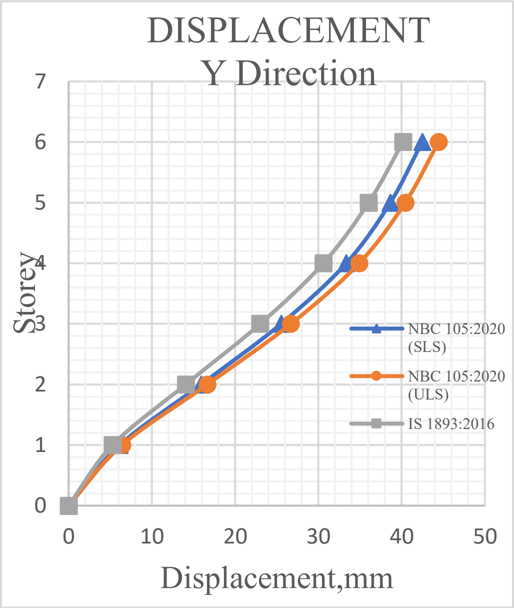

Figure 9: Displacement in Y-Direction of C- shaped Building

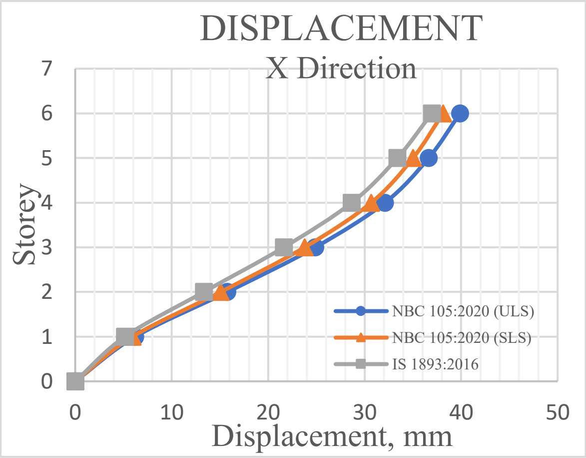

Figure 10: Displacement in X-Direction of E-shaped Building

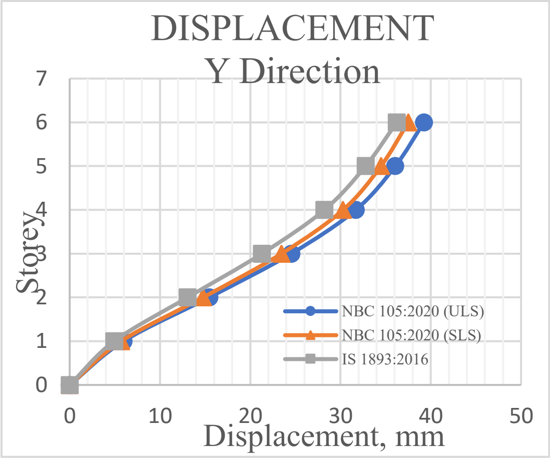

Figure 11: Displacement in Y-Direction of E- shaped Building

The comparison of results in both X and Y directions shows that the values obtained using NBC provisions are higher for all building configurations. In the X direction, the Regular and C-shaped buildings show the highest increase of 21%, followed by the E-shaped building (15%) and the L-shaped building (10%). Similarly, in the Y direction, the Regular building again shows the highest increase (12%), while the L-shaped building shows the lowest difference (7%). The C-shaped and E-shaped buildings show increases of 11% and 8%, respectively. Overall, the results indicate that NBC tends to produce higher response values compared to the other code, suggesting a more conservative design approach for different building configurations and directions.

The story drift graphs are compared and demonstrated:

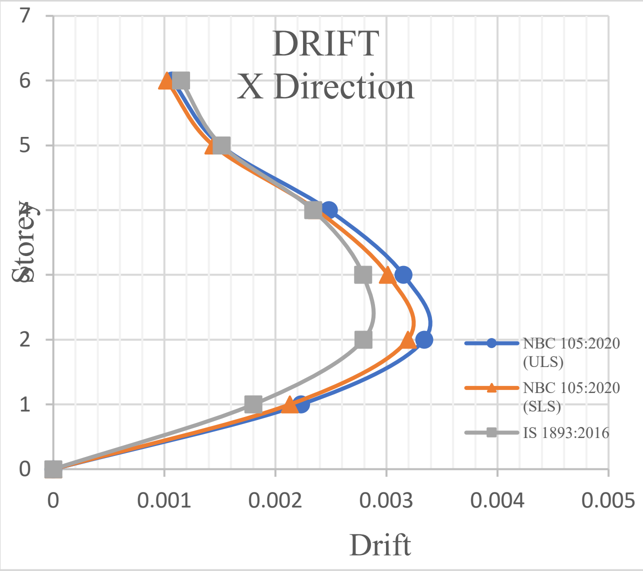

Figure 12: Inter Story Drift in X- Direction of Regular Building

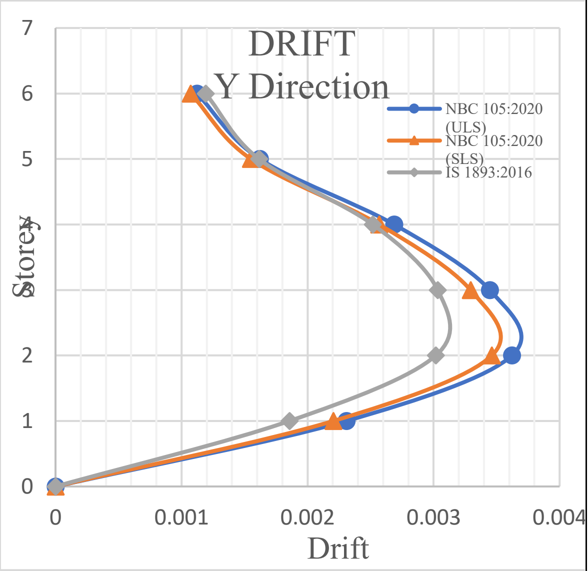

Figure 13: Inter Story Drift in X- Direction of Regular Building

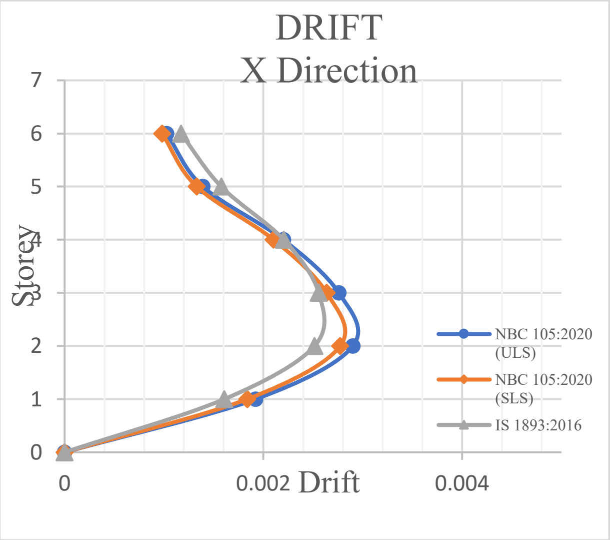

Figure 14: Inter Story Drift in X- Direction of L- Shaped Building

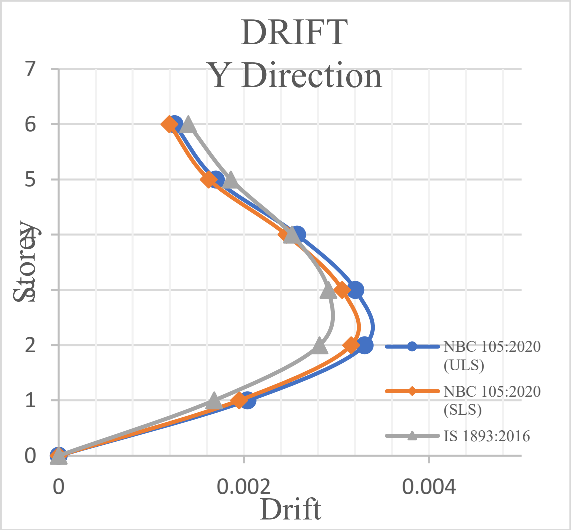

Figure 15: Inter Story Drift in X- Direction of L- Shaped Building

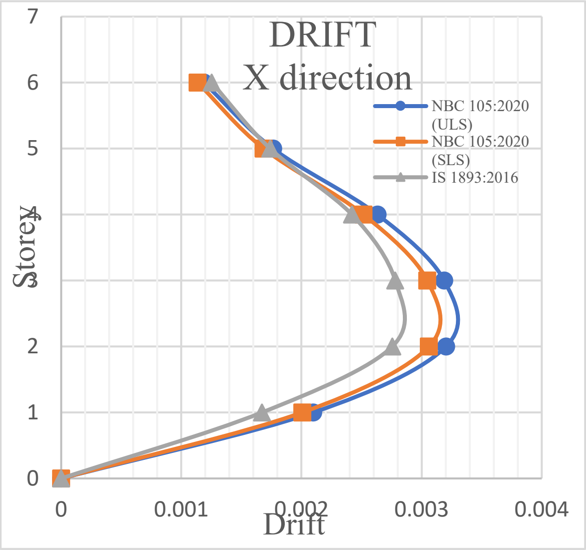

Figure 16: Inter Story Drift in X- Direction of C- Shaped Building

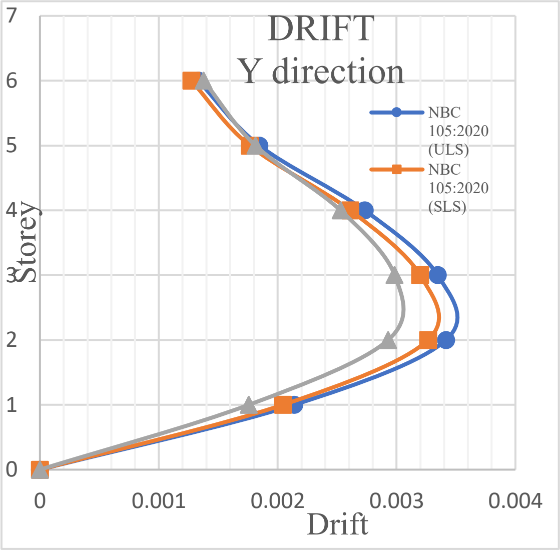

Figure 17: Inter Story Drift in X- Direction of C- Shaped Building

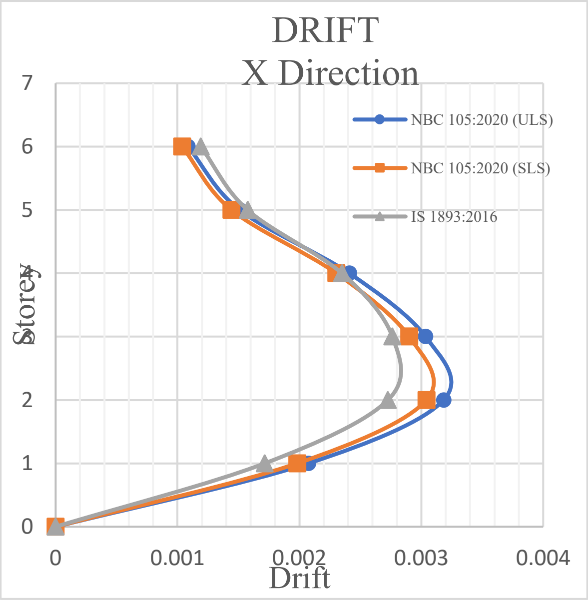

Figure 18: Inter Story Drift in X- Direction of E- Shaped Building

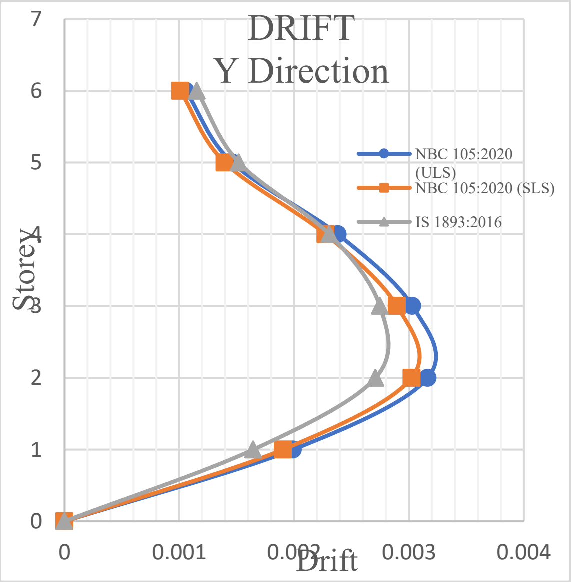

Figure 19: Inter Story Drift in X- Direction of E- Shaped Building

The comparison of storey drift at the 2nd storey shows that the values obtained from NBC are higher than IS code for all building configurations in both directions. In the X-direction, the Regular building shows drift higher in NBC by 18%, while the L-shaped building shows an increase of 15%. Similarly, the C-shaped and E-shaped buildings show higher drift values in NBC by 16% each. In the Y-direction, the Regular building again shows the highest difference where NBC gives 19% higher drift than IS code. The L-shaped building shows 16% higher drift, and the C-shaped and E-shaped buildings also show 16% higher drift compared to IS code. From the above comparison, it is clear that NBC consistently produces higher maximum storey drift values than IS code, with differences ranging from 15% to 19% in the X-direction and 16% to 19% in the Y-direction for both regular and irregular building configurations.

The torsion graphs are compared and illustrated as:

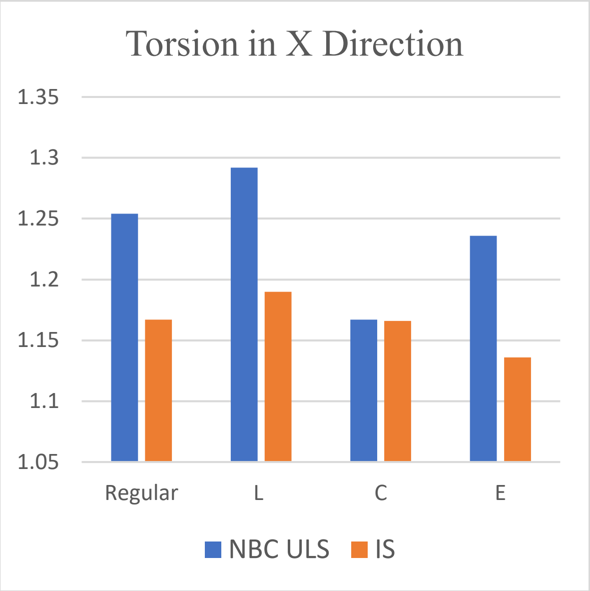

Figure 20: Maximum torsion in EQX

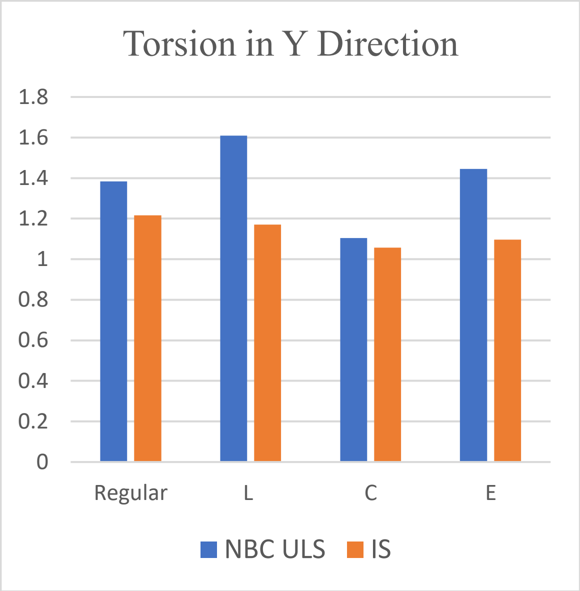

Figure 21: Maximum torsion in EQY

Table 5: Torsion comparison in X direction

Buildings	Remarks (Torsion in X Direction)
Regular	Higher in NBC by 8%
L	Higher in NBC by 9%
C	Higher in NBC by 1%
E	Higher in NBC by 9%

Table 6: Torsion comparison in Y direction

Buildings	Remarks (Torsion in Y Direction)
Regular	Higher in NBC by 13%
L	Higher in NBC by 32%
C	Higher in NBC by 5%
E	Higher in NBC by 28%

The NBC code predicts higher torsional response in irregular building shapes such as L, C, and E configurations compared to the IS code. This increased torsional effect is mainly due to the stricter eccentricity provisions specified in NBC, which consider greater accidental eccentricity in the analysis. Furthermore, the lower Response Reduction Factor (R) adopted in NBC results in higher design seismic forces, which consequently increases the torsional response of the structure.

The Comparison Graph of Maximum Percentage of reinforcement in Column

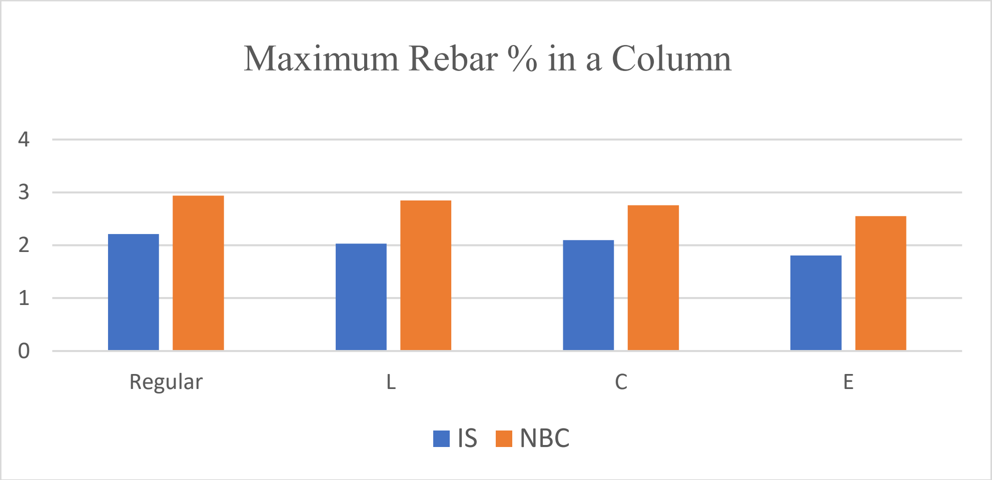

Figure 22: maximum percentage of reinforcement in column

NBC requires up to 20% higher reinforcement than the IS code, which increases construction cost but ensures a safer and more earthquake-resistant structural design.

Discussions:

This research compares the seismic performance of buildings using two codes: NBC 105:2020 and IS 1893:2016. Both codes have different rules for handling horizontal irregularities like L, U and C shaped buildings. These irregular shapes affect how buildings behave during earthquakes. The discussion focusses on how the results differ between two codes in terms of drift, displacement and torsion. The seismic responses of irregular buildings vary under NBC 105:2020 and IS 1893:2016 due to differences in key parameters such as seismic zoning factor, response reduction factor, importance factor, and base shear calculation method.

1. NBC 105:2020 uses Peak Ground Acceleration (PGA) values derived from Probabilistic Seismic Hazard Analysis (PSHA), which results in higher seismic demand in regions with greater seismic risk. In contrast, IS 1893:2016 uses a zone factor (Z) based primarily on historical seismic data, which may lead to comparatively lower seismic design forces. As a result, NBC generally produces higher base shear, displacement, and storey drift values compared to IS code, leading to a more conservative seismic design approach.

2. In NBC, the Response Reduction Factor (R) for Special Moment Resisting Frame (SMRF) is taken as 4.0, whereas in IS 1893:2016, the value of R for SMRF is 5.0. A higher value of R reduces the design seismic force, as it assumes greater capacity of the structure to undergo inelastic deformation during earthquakes. Due to the higher R value in IS, the design seismic forces are generally lower, which may lead to lighter and more flexible structural members. In contrast, the lower R value in NBC results in higher design forces, leading to stronger and relatively stiffer structural members with lower ductility demand, and less emphasis on ductile

detailing. The elastic properties like Young's modulus remain unchanged, but the structural behaviour shifts between elastic and inelastic depending on R.

3. The NBC 105:2020 considers 30% of live load for seismic weight under the category live load for other purposes, which applies to our building type. IS 1893:2016 considers 25% of live load for seismic weight when the live load is less than or equal to 3 KN/m², which also the case for our structure. A higher seismic weight leads to a higher base shear. As a result, the NBC generally predicts greater seismic forces, making the design safer but more conservative compared to the IS. This difference, though small (only 5%), can influence member sizing, reinforcement, and overall cost.

4. For torsional Criteria NBC uses stricter limits for allowable torsion ratio (Dmax/Davg > 1.5) to define irregularity. IS allows a slightly more relaxed criterion. In the range 1.5-2.0, (a) the building configuration shall be be revised to ensure that the natural period of the fundamental torsional mode of oscillation shall be smaller than those of the first two translational modes along each of the principal plan directions, and then (b) three-dimensional dynamic analysis method shall be adopted and more than 2.0, the building configuration shall be revised. As a result, IS flags torsional irregularity more aggressively, while NBC gives a more realistic response based on true building geometry. So, it requires heavier design in IS; NBC allows more efficient design but only if torsion is within limits.

5. Regarding eccentricity NBC considers a fixed accidental eccentricity of ±0.1b (10% of building width perpendicular to seismic force direction). It doesn't include or amplify the static eccentricity (actual offset between centre of mass and centre of rigidity). IS considers design eccentricity= 1.5× static eccentricity ±0.05b. it accounts for both actual torsional irregularity and accidental uncertainty. IS is more conservative, leading to higher torsional moments and safer design, especially for irregular buildings. NBC may underestimate torsion, which could lead to less safe design in buildings with significant asymmetry.

4. Conclusions

The reasons why these differences matter are stated as:

- Base Shear directly influences the total lateral force; higher base shear causes higher drift and displacement.

- The comparison of base shear values indicates that the NBC (National Building Code) produces higher base shear values for all building configurations compared to the Indian Code, leading to potentially safer structural designs but less economic.
- The Base shear of Regular-shaped building shows the highest difference, where the NBC value is 26.5% greater. Similarly, the L-shaped, C-shaped, and E-shaped buildings show increases of 19.92%, 24.78%, and 23.48%, respectively.
- Overall, NBC 105:2020, requires a higher percentage of longitudinal rebar than IS 1893: 2016 in structural members.

- Torsion becomes critical in irregular buildings where mass and stiffness are not symmetrically distributed; stricter torsion checks in NBC mean it catches irregular behavior earlier.

- The NBC code assumes a 10% accidental eccentricity compared to 5% in the IS code, resulting in higher torsional forces in structural design.
- The comparison of results in both X and Y directions shows that the values obtained using NBC provisions are higher for all building configurations. In the X direction, the Regular and C-shaped buildings show the highest increase of 21%, followed by the E-shaped building (15%) and the L-shaped building (10%).
- Drift affects structural safety and serviceability and NBC tends to produce higher drift values than IS code due to higher input forces, with differences ranging from 15% to 19% in the X-direction and 16% to 19% in the Y-direction for both regular and irregular building configurations.

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