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Seismic Performance of Regular and Irregular High-Rise Buildings: Influence of Geometrical Configuration on Structural Response

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Abstract: This research investigates the comparative seismic performance of regular and irregular high-rise building geometries using ETABS software. Five building configurations—square, rectangular, L-shaped, C-shaped, and T-shaped—were analyzed under dynamic loading conditions as per relevant Indian Standards. Key structural parameters such as storey displacement, storey drift, base shear, time period, and frequency were evaluated to assess stability and load resistance.Results indicate that regular configurations, particularly square-shaped buildings, perform better due to symmetrical stiffness and uniform mass distribution, resulting in reduced displacement and drift. Irregular structures, especially L and T shapes, exhibit higher torsional effects and stress concentration, leading to increased lateral response.The study highlights the significant impact of building geometry on seismic behavior and structural efficiency. The findings provide practical guidance for optimizing high-rise building design in earthquake-prone regions, ensuring improved safety, serviceability, and overall structural performance while balancing architectural requirements.

Keywords: Seismic performance, Regular buildings, Irregular buildings, High-rise structures, Response Spectrum, ETABS, Plan Irregularity, Storey Drift, Torsion, IS 1893.

I. INTRODUCTION

High-rise buildings have become a defining feature of modern urban landscapes, accommodating residential, commercial, and mixed-use purposes. With rapid urbanization and land scarcity, vertical expansion is often preferred over horizontal growth. However, in seismically active regions, these tall structures are highly vulnerable due to their considerable height, slenderness, and complex dynamic behavior. According to Chopra (2012), earthquakes subject high-rise buildings to significant ground motions that may lead to excessive inter-storey drifts, torsional effects, and, in severe cases, progressive collapse. Similarly, Paulay and Priestley (1992) emphasized that ensuring seismic safety in high-rise buildings is vital not only for safeguarding human lives but also for protecting infrastructure investments and maintaining socio-economic stability.From a seismic design perspective, buildings are broadly classified as regular or irregular based on their geometry, mass distribution, and stiffness characteristics. Regular buildings exhibit uniformity in mass, stiffness, and geometry in both plan and elevation, making their seismic response more predictable (Chopra, 2012). In contrast, irregular buildings deviate from this uniformity, resulting in complex and less predictable seismic behavior (Boen, 2001). Irregularities are typically grouped into plan irregularities, such as L-shaped, T-shaped, or U-shaped layouts that induce torsional effects; vertical irregularities, such as soft storeys, setbacks, and abrupt changes in stiffness; and mass or stiffness irregularities due to uneven load distribution across storeys (Murty, 2010). These discontinuities disrupt load transfer paths, creating stress concentrations that often amplify seismic demands when compared to regular configurations (Das &Murty, 2004).

The increasing demand for architectural flexibility and aesthetic innovation has further contributed to the proliferation of irregular geometrical forms in tall buildings. While such designs enhance visual appeal and functionality, they also compromise seismic resilience. For example, studies by De Stefano and Pintucchi (2008) showed that plan irregularities significantly increase torsional response, while vertical irregularities amplify inter-storey drifts and soft-storey mechanisms. A comparative evaluation of regular and irregular geometrical forms is therefore essential to understand their influence on dynamic characteristics such as natural period, base shear, displacement, and drift. Research by Kappos et al. (2006) and Ghosh & Datta (2010) demonstrated that such comparative studies are crucial for assessing the limitations of current seismic codes and for developing effective design and mitigation strategies.High-rise buildings are increasingly adopted in urban regions due to land scarcity and growing functional demands.

In seismic zones, the structural response of such buildings becomes critical because lateral forces induced by earthquakes often govern design. Among the factors influencing seismic performance, plan irregularity plays a significant role by introducing eccentricity between the centre of mass and centre of stiffness, leading to torsional effects and uneven distribution of seismic forces.Buildings with regular plan configurations generally exhibit more uniform stiffness and predictable seismic behaviour, whereas irregular plans such as L-, C-, and T-shaped configurations tend to experience amplified storey drift, torsion, and displacement demands. These plan forms are commonly adopted in practice due to architectural and functional requirements, despite their known vulnerability under seismic excitation. Several journal studies have reported that plan irregularity significantly alters dynamic characteristics such as natural period, base shear, and torsional response, making direct comparison with regular configurations essential for performance assessment.Although seismic design codes provide qualitative guidelines for identifying irregularities, they offer limited quantitative insight into how different plan configurations influence structural response parameters. Hence, a comparative analytical study using numerical tools becomes necessary to evaluate the seismic behaviour of buildings with varying plan geometries under consistent loading and modelling conditions.In this study, square, rectangular, L-shaped, C-shaped, and T-shaped buildings are analysed using response spectrum analysis to systematically investigate the effect of plan irregularity on storey drift, displacement, base shear, and torsional response. The outcomes aim to contribute to a clearer understanding of how plan irregularity influences seismic performance and to support more informed design decisions for irregular high-rise buildings.

A. Seismic Design Philosophy

The seismic design philosophy for high-rise buildings is primarily guided by the principles of strength, stiffness, ductility, and energy dissipation. As emphasized by Chopra (2012), seismic-resistant design does not aim to make structures completely earthquake-proof but rather to ensure that they can withstand seismic forces without collapse, thereby safeguarding lives and minimizing damage. Strength ensures that the structure can resist expected seismic loads, while stiffness limits excessive deformations that may affect both structural and non-structural components. Ductility, defined as the capacity of structural members to undergo large inelastic deformations without significant loss of strength, plays a crucial role in preventing sudden brittle failures (Paulay& Priestley, 1992). In addition, modern seismic design incorporates energy dissipation mechanisms, either through inherent material behavior or through supplemental devices such as dampers and base isolators, which reduce seismic demand on the main structural system (Priestley et al., 2007).

Globally, several design codes provide guidelines for ensuring seismic safety. The Indian Standard IS *1893 (Part 1: 2016)* specifies criteria for earthquake-resistant design, including provisions for irregular buildings. Eurocode 8outlines seismic design principles in Europe, emphasizing performance-based criteria and ductility classes. In the United States, FEMA 356andASCE 7-16provide performance-based seismic evaluation and load requirements, while the Uniform Building Code (UBC, 1997)served as a foundation for modern seismic provisions before being replaced by the International Building Code (IBC). Despite differences in detailing and numerical criteria, these codes share a common goal of safeguarding structures against collapse, limiting damage, and ensuring post-earthquake functionality, particularly for critical facilities such as hospitals and emergency response centers (Kappos et al., 2006).

However, applying these guidelines to irregular structures remains challenging. Irregularities in plan or elevation introduce torsional responses, concentration of stresses, and abrupt changes in dynamic characteristics, which are not fully captured by simplified code-based methods (De Stefano &Pintucchi, 2008). While codes such as IS 1893 and Eurocode 8 provide additional checks for irregular buildings, they often rely on empirical limits and do not always reflect the complex nonlinear behavior observed during strong ground motions. Moreover, performance-based seismic design, although widely promoted, is still difficult to implement for highly irregular geometries due to computational demands and uncertainties in ground motion prediction (Ghosh & Datta, 2010). Thus, there is a continuing need for comparative studies and advanced numerical analyses to bridge the gap between code provisions and the real behavior of irregular high-rise buildings.

IS 1893 (Part 1: 2016), the Indian standard for earthquake-resistant design, defines both plan and vertical irregularities, including torsional irregularity, re-entrant corners, setbacks, soft storeys, and mass or stiffness variations. For buildings taller than 12 meters with such irregularities, the code mandates dynamic analysis using either response spectrum or time-history methods. Additional provisions include applying penalties on drift and storey shear for soft storeys and performing supplementary checks for torsional effects. However, IS 1893 relies on simplified modeling approaches and may not fully capture the nonlinear behaviour of highly complex irregular geometries.

Eurocode 8 (EN 1998-1: 2004) classifies buildings based on plan and elevation regularity and provides detailed limits for eccentricity, setbacks, and stiffness and mass distribution.

While regular buildings can be designed using simplified lateral force methods, irregular buildings require modal response spectrum or time-history analysis. The code, however, has complex detailing requirements, and its definitions of irregularities may not always align precisely with practical architectural forms.

ASCE 7-16, the American seismic design standard, identifies plan irregularities such as torsion, diaphragm discontinuities, and re-entrant corners, as well as vertical irregularities like soft or weak storeys and mass irregularities. It requires response spectrum analysis for most irregular structures, with additional redundancy and overstrength factors applied, and includes detailed checks for soft-storey drift. The standard is generally conservative, and nonlinear response of tall irregular structures can sometimes be underestimated.

FEMA 356, a prestandard for seismic rehabilitation in the USA, focuses on performance-based assessment of irregular and existing buildings. It defines performance levels such as Immediate Occupancy, Life Safety, and Collapse Prevention, and recommends nonlinear pushover analysis for irregular structures. Its primary limitation is that it is intended for rehabilitation rather than prescriptive design, and its application to new high-rise irregular buildings is limited.

The Uniform Building Code (UBC 1997), also from the USA, provides definitions of irregularities similar to ASCE 7, including torsion, discontinuities, and setbacks. Dynamic analysis is mandatory for irregular structures taller than 73 meters, with enhanced base shear and drift checks. Although largely superseded by IBC and ASCE codes, UBC 1997 laid the foundation for many modern global seismic design provisions.

A review of global seismic codes reveals both commonalities and differences in the treatment of irregular high-rise buildings. Most codes, including IS 1893, Eurocode 8, and ASCE 7, classify irregularities into plan-based (torsion, re-entrant corners, diaphragm discontinuities) and vertical-based (soft storey, weak storey, mass or stiffness discontinuities). While regular buildings are often permitted to use simplified lateral force methods, irregular buildings are generally required to undergo dynamic analysis such as response spectrum or time-history evaluation. Eurocode 8 provides some of the most detailed criteria for defining and limiting irregularities, particularly with respect to eccentricity and setbacks, whereas ASCE 7 emphasizes redundancy and overstrength factors to improve resilience. IS 1893 adopts penalty provisions, especially for soft-storey conditions, and mandates higher-level analysis for irregular configurations. FEMA 356, while not a prescriptive design code, contributes significantly by introducing performance-based seismic assessment methods that are particularly relevant for irregular and existing structures. Overall, the comparative review highlights that although global codes broadly agree on the vulnerability of irregular configurations, their provisions often remain empirical and conservative, and they may not fully capture the complex nonlinear behavior observed in actual earthquakes. This underscores the importance of advanced numerical modeling, experimental validation, and continued refinement of seismic guidelines to ensure the safety of irregular high-rise buildings.

B. Classification of Irregularities

Seismic performance of buildings is highly influenced by their geometrical and structural configuration. Irregularities, whether in plan or elevation, disrupt the uniform distribution of mass and stiffness, resulting in complex dynamic behavior and localized stress concentrations. Past earthquake damage reports, such as those analyzed by Murty (2010) and Das &Murty (2004), confirm that irregular buildings generally suffer more severe damage compared to their regular counterparts. Based on international design codes (IS 1893, Eurocode 8, ASCE 7).

C. Structural Irregularities Can Broadly Be Classified into Three Categories:

1) Plan Irregularities

Plan irregularities occur when the horizontal layout of a structure deviates from a simple, compact geometry such as a rectangle or square. Common forms include L-shaped, T-shaped, and U-shapedbuildings, which often result from functional or architectural requirements. These configurations create torsional effects during seismic excitation due to eccentricity between the center of mass and the center of rigidity (De Stefano &Pintucchi, 2008). Other forms of plan irregularities include re-entrant corners**,** setbacks, and diaphragm discontinuities, which cause stress concentrations at corners or abrupt junctions. Such irregularities typically increase torsional response and amplify seismic demands, particularly in the lower stories.

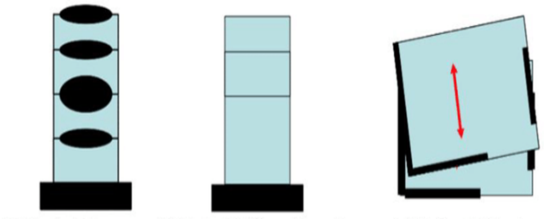
2) Vertical Irregularities

Vertical irregularities arise when there is a sudden change in stiffness, mass, or geometry along the height of the structure. The most common type is the soft storey, where one floor (often the ground level used for parking or commercial space) has significantly less stiffness compared to the floors above. This creates a “weak link” that concentrates drift and often leads to collapse, as observed in the 2001 Bhuj and 1999 Kocaeli earthquakes (Boen, 2001).

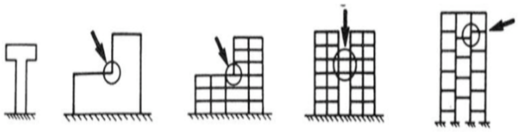
Other vertical irregularities include mass irregularity, where a sudden change in mass distribution (e.g., heavy mechanical floors or transfer girders) alters dynamic response, and stiffness irregularity, where abrupt reductions in stiffness due to setbacks or changes in structural system cause concentration of seismic forces. These irregularities are especially critical in high-rise buildings, where cumulative drift magnifies damage effects.

D. Mass and Load Distribution Irregularities

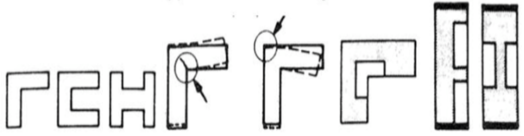
Mass and load distribution irregularities occur when there is an uneven placement of loads or structural mass across the building. Examples include heavy roof equipment, asymmetric live loads, or partial occupancy patterns. These irregularities shift the building's center of mass away from its geometric center, creating unbalanced inertial forces during earthquakes. As highlighted by Ghosh & Datta (2010), such irregularities can significantly increase torsional effects and make dynamic analysis essential, as simplified static methods often underestimate seismic demand.



(a) Vertical Mass (b) Vertical Stiffness/Strength (c) Horizontal Torsion



(d) Vertical Discontinuity



(e) Plan Discontinuity

Figure 1.Mass and Load Distribution Irregularities

The figure 1 shows the main types of structural irregularities that affect seismic performance. The classification of irregularities in high-rise buildings is an essential step in understanding their seismic behavior. Plan irregularities arise when the horizontal configuration of a structure deviates from a compact form, as in L-, T-, or U-shaped layouts. These configurations introduce re-entrant corners and setbacks that create stress concentrations and torsional effects during earthquakes, often resulting in uneven displacement demands; such phenomena have been highlighted in analytical studies by De Stefano and Pintucchi (2008). Vertical irregularities are associated with sudden changes in mass, stiffness, or geometry along the height of the structure. The most common case is the soft storey, where the ground or intermediate level has much lower stiffness compared to adjacent storeys, leading to significant drift concentration and collapse, as documented in earthquake surveys by Murty (2010) and Boen (2001). Mass irregularity occurs when certain floors carry disproportionately higher loads, while stiffness irregularity results from abrupt reductions in rigidity, both of which alter the dynamic characteristics of the building and increase seismic vulnerability (Chopra, 2012). Horizontal torsional irregularity, which develops when the center of mass and center of stiffness are not aligned, has been shown by Paulay and Priestley (1992) to cause amplified displacements at the edges of structures. Beyond plan and vertical irregularities, mass and load distribution irregularities occur due to uneven placement of structural or functional elements, which shift the center of mass away from the building's geometric center and generate unbalanced inertial forces, as discussed by Ghosh and Datta (2010). These classifications are consistently recognized in seismic codes such as IS 1893 (2016), Eurocode 8 (2004), and ASCE 7-16, all of which emphasize that irregular structures demand rigorous dynamic analysis compared to their regular counterparts. To enhance clarity, schematic diagrams are widely used in both research and design practice to illustrate these irregularities and to demonstrate why irregular structures are more vulnerable during strong ground motion.

E. Seismic Response of Regular vs. Irregular Buildings

Natural frequency and vibration modes**.** Irregular geometry and abrupt changes in stiffness or mass change a building's dynamic properties, typically lowering higher-mode frequencies and redistributing modal participation (Chopra, 2012). Plan irregularities and mass concentrations modify mode shapes and can activate torsional modes that are negligible in regular, symmetric buildings (Paulay& Priestley, 1992). In practice, irregular buildings often show more complex modal coupling (translational → torsional), which reduces the effectiveness of single-mode approximations used for simple regular frames (Krawinkler, 1998).

Base shear distribution. For regular buildings base shear under code spectra is more uniformly distributed and often predicted adequately by simplified lateral-force methods. Irregular configurations, however, produce non-uniform base shear demands and localized concentration of shear at weak or stiff regions (Murty, 2010). Vertical discontinuities and stiffness changes cause floors to attract disproportionate shear, which may not be captured by simplified code coefficients and thus necessitate response-spectrum or time-history analyses (De Stefano &Pintucchi, 2008).

Storey drift and displacement. Irregularities—especially soft-storey conditions and setbacks—lead to amplified inter-storey drifts concentrated at specific levels, increasing the risk of story mechanisms and localized collapse (Boen, 2001; Murty, 2010). Plan irregularities that produce torsion also increase peak displacements at the building perimeter. Numerical studies consistently report larger maximum storey drifts and asymmetric drift profiles in irregular buildings compared with regular counterparts of similar overall stiffness and mass (Ghosh & Datta, 2010).

Torsional effects. Torsion is negligible in ideally symmetric (regular) buildings but becomes an important and sometimes dominant response mechanism in irregular plans where the center of mass and center of rigidity are offset. Paulay& Priestley (1992) showed that torsion can amplify demands on columns and walls on one side by factors significantly greater than the mean displacement, producing failures not predicted by translational analyses. Codes therefore include explicit torsion checks for irregular plans (ASCE/IS/Eurocode provisions).

Structural damage patterns. Empirical post-earthquake surveys and experimental studies indicate that irregular buildings tend to exhibit more concentrated damage—soft-storey collapse, pounding at re-entrant corners, shear failures adjacent to setbacks, and brittle failures in overloaded transfer elements—while regular buildings more often display distributed, ductile yielding if properly detailed (Kappos et al., 2006; Murty& Das, 2004). Irregular forms also increase the probability of unexpected failure modes due to unexpected modal interactions and localized stress concentrations.

II. LITERATURE REVIEW

A. Introduction

The literature on seismic analysis of high-rise buildings highlights how structural configuration significantly influences a building's response during earthquakes. Researchers have consistently emphasized that regular-shaped buildings exhibit more uniform stiffness and predictable earthquake behavior, whereas irregular geometries—such as L-shaped, T-shaped, and setback structures—tend to experience higher torsion, differential displacement, and stress concentration.

K. Soni and P. Gupta (2025) conducted a comparative study on the seismic performance of regular versus irregular high-rise buildings using finite element methods (FEM) and response spectrum analysis. Their findings indicate that irregular buildings experience higher torsion, uneven seismic loading, and greater inter-storey drift. To mitigate these effects, the authors recommend optimization of stiffness and mass distribution within the structure.

S. Jayan and T. Amudha (2025) explored the application of machine learning techniques to identify the seismic roles of structural components in irregular high-rise buildings. Their study demonstrated that machine learning algorithms can accurately classify component behaviour under seismic loading, thereby improving the analysis and design of buildings with complex geometries.

R. N. Mehta and S. Agarwal (2025) examined the influence of building geometry on seismic behaviour. Their research highlighted that irregularly shaped buildings are prone to higher torsion, uneven force distribution, and localized stresses. Based on these findings, the authors emphasize the importance of geometry-conscious design and the strategic use of reinforcements to enhance structural resilience.

R. N. Patel and R. Sharma (2025) evaluated the seismic performance of irregular buildings through nonlinear analysis. They reported that such structures exhibit greater torsion and displacement compared to regular buildings, necessitating specialized design strategies and retrofitting measures to ensure safety.

R. Soni et al. (2025) developed hybrid machine learning models, including neural networks, support vector machines, and decision trees, to predict seismic behaviour in irregular structures. Their results indicate that these hybrid models improve prediction accuracy and provide valuable support for safer structural design.

B. Analytical and Experimental Studies Reviewed

Finite Element Simulations have been widely used in recent years to understand how irregular geometries, soil-structure interaction (SSI), and non-structural components impact seismic response. A number of studies have contrasted regular vs irregular buildings using ETABS, SAP2000, ABAQUS, OpenSees, etc. For example, Mishra & Yadav (2022) conducted time-history analyses in ETABS for regular and irregular (different slab geometry/stiffness) 9-storey buildings under varied soil conditions in seismic Zone IV; they found that soil softness increases displacements and drift more severely for irregular buildings compared to regular ones. Another study by Rahnavard et al. examined asymmetric sliding steel structures with various levels of irregularity (20-60%) using ABAQUS and ETABS, including SSI, showing that increasing irregularity (both plan misalignment and mass or stiffness eccentricity) markedly increases displacements and accelerations. Similarly, “Spectral Modal Modeling by FEM of RC framed buildings irregular in elevation” (2021) showed that elevation irregularity leads to greater displacement demands and that dynamic analysis (modal or spectral) is needed rather than simplified static methods.

On the experimental side, shake table tests and scaled model experiments give insight into real behaviour, including non-linear effects, damage, and modal degradation. For instance, the “Shaking-Table Test and Finite Element Simulation of a Novel Friction Energy-Dissipating Braced Frame” (MDPI) compared test results with FEM models and found good agreement in natural frequencies and displacement/time history responses; energy dissipation devices like friction-braces significantly reduce peak accelerations and top-floor displacements. Another example is the “Shaking Table Test and Finite Element Analysis of Isolation Performance for Diesel Engine Building in a Nuclear Power Plant,” where SAP2000 models of the base-isolated structure produced displacement responses that were within about 90-95% of the experimental measured values. A high-rise RC shear wall structure tested via shaking table in “Shaking-Table Test and Finite Element Analysis” (Li et al., 2019) exhibited that FE models captured acceleration amplification well, drift envelopes matched experimental ones in upper stories, though some stiffness degradation was observed experimentally when compared to models.

III. METHODOLOGY

A. Introduction

Modelling of a building involves idealizing and assembling its structural components in a manner that realistically represents the distribution of mass, stiffness, strength, and deformability. In the present study, three-dimensional analytical models of buildings with different plan configurations are developed to evaluate the influence of plan irregularity on seismic response. The plan and three-dimensional views of the considered building models are generated using ETABS.

B. Models

Five reinforced concrete building models having identical height, material properties, and loading conditions but different plan configurations are considered:

Model 1: Square-shaped building
Model 2: Rectangular-shaped building
Model 3: C-shaped building
Model 4: L-shaped building
Model 5: T-shaped building

Table 1: Building components and details

Nameofparameter	Value	Unit
No.ofstorey	G + 39 (40 storeys)	Nos.
Bottomstoreyheight	1.5	m
Storeyheight	3	m
Soiltype	Medium	
Planarea	2500	m^2
Gridsize	5x5	m
Thicknessofslab	150	mm

Sizeofbeam	300X450	mm
Sizeofcolumn	650X 650	mm
Materialproperties		
Gradeofconcrete	M40	N/mm^2
Gradeofsteel	Fe500	N/mm^2
Deadload intensities		
FFonfloors	1.5	kN/m^2

C. Seismic Analysis Parameters

Response spectrum analysis is carried out in accordance with IS 1893 (Part 1): 2016, considering identical seismic input parameters for all models to ensure meaningful comparison.

Table 2: Seismic Input Parameters Used in the Study

Parameter	Value / Description
Seismic zone factor (Z)	0.16 (Zone III)
Importance factor (I)	1.0
Response reduction factor (R)	5.0 (SMRF)
Soil type	Medium soil (Type II)
Damping ratio	5%
Response spectrum	IS 1893 (2016) design spectrum
Modal combination method	Complete Quadratic Combination (CQC)
Fundamental time period	Obtained from ETABS eigenvalue analysis
Load combinations	As per IS 1893 (2016) and IS 456 (2000)

D. Load calculation

1) Self-weight of the slab

The self-weight of the slab is calculated as:

Self-weight (kN/m^2) =thickness (m)×density of concrete (kN/m^3)

- Thickness = 150 mm=0.15 m
- Density of M40 grade concrete = 25 kN/m^3
- Self-weight=0.15×25=3.75 kN/m^2

2) Additional Loads

If additional loads (like live load or floor finish) are specified, they need to be added to the self-weight to find the **total load**.

For example:

- Live load = 3 kN/m^2
- Floor finish = 1.5 kN/m^2

Total Load=Self-weight + Live load + Floor finish

Total Load=3.75+3+1.5=8.25 kN/m^2

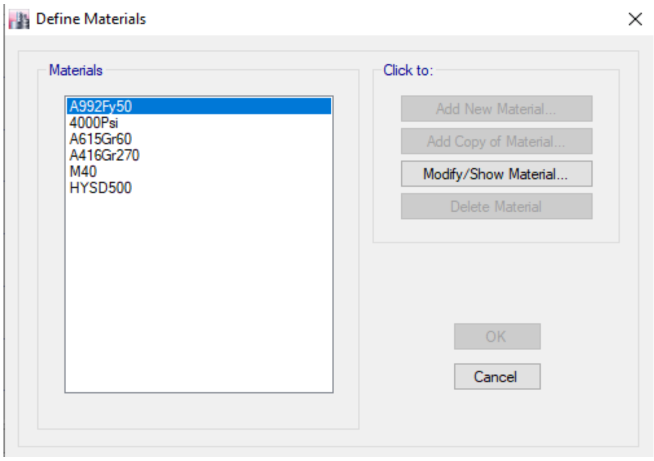
3) Wall load

The structure's dead load is made up of wall load, parapet wall load, and floor load, according to IS 875 - Part 1.

I. Wall load: weight unit of brick masonry * thickness of wall * height of wall = 20kN/m3 * 0.23m * 3m = 13.8kN/m3.

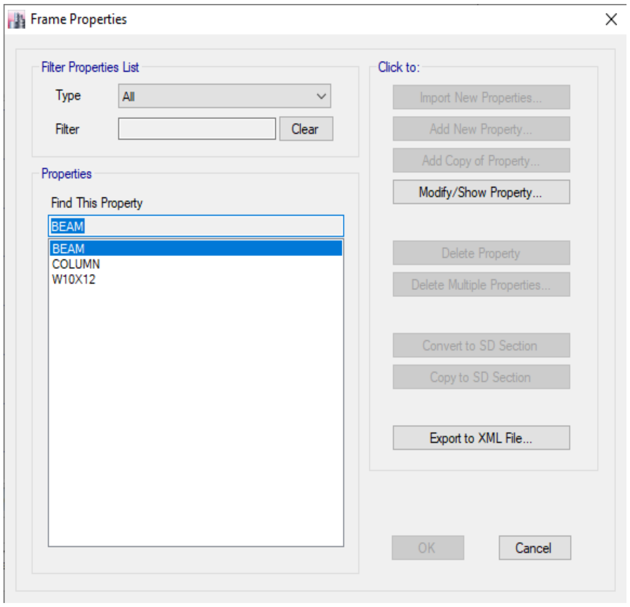
II. Wall load (parapet wall at top floor): weight unit of brick masonry * thickness of wall * height of wall = 20kN/m3 * 0.115m * 0.9m = 2.07KN/m

IV. MODELING IMAGES



A992Fy50
4000Psi
A615Gr60
A416Gr270
M40
HYSD500

Figure 2: Defining material properties

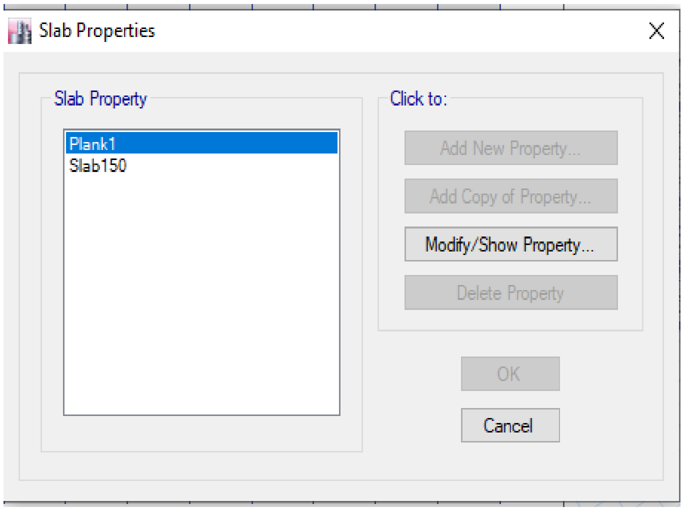


Type: All

Find This Property: BEAM

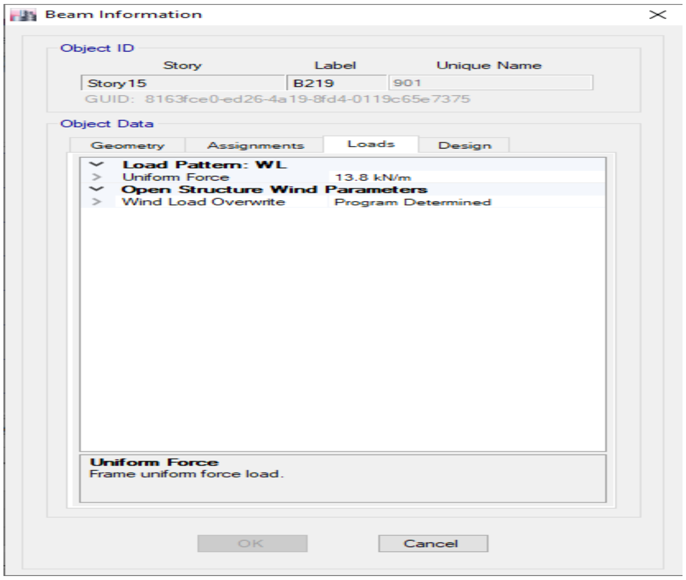
BEAM
COLUMN
W10X12

Figure 3: Defining frame sections



Plank1
Slab150

Figure 4:Defining slab sections



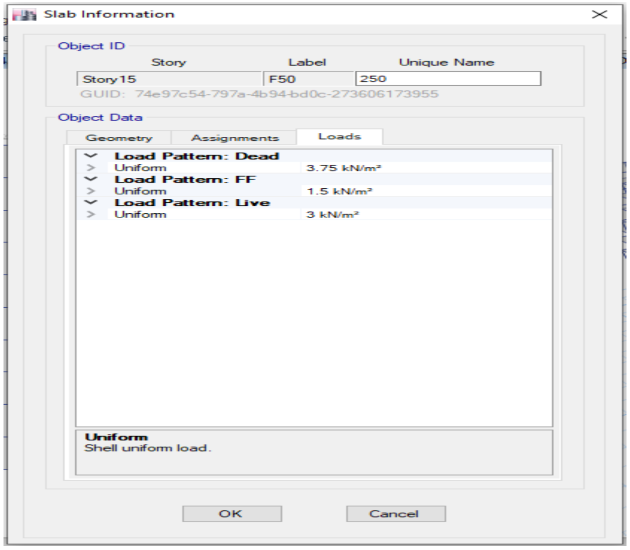
Story	Label	Unique Name
Story15	B219	901

GUID: 8163fce0-ed26-4a19-8fd4-0119c65e7375

Load Pattern: WL
Uniform Force 13.8 kN/m
Open Structure Wind Parameters
Wind Load Overwrite Program Determined

Uniform Force
Frame uniform force load.

Figure 5: Assigning wall load on beams



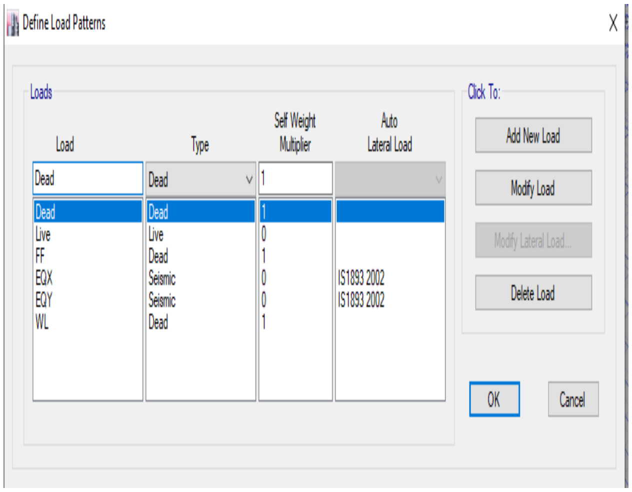
Story	Label	Unique Name
Story15	F50	250

GUID: 74e97c54-797a-4b94-bd0c-273606173955

Load Pattern: Dead
Uniform 3.75 kN/m²
Load Pattern: FF
Uniform 1.5 kN/m²
Load Pattern: Live
Uniform 3 kN/m²

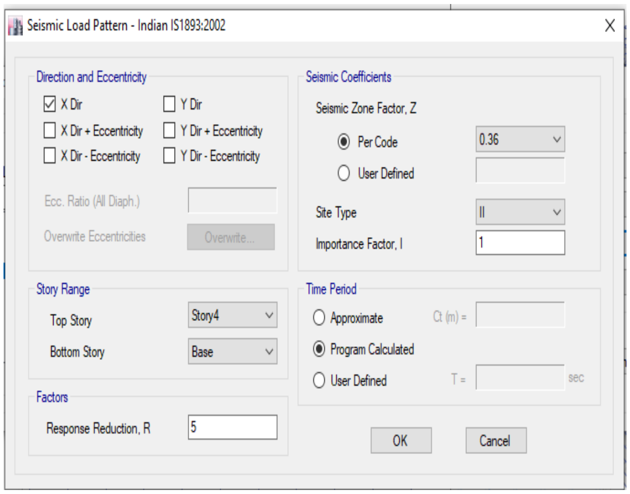
Uniform
Shell uniform load.

Figure 6: Assigning dead, live and floor finish load on slabs



Load	Type	Self Weight Multiplier	Auto Lateral Load
Dead	Dead	1	
Dead	Dead	1	
Live	Live	0	
FF	Dead	1	
EQX	Seismic	0	IS1893 2002
EQY	Seismic	0	IS1893 2002
WL	Dead	1	

Figure 7: Defining load patterns



Seismic Load Pattern - Indian IS1893:2002

Direction and Eccentricity

☑ X Dir ☐ Y Dir
☐ X Dir + Eccentricity ☐ Y Dir + Eccentricity
☐ X Dir - Eccentricity ☐ Y Dir - Eccentricity

Seismic Coefficients

Seismic Zone Factor, Z: ● Per Code 0.36 ○ User Defined
Site Type: II
Importance Factor, I: 1

Story Range

Top Story: Story4
Bottom Story: Base

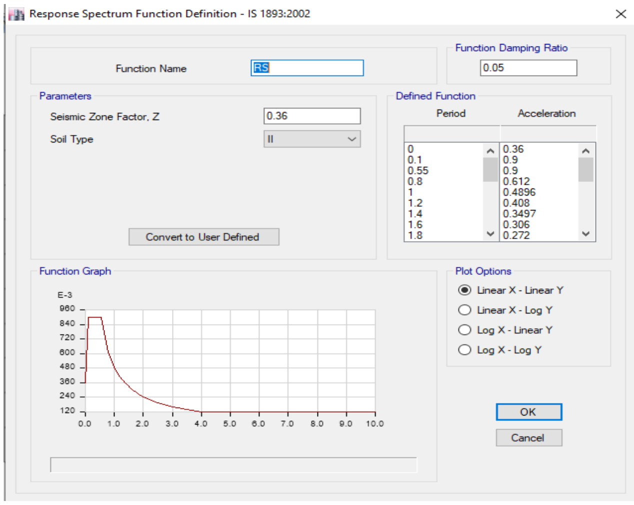
Time Period

○ Approximate
● Program Calculated
○ User Defined

Factors

Response Reduction, R: 5

Figure 8: Defining earthquake load



Response Spectrum Function Definition - IS 1893:2002

Function Name: RS

Function Damping Ratio: 0.05

Parameters

Seismic Zone Factor, Z: 0.36
Soil Type: II

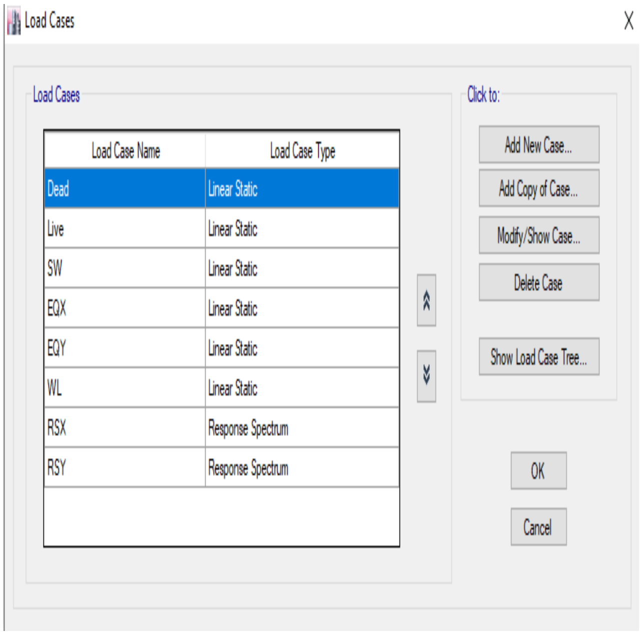
Defined Function

Period	Acceleration
0	0.36
0.1	0.9
0.55	0.9
0.8	0.612
1	0.4896
1.2	0.408
1.4	0.3497
1.6	0.306
1.8	0.272

Plot Options

● Linear X - Linear Y
○ Linear X - Log Y
○ Log X - Linear Y
○ Log X - Log Y

Figure 9: Defining response spectrum function



Load Cases

Load Case Name	Load Case Type
Dead	Linear Static
Live	Linear Static
SW	Linear Static
EQX	Linear Static
EQY	Linear Static
WL	Linear Static
RSX	Response Spectrum
RSY	Response Spectrum

Figure 10: Defining load cases

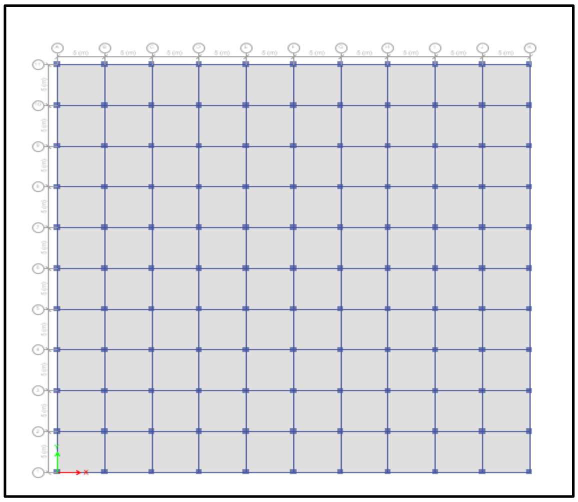


Figure 11: Plan view of square shape building

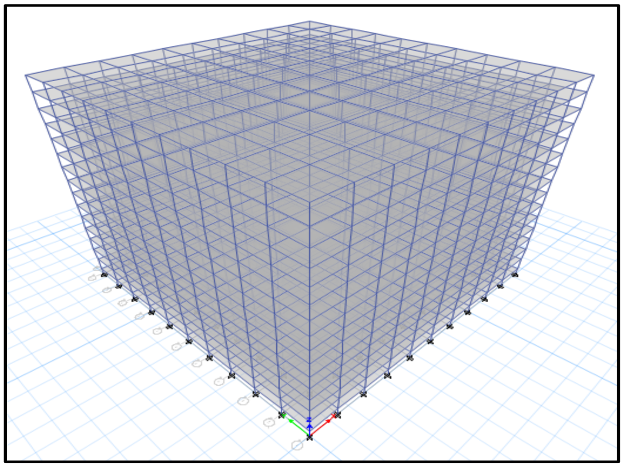


Figure 12: 3D view of square shape building

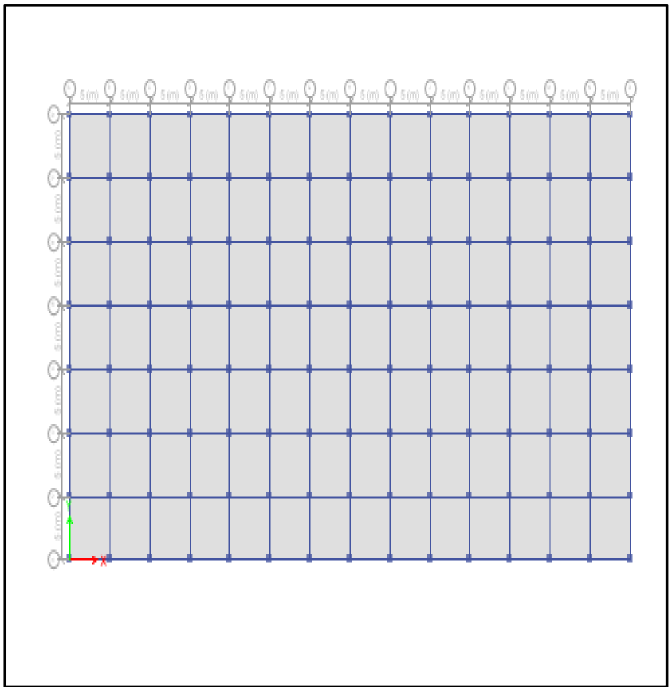


Figure 13: Plan view of rectangular shape building

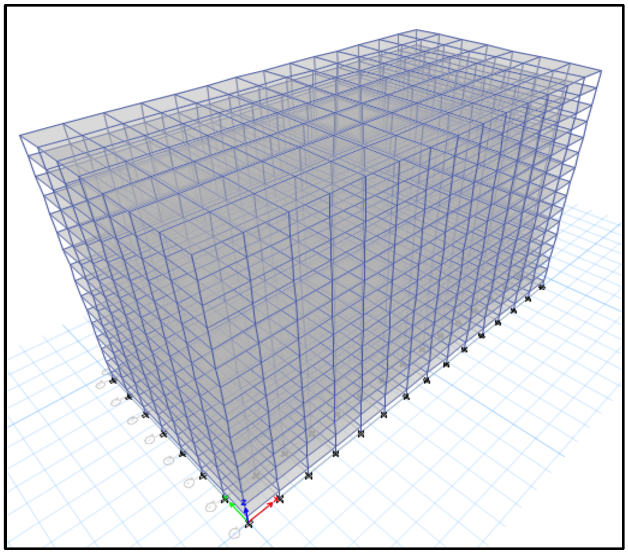


Figure 14: 3D view of rectangular shape building

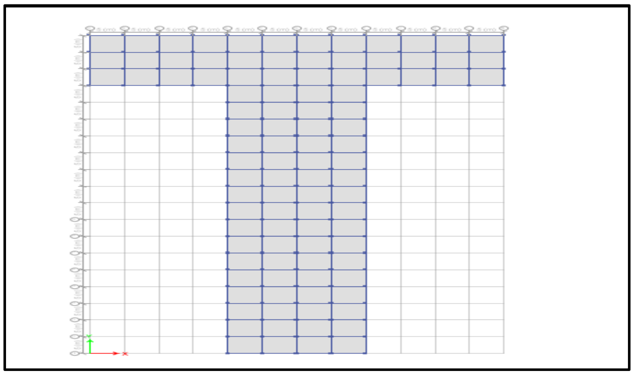


Figure 15: Plan view of T shape building

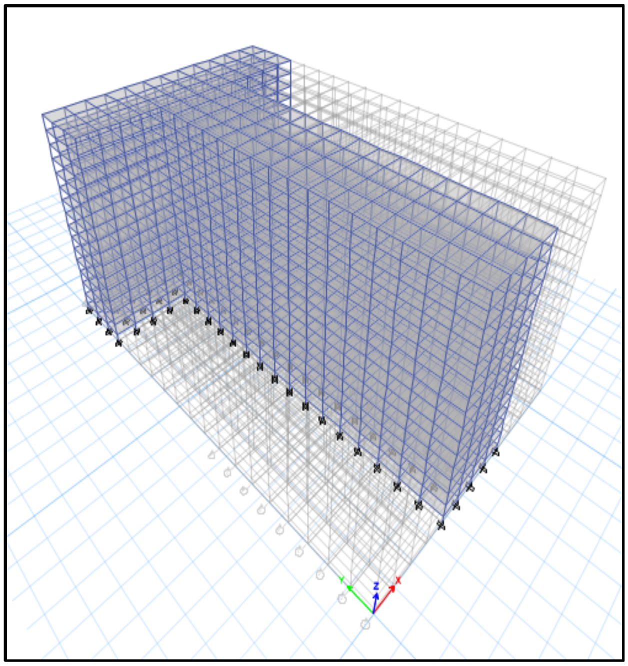


Figure 16: 3D view of T shape building

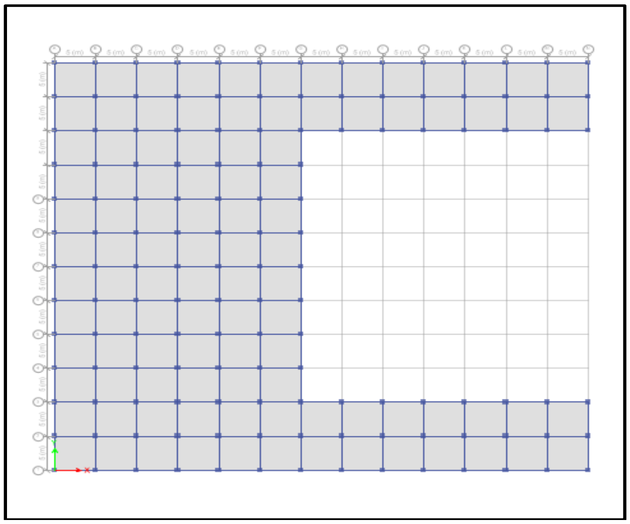


Figure 17: Plan view of C shape building

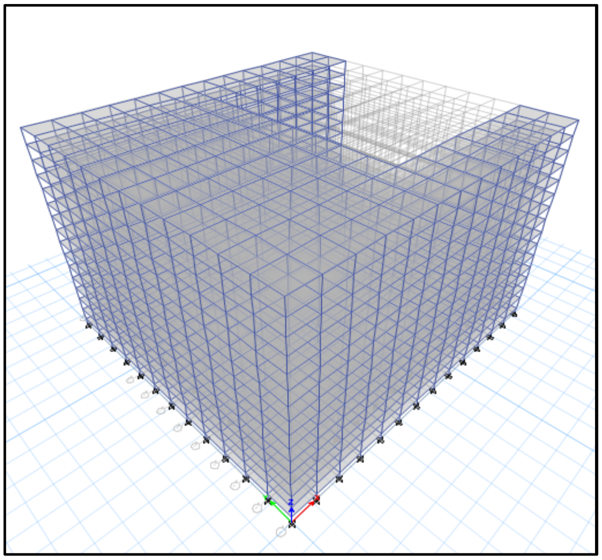


Figure 18: 3D view of C shape building

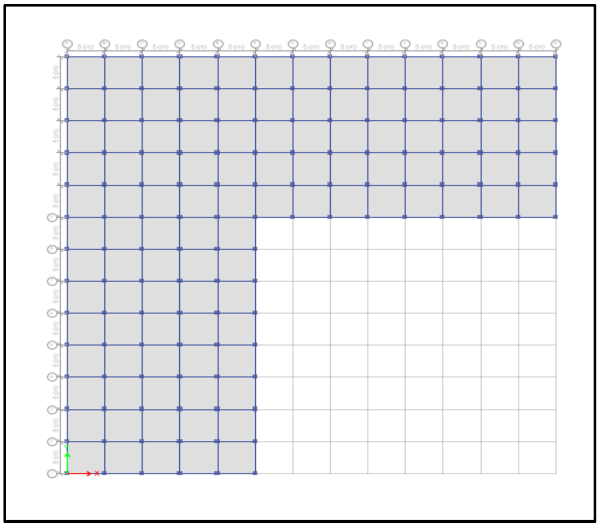


Figure 19: Plan view of L shape building

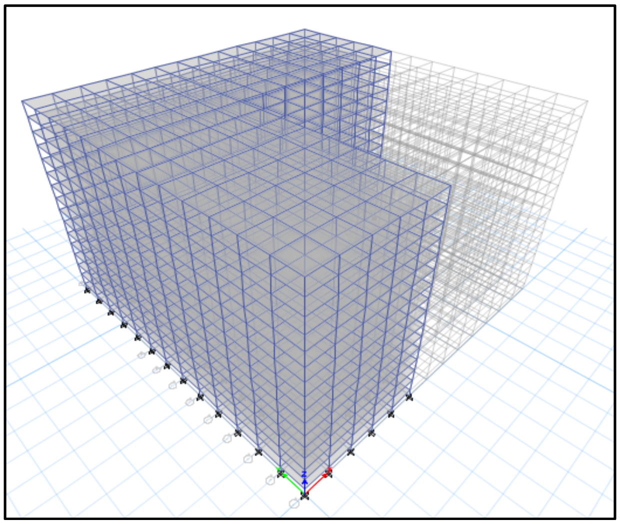


Figure 20: 3D view of L shape building

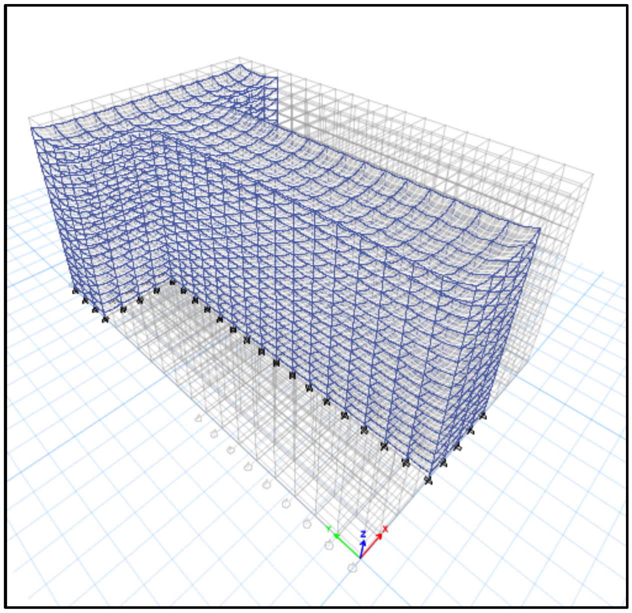
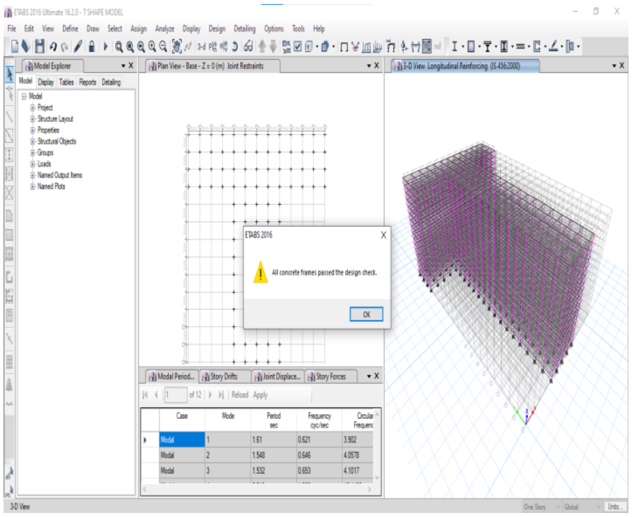


Figure 21: Run model



All concrete frames passed the design check.

Case	Mode	Period sec	Frequency cyc/sec	Circular Frequenc
Modal	1	1.61	0.621	3.902
Modal	2	1.548	0.646	4.0578
Modal	3	1.532	0.653	4.1017

Figure 22: All members passed for load combinations

Results

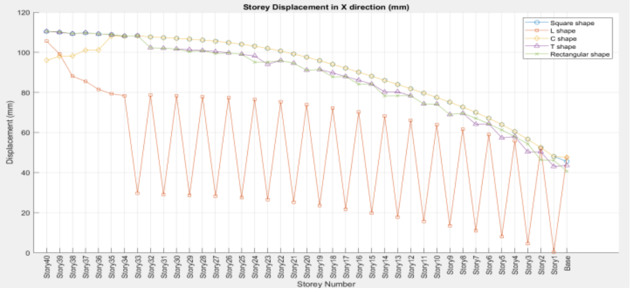


Figure 23: Storey Displacement in X Direction (in mm) for Various Building Plan Shapes

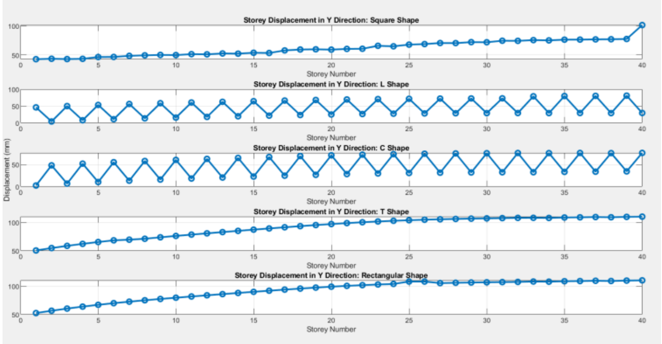


Figure 24: Storey-Wise Displacement in YDirection for Different Building Shapes

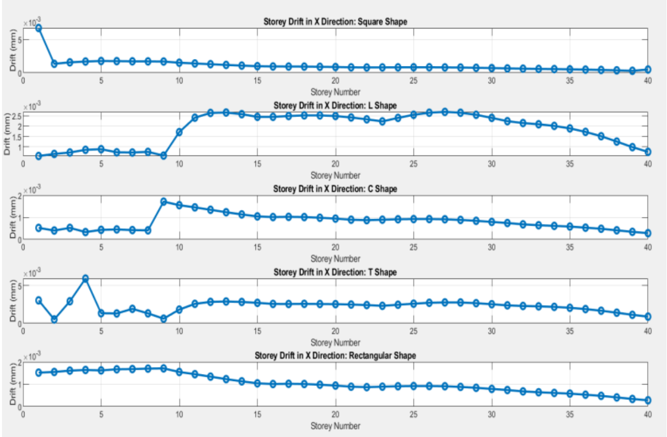


Figure 25: Storey-Wise Drift in X Direction for Different Building Shapes

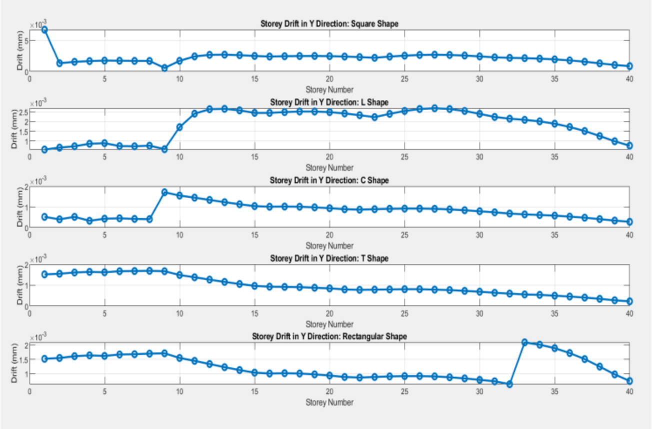


Figure 26: Storey-Wise Drift in Y Direction for Different Building Shapes

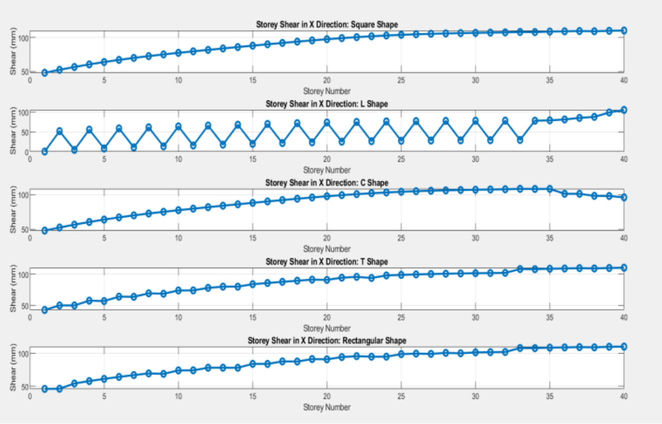
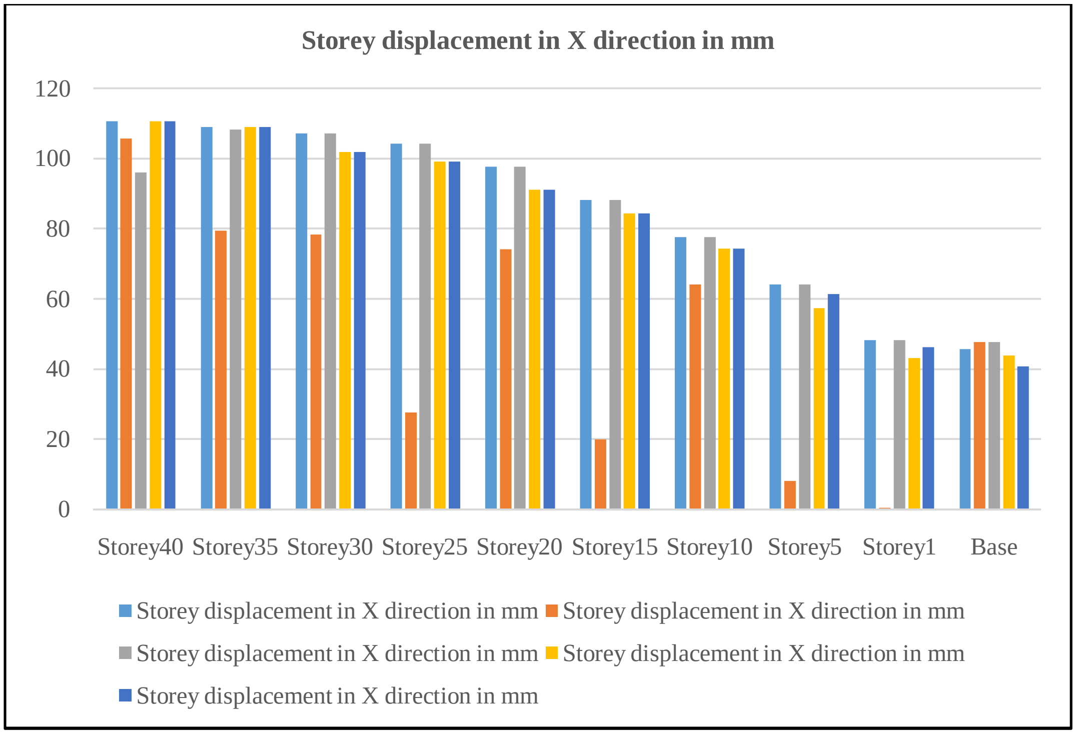


Figure 27: Storey Shear Variation in X Direction for Different Building Shapes

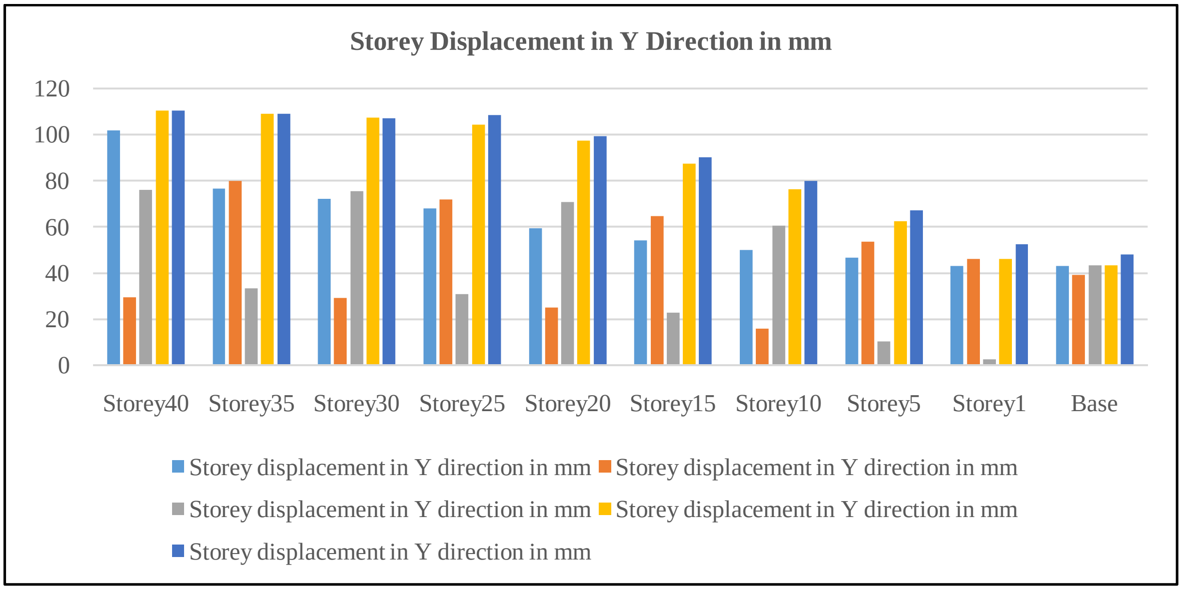
V. RESULT AND DISCUSSION

The data presented in accompanying graphs provide an in-depth analysis of storey-wise displacement, drift, and shear in both X and Y directions for various building plan shapes. The study covers five distinct building shapes: Square, L, C, T, and Rectangular, across 40 storeys. The results highlight how different shapes influence the displacement, drift, and shear responses, with the T and Rectangular shapes showing higher displacements and shear values, particularly at the top storey. The L and C shapes exhibit more irregular behavior due to their asymmetry, affecting the overall structural response under seismic loading.



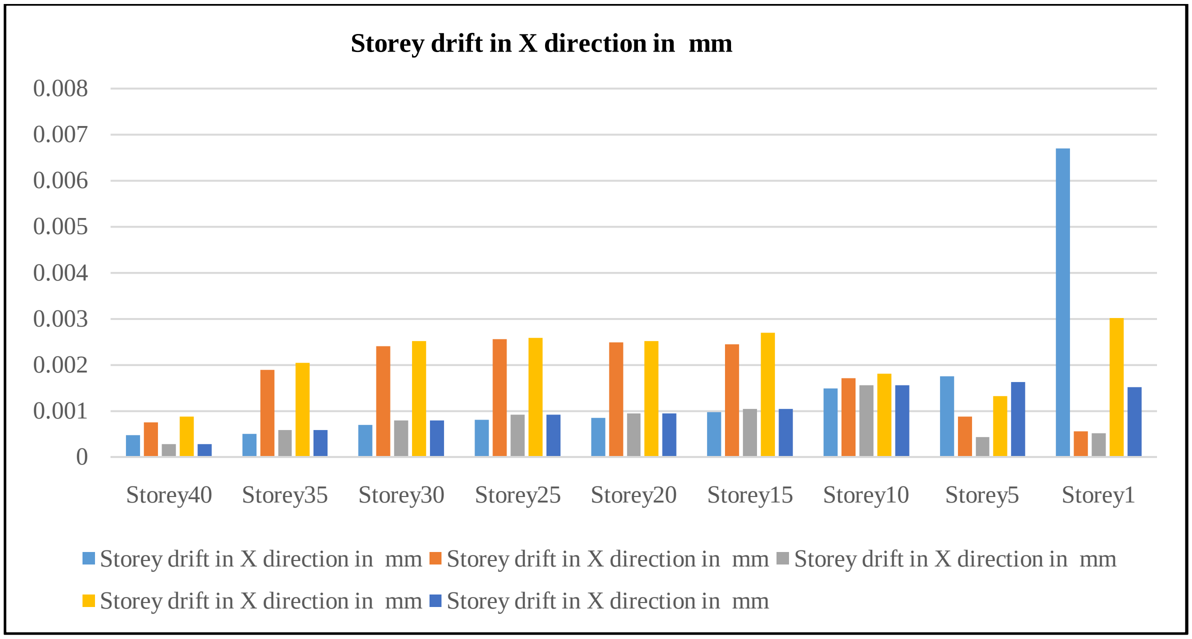
Graph 1:Storey Displacement in X Direction (mm)

The graph illustrates the displacement of different storey shapes (Square, L, C, T, and Rectangular) in the X direction across multiple stories. The displacement is highest for the L-shape configuration, showing a significant fluctuation between stories, while the rectangular shape exhibits relatively stable displacement. The square and T shapes show moderate displacement behavior, while the rectangular shape demonstrates minimal variation. This analysis helps in understanding the impact of building shape on displacement behavior under lateral loading.



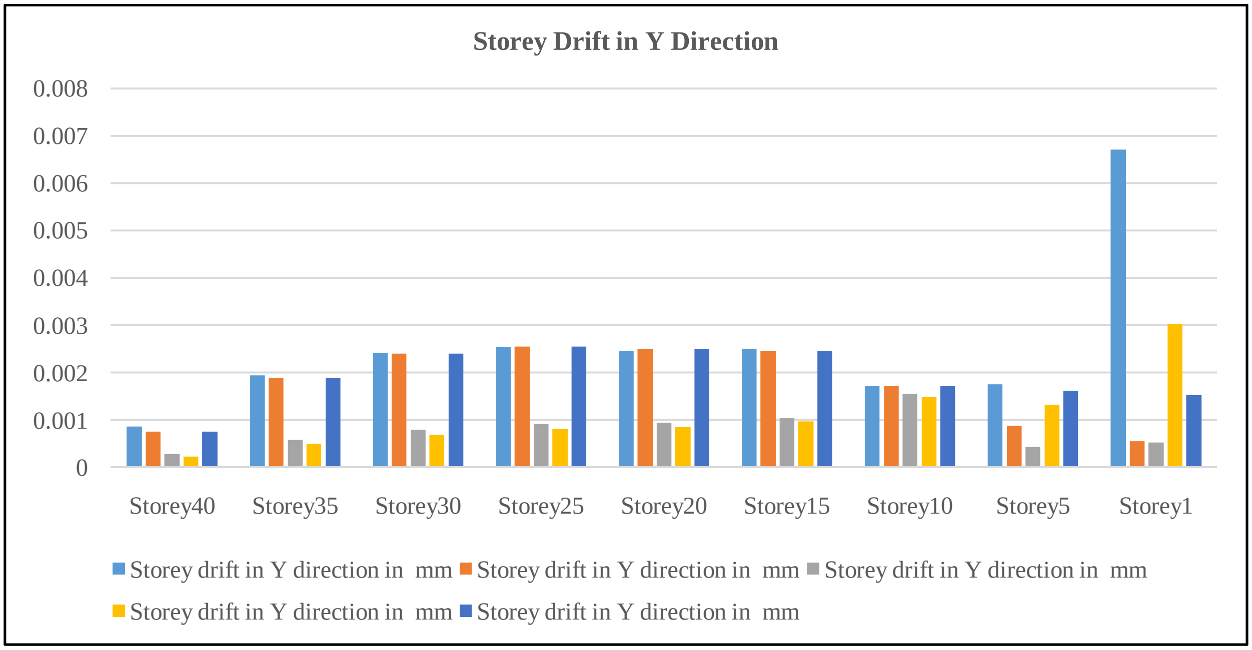
Graph 2:Storey Displacement in Y Direction

The graph illustrates the vertical variation of displacement along the Y direction for five different structural plan shapes across 40 storeys. The T-shaped and Rectangular-shaped buildings exhibit the highest and most consistent displacements towards the top, indicating greater lateral flexibility. In contrast, the L-shaped and C-shaped buildings show fluctuating displacements, suggesting irregular structural behavior due to asymmetry. The Square shape maintains a steady displacement increase, showing balanced and symmetrical performance.



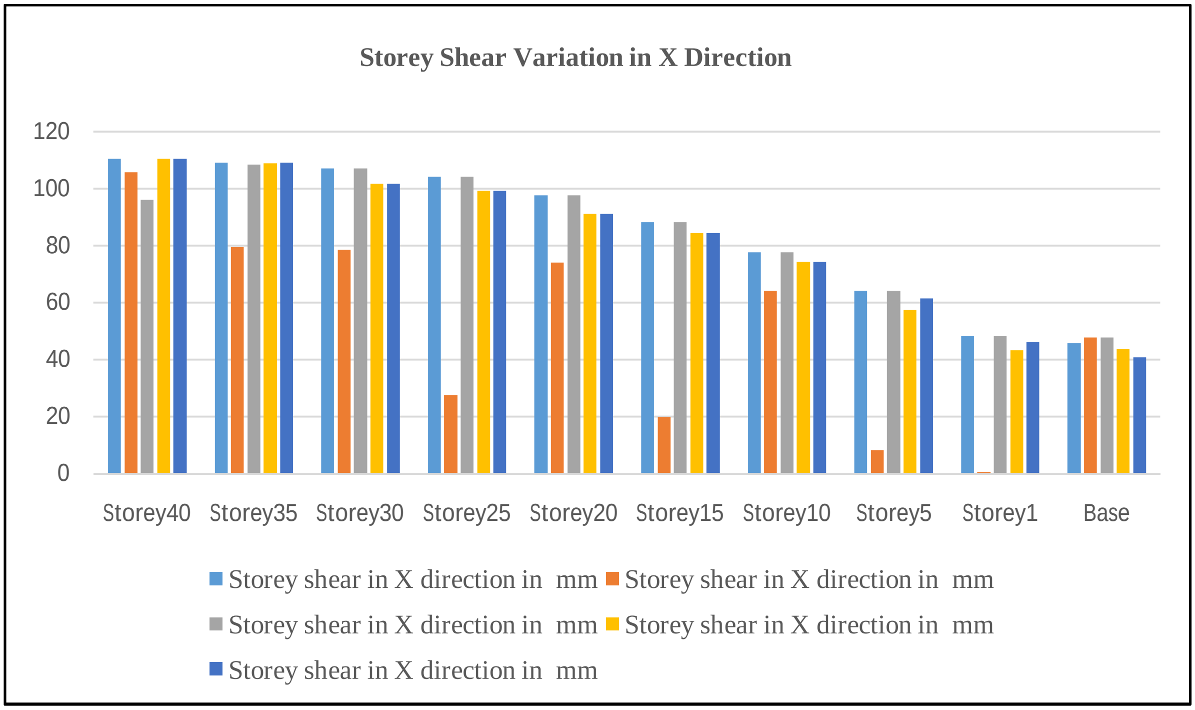
Graph 3:Storey Drift in X Direction

The graph illustrates the variation in storey drift along the X direction for five different building shapes. The T-shaped structure shows a sudden spike in drift at the lower levels, indicating possible irregular stiffness distribution. The L-shaped and C-shaped buildings exhibit higher drift in mid-storeys, suggesting torsional effects due to asymmetry. The Square and Rectangular shapes maintain relatively uniform and lower drift, indicating more stable lateral behavior under seismic loading.



Graph 4:Storey Drift in Y Direction

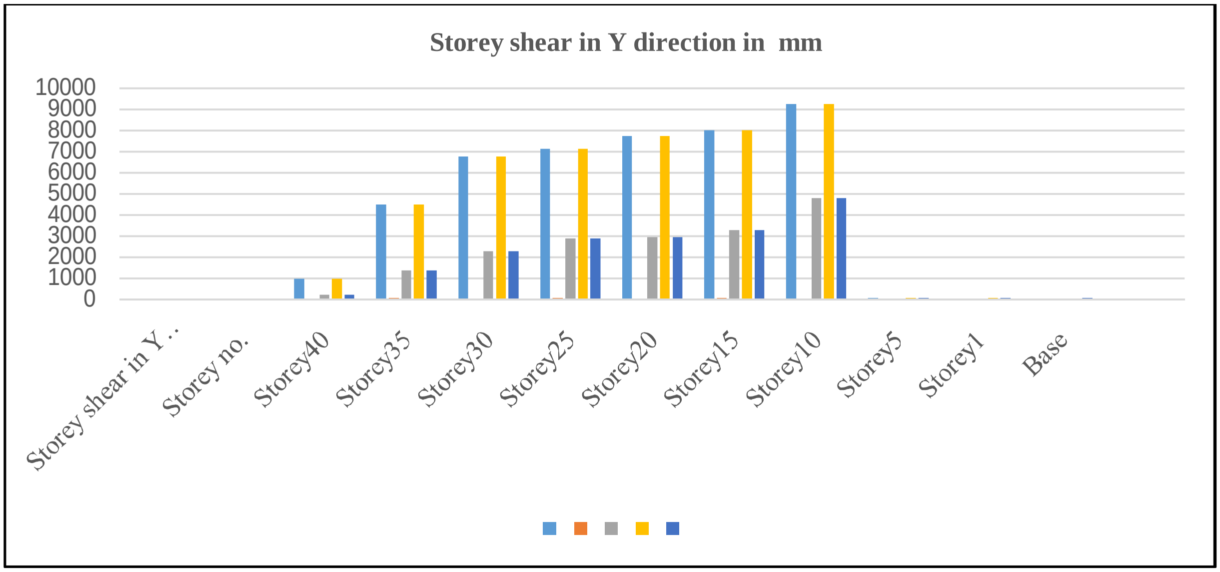
This graph illustrates the variation of storey drift in the Y direction across 40 storeys for five building shapes. The Square, C, and rectangular shapes exhibit relatively smooth and symmetric drift trends, with minor fluctuations. The L and T shapes show noticeable irregularities and peaksespecially L-shape at mid-heights and T-shape at the base—indicating possible structural irregularities and potential torsional effects. Rectangular shape also exhibits an unexpected spike near the upper storeys, suggesting a local stiffness anomaly.



Graph 5:Storey Shear Variation in X Direction

The graph illustrates the distribution of storey shear in the X direction across 40 storeys for five structural configurations: Square, L, C, T, and rectangular shapes.

Most shapes show a gradual increase in shear from the base to the top. However, the L-shape structure exhibits alternating peaks and valleys, indicating irregular shear response due to geometric asymmetry. The Square, T, and rectangular shapes maintain consistent and steadily increasing shear, reflecting better lateral load distribution.



Graph 6:Variation of Storey Shear in Y Direction

The figure illustrates the variation of storey shear in the Y direction for five different building shapes: Square, L, C, T, and Rectangular. Square and T shapes exhibit higher peak shear values, indicating greater force concentration in mid-storeys. The L-shaped structure shows alternating peaks, suggesting irregular lateral load distribution. C and Rectangular shapes have smoother, gradually decreasing shear patterns, indicating more uniform load transfer. The sudden jump around the 9th storey in most shapes suggests a structural change or irregularity affecting shear distribution. Shape geometry significantly influences seismic force behavior.

VI. CONCLUSION

1) The study establishes that building geometry plays a crucial role in determining the seismic performance of high-rise structures under dynamic loading conditions.
2) Regular-shaped buildings, especially square configurations, exhibit better structural stability with lower storey displacement, reduced drift, and uniform base shear distribution due to symmetrical mass and stiffness.
3) Irregular geometries such as L-, C-, and T-shaped buildings show higher lateral displacement, increased torsional effects, and stress concentration, particularly at upper storeys.
4) Dynamic characteristics, including time period and flexibility, vary with geometry, with irregular buildings demonstrating comparatively higher vulnerability during seismic excitation.
5) For improved safety and serviceability in seismic-prone regions, regular building configurations are preferable, while irregular structures require additional strengthening measures and careful structural optimization.

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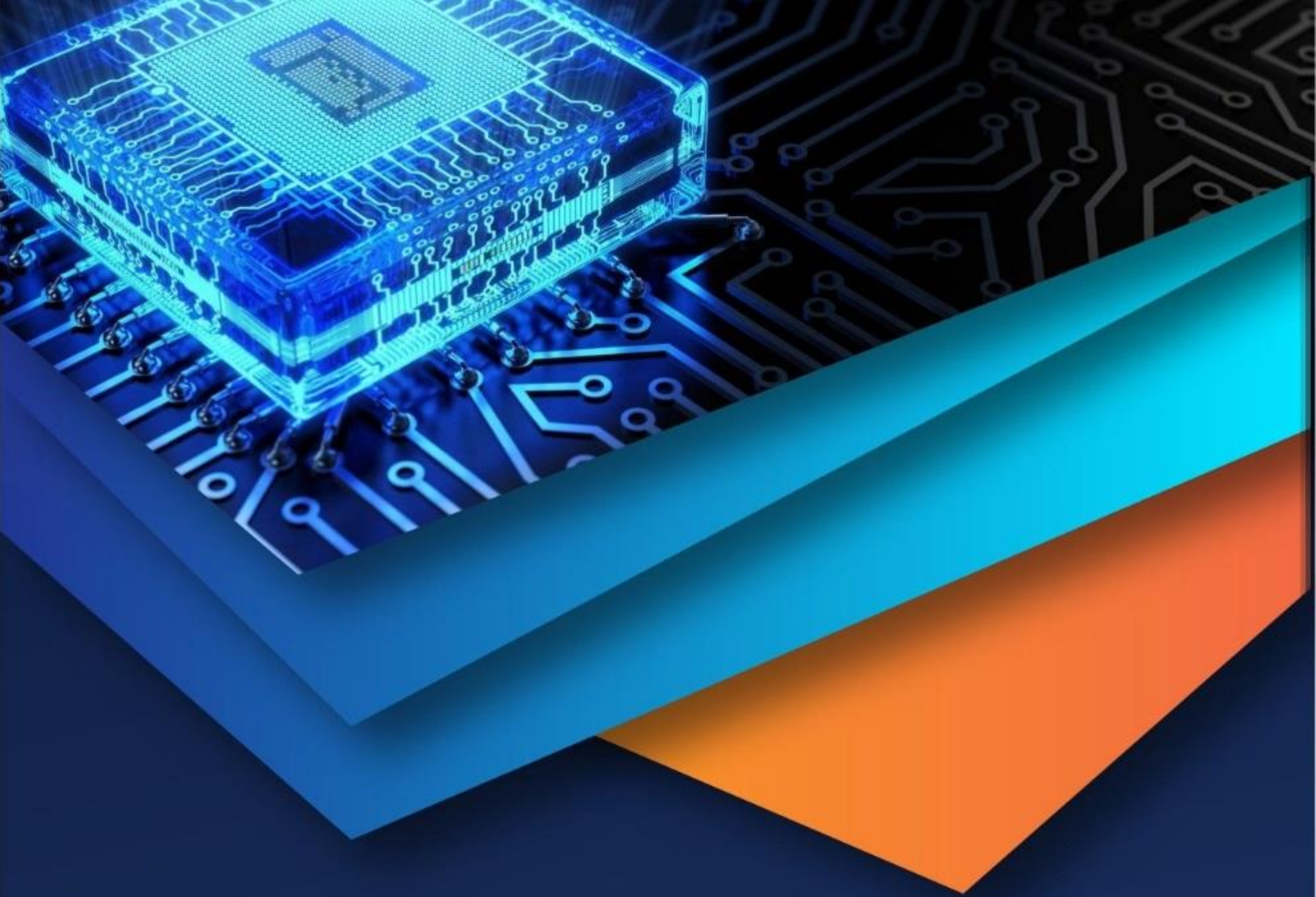

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