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Analysing the Effect of Structural Configuration on Earthquake-Induced Response Parameters

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Abstract: The seismic performance of high-rise buildings is significantly influenced by their plan geometry. This study evaluates and compares the structural behaviour of buildings with different plan configurations—Rectangular, L-shaped, H-shaped, and C-shaped—using ETABS software, as per IS 1893:2016 guidelines. Response Spectrum Analysis is conducted to assess the performance under seismic loading conditions. Key parameters such as lateral displacement, story drift, story stiffness, are used for comparison. The results highlight the impact of plan geometry on overall seismic response and identify configurations that demonstrate better structural performance. This research offers useful insights for structural engineers during the conceptual planning and design phase of high-rise buildings in seismic-prone areas.
Keywords: ETABS, Response Spectrum Analysis, Story Drift.

I. INTRODUCTION

In recent decades, rapid urbanization and increasing land scarcity have led to a growing demand for high-rise buildings in urban areas. In regions prone to seismic activity, the safety and performance of such structures during earthquakes are of paramount importance. Among various factors influencing the seismic behavior of buildings, the plan geometry plays a crucial role in determining how a structure responds to lateral loads during an earthquake. Irregularities in the plan configuration can lead to uneven distribution of mass, stiffness, and strength, which may cause undesirable seismic responses such as torsion, stress concentration, and excessive deformation. As a result, buildings with irregular shapes often experience higher levels of damage compared to their regular counterparts. Building codes, including IS 1893:2016, emphasize the importance of considering structural irregularities during seismic design, but do not explicitly state which configurations are more vulnerable or efficient. This study focuses on evaluating the seismic performance of high-rise buildings with different plan geometries—Rectangular, L-shaped, H-shaped, and C-shaped—through analytical modeling using ETABS software. By performing Response Spectrum Analysis in accordance with IS 1893:2016, the study aims to quantify and compare key seismic response parameters such as lateral displacement, story drift, story stiffness. The objective is not to propose strengthening techniques, but rather to identify which plan configurations inherently offer better structural performance under seismic loading. The outcomes of this research are intended to assist structural engineers and architects in making informed decisions during the conceptual design phase, promoting safer and more efficient high-rise building designs in seismic zones.

The main objectives of this study are:

1) To evaluate the seismic performance of high-rise buildings with different plan configurations—Rectangular, L-shaped, H-shaped, and C-shaped—using Response Spectrum Analysis as per IS 1893:2016 in ETABS software.
2) To compare the structural response of each configuration based on parameters such as lateral displacement, story drift, in order to identify the most efficient plan shape under seismic loading.

II. METHODOLOGY

To perform the seismic analysis and design of a structure to be built at a particular location, the actual time history record is required. However, it is not possible to have such records at every location. Further, the seismic analysis of structures cannot be carried out simply based on the peak value of the ground acceleration as the response of the structure depends upon the frequency content of ground motion and its dynamic properties. To overcome the above difficulties, the earthquake response spectrum is the most popular method in the seismic analysis of structures. There are computational advantages in using the response spectrum method of seismic analysis for the prediction of displacements and member forces in structural systems.

The response spectrum analysis is performed for the damping of 5% and V th seismic zone. The response spectrum analysis is performed to design the sections and then to optimize the design.

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III. ANALYSIS OF HIGH-RISE BUILDING SHAPES USING ETABS

ETABS (Extended Three-Dimensional Analysis of Building Structure) is an integrated building design software developed by Computers and Structures Inc., also known as CSI. It is one of the most powerful software in structural engineering in the design of high-rise buildings. It is used worldwide due to its features in rapid modeling of framing systems and in analyzing large and complicated building structures

For the formation of model following material specifications are used based on Code:IS1893:2016 and IS13920:2016

TABLE I- Material Properties And Section Details

Grade of Concrete M 30	Fck 30 N/mm^2
Grade of Steel	Fy 415 N/mm^2
Density of Concrete	= 25 KN/m^3
Density of Brick Wall Considered	= 20 KN/m^3
Number of Story	G + 15
Story Height	3m
Beam Dimensions	250 x 450 mm
Column Dimensions	250 x 450 mm
Slab Thickness	150 mm
Thickness of Main Wall	230 mm
Height of Parapet Wall	1.5 m
Thickness of Parapet Wall	125 mm
Support Condition	Fixed
Thickness of Internal Wall	125 mm

IV. MODELLING IN ETABS SOFTWARE

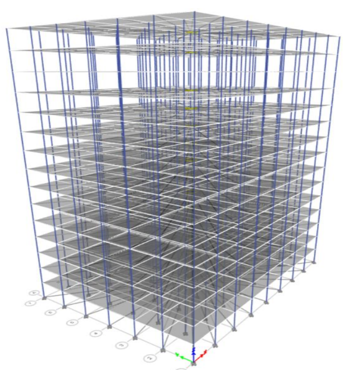

Fig. 1 Rectangular Plan Shape

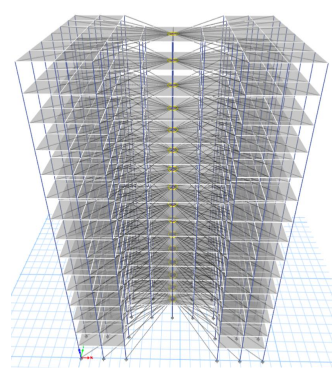

Fig. 2 H Plan Shape

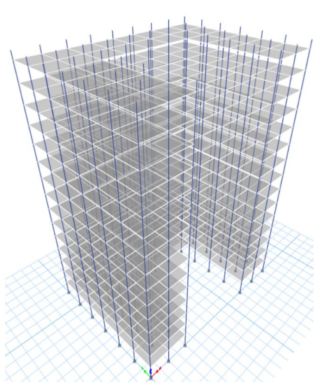

Fig. 3 C Plan Shape

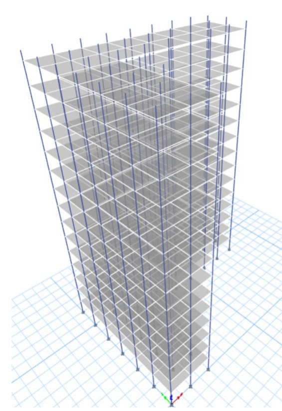

Fig. 4 L Plan Shape

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After performing Response Spectrum Analysis on the above selected building configuration. following parameters are obtained
Storey Displacement
Storey Drift

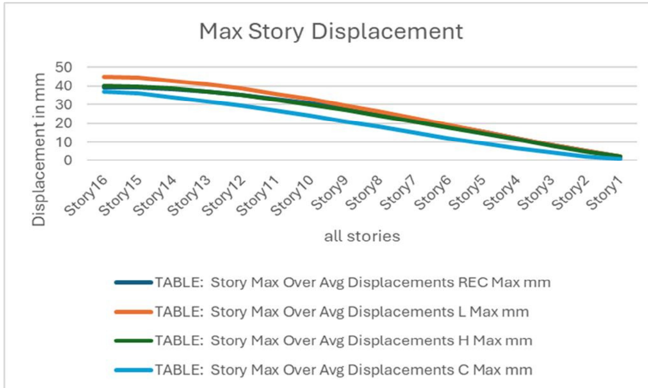

Fig. 5 Shows the graph for story displacement for different structural configurations

Storey Displacement: Story displacement refers to the deflection (movement) of a single storey (floor level) relative to the base or ground level of a building structure during seismic events. The C-shaped structure showed the lowest displacement (36.81 mm at top), indicating better lateral control. The L-shaped structure had the highest displacement (44.86 mm), showing more flexibility. Rectangular (39.28 mm) and H-shaped (40.08 mm) structures showed moderate performance. Structural shape clearly affects seismic response.

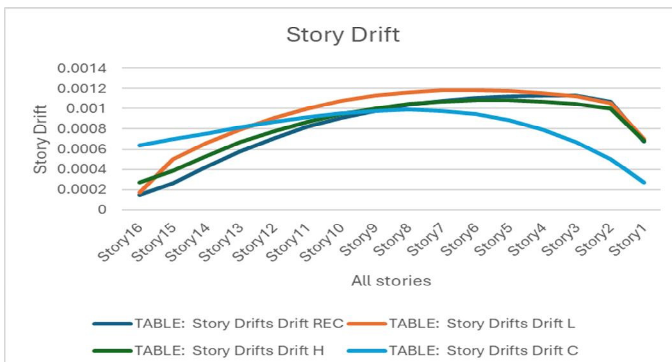

Fig. 6 Shows the graph for story drift for different structural configurations

Storey Drift: Story drift refers to the horizontal movement of a building or structure due to the action of external forces. It quantifies how much each storey (floor level) moves horizontally relative to the base or ground level of the building. Storey drift is typically measured in millimeters.

$$\text{Storey Drift} = \frac{\text{Relative Movement } (\Delta 2 - \Delta 1)}{\text{Storey Height } (H2)}$$

The storey drift analysis reveals that the Rectangular (REC) structure consistently showed the lowest drift values,

V. RESULTS AND DISCUSSION

The Response Spectrum Analysis was carried out in accordance with IS 1893:2016 for four different building configurations—Rectangular, L-shaped, H-shaped, and C-shaped—to assess their seismic performance based on story drift and displacement parameters.

A. Displacement

The displacement results for all configurations are shown in Graph 1. Across all structural shapes, the maximum displacement was observed at the top story, while the minimum displacement occurred at the base, which is consistent with expected seismic response behavior. Among the four, the L-shaped structure recorded the highest displacement (44.86 mm at the top), indicating greater flexibility and reduced lateral stiffness.

Conversely, the C-shaped structure experienced the lowest displacement (36.81 mm at the top), demonstrating enhanced stiffness and better control of seismic-induced lateral movement. The Rectangular (39.28 mm) and H-shaped (40.08 mm) structures displayed moderate displacement values, falling between those of the L and C configurations.

B. Storey Drift

Storey drift values were plotted in Graph 2, where the C-shaped structure exhibited the maximum story drift, peaking at 0.000988 at Story 8, indicating higher vulnerability and lateral deformation. The Rectangular-shaped structure showed the minimum drift of 0.00015 at Story 16, reflecting better seismic performance and structural integrity. The L-shaped and H-shaped structures displayed intermediate drift behaviors, with the L-shape generally exhibiting slightly higher drift values than the H-shape, particularly in the mid to upper stories.

VI. CONCLUSIONS

Based on the Response Spectrum Analysis performed in ETABS for different plan configurations, the following conclusions are drawn:

1) Rectangular-shaped structures demonstrated the lowest storey drift across all floors, indicating superior performance in terms of lateral stability and seismic resistance.
2) L-shaped structures experienced the highest displacement, highlighting their greater flexibility and lower stiffness, while C-shaped structures showed the least displacement, suggesting better control of lateral movements.
3) Structural irregularities in the L, H, and C-shaped plans led to increased lateral deformation, which may cause stress concentration and reduced seismic resilience.
4) Overall, plan geometry significantly affects the seismic behavior of high-rise buildings.

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