# Seismic Analysis of RCC Symmetrical and Unsymmetrical Building with Stiffness Irregularities

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***Abstract*—It is very essential to identify the behavior and damages of buildings, which initiate at locations of the structural weak planes present in the building systems, due to various shape of building i.e., Rectangular, L-Shape and T- Shape building. The contribution of lateral load resisting system, number of stories, type and different type of analysis method has to be properly assessed and evaluated in order to avoid torsional effect and collapse of the structure. The behaviors of building during earthquake depends critically on its overall shape, size and geometry. Buildings with irregular geometry respond differently against seismic action. Plan geometry is the parameter which decides its performance against different loading conditions. The effects of irregularity (plan and shape) on structure have been carried out by using structural analysis software ETABS. The aim of present study is to compare seismic performance of Equivalent Static Method, Response Spectrum Method using medium soil. The G+15 story structures situated in earthquake zones III. All frames are designed under same gravity loading. Response spectrum method is used for seismic analysis. ETABS software is used and the results are compared. The results were obtained in the form of Earthquake Displacement, Story Force, Base Shear and Modal Mass Participations.**

***Index Terms*—ETABS, Earthquake Load, Torsion, Response Spectrum, Modal Mass Participation.**

## I. INTRODUCTION

The behavior of a building during an earthquake depends on several factors, stiffness, adequate lateral strength and ductility, simple and regular configurations. The buildings with symmetrical framing and equally distributed mass and stiffness in plan as well as in elevation suffer much less damage compared to unsymmetrical configurations. Most recent earthquakes have shown that the irregular distribution of mass, stiffness and strengths may cause serious damage in structural systems. The area of vertically irregular type of building is now having a lot of interest in seismic research field. Many structures are designed with vertical irregularity for architectural views. Structural design of buildings for seismic loads is primarily concerned with structural safety during major ground motions. Regular structures have uniformly distributed mass, stiffness, strength and structural form. When one or more of these properties is non-uniformly distributed, either individually or in combination with other properties in any direction, the structure is referred to as being irregular.

During an earthquake, failure of structure starts off-evolved at factors of weak spot. This weak point arises due to discontinuity in mass, stiffness and geometry of structure. The systems having this discontinuity are termed as irregular systems. Irregular structures contribute a massive portion of city infrastructure. Vertical irregularities are one of the essential motives of failures of systems during earthquakes. Asymmetry in structures makes Dynamic analysis of the seismic behaviors very complicated. Seismic demand in peripheral elements is enhanced. Uniformity in load distribution gets disturbed. Torsional behaviors of asymmetric building is one of the most frequent causes of structural damage and failure during strong ground motions Torsion responses in structures arise from two sources: Eccentricity in the mass and stiffness distributions, causing a torsion response coupled with translation response; Torsion arising from accidental causes, including uncertainties in the masses and stiffness, the differences in coupling of the structural foundation with the supporting earth or rock beneath it.

Dynamic analysis damage surveys and analyses conducted on modes of failure of building structures during past severe earthquakes concluded that most vulnerable building structures are those, which are symmetrical and asymmetric in nature. Asymmetric-plan buildings, namely buildings with in-plan asymmetric mass and strength distributions, are systems characterized by a coupled torsional-translational seismic response. For many irregular structures, excessive torsion is the main reason of the poor seismic performance. Torsion effects increase lateral deflections on the weak direction of the structure and decrease on the strong direction.

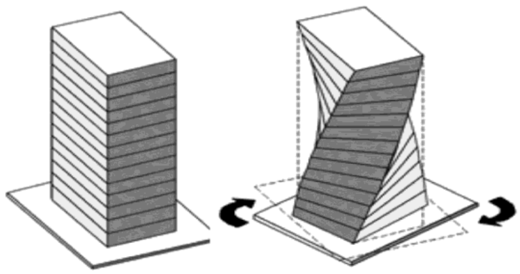


Figure 1.1. Twisting of Structures

For many asymmetrical structures, excessive torsion is the main reason of the poor seismic performance. Torsional effects increase lateral deflections on the weak direction of the building and decrease on the strong direction. Concrete walls, slab holes, overhangs, column clouds, etc. may cause eccentricity between center of mass and center of rigidity. Modern codes deal with torsion by placing restrictions on the design of buildings with irregular layouts and also through the introduction of an accidental eccentricity that must be considered in design.

Objective Statements

1. The response of building frames of various heights plans is proposed to analyze dynamic analysis.
2. The parameters like time period, displacement, drift, base shear is compared.
3. Various mass irregularities are proposed to analyze for various height and for various plan geometry.
4. Various stiffness irregularities are proposed to analyze for various height and for various plan geometry.

## II. LITERATURE REVIEWS

The following researchers have carried out the study related to the dissertation topic.

Saylee Nikale et. al (2025) The structural configuration of a building whether regular or irregular plays a crucial role in its behavior under lateral loads such as wind and seismic forces. Regular buildings, with uniform mass and stiffness distributions, typically exhibit predictable and uniform responses. This review underscores the need for updated design guidelines tailored specifically for irregular configurations, especially in high-risk seismic zones.

Kaushal Basaraf et. al (2024) The study adopts the IS 1893:2016 (Part 1) guidelines due to their established standards in seismic analysis and design. The results show that uneven mass distribution causes strong sideways forces and instability in the structure, highlighting the crucial need for accurate mass placement to lower earthquake risks. Additionally, the study finds that buildings with an uneven stiffness distribution are more susceptible to torsional effects during seismic events, further increasing the risk of structural failure. Overall, this research emphasizes the importance of considering both mass and stiffness distribution in seismic design to ensure the safety and stability of buildings in earthquake-prone areas. This approach can help save lives and reduce the economic impacts of future earthquakes.

Mahesh Raj Bhatt et.al (2021) They studied the Regular model having regular distribution of mass and stiffness in elevation were analyzed and designed as per IS 1893:2002 by equivalent static method. Comparison has been done among the fundamental periods of 6th, 9th and 12th stores among regular, irregular and bare framed buildings. Results show that there is significant contribution of infill in fundamental periods and there is significant effect of location and magnitude of irregularity in fundamental period. The fundamental periods of the irregular buildings were found longer than regular and shorter than bare frame buildings. Fundamental period was longest with mass irregularities in top story and stiffness irregularities in second story. There was not significant effect in fundamental period when mass irregularity was in bottom portion of building and stiffness irregularity was in top portion of the building.

Gokulesh C. Chopde (2021) Multi-story RC Structure has subjected to most dangerous earthquakes. It was found that a main reason for the failure of RC building is irregular distributions of the mass, stiffness and strength or due to irregular geometrical configurations. In a reality, many existing buildings contain an irregularity due to functional and aesthetic requirements. They work vertical Irregularities were analyzed at various floor levels and comparative results were plotted from this it is found that a more amount of research can be done on this topic.

Pradnya K. Lautre (2021) A building shall be considered as an irregular as per "IS 1893-2002, if it lacks symmetry and has discontinuity in geometry, mass or load resisting elements." The dynamic load includes many loads such as wind, waves, traffic, earthquakes, and blasts. Structural symmetry might be a major reason of poor performance of buildings under extreme seismic loading; asymmetry contributes significantly to increase lateral deflections, increased member forces and ultimately the building tends to collapse. Multi-storied buildings IJRAR21C1377 can be of the following types: - Load Bearing Construction, Composite Construction and Framed Construction. Load bearing constructions are economical only up to 2-3 story. Composite construction, a combination of both load bearing and framed construction, is economical up to 5 story. For 6 or more story, it is necessary dealt with the framed construction.

Vikas Joshi [2018]: studied Vertical irregularities were one of the essential motives of failures of systems during earthquakes. The main objective of the analysis was to study the behavior of flat slab system in vertical irregular multi-storied building against different forces acting on it during earthquake. The analysis was carried out using STAAD Pro2007 software. Flat slab system was modelled and analyzed for the dynamic loading. The analysis was made between in the four types of G+10 story building with vertical geometric irregularity & mass irregularity increasing toward top & decreasing toward top. Total 12 modelled were studied and their results were compared. To know the effect of Geometric irregularity on the shape (vertical geometric) irregular constructing the geometry was changed through reducing the no. of bays in X- direction vertically downward. Comparison in made between flat slab shear stresses, Bending Moment, node displacement, Base shear, Story drift & the result was brought out.

## III. METHODOLOGY

Multi-storied Reinforced concrete building, moment resisting space frame have been analyzed using professional software. Model of Multistoried building frame and dumbbell shaped shear wall is analyzed by response spectrum Method. The plan dimensions of buildings are shown in table below. The plan view of building, elevation of different frame.

Proposed Study

1. It is proposed to study the response of building (as per IS 13920: 2016)
2. The seismic parameters like time period, displacement, drift, base shear will be evaluated.
3. An attempt will be made on appropriate provision of lateral load resisting system i.e. vertical irregularity use for lateral load.
4. The effectiveness of lateral load system on different vertical shapes of buildings.
5. The feasible structural configuration for economical housing tall buildings will be suggested.

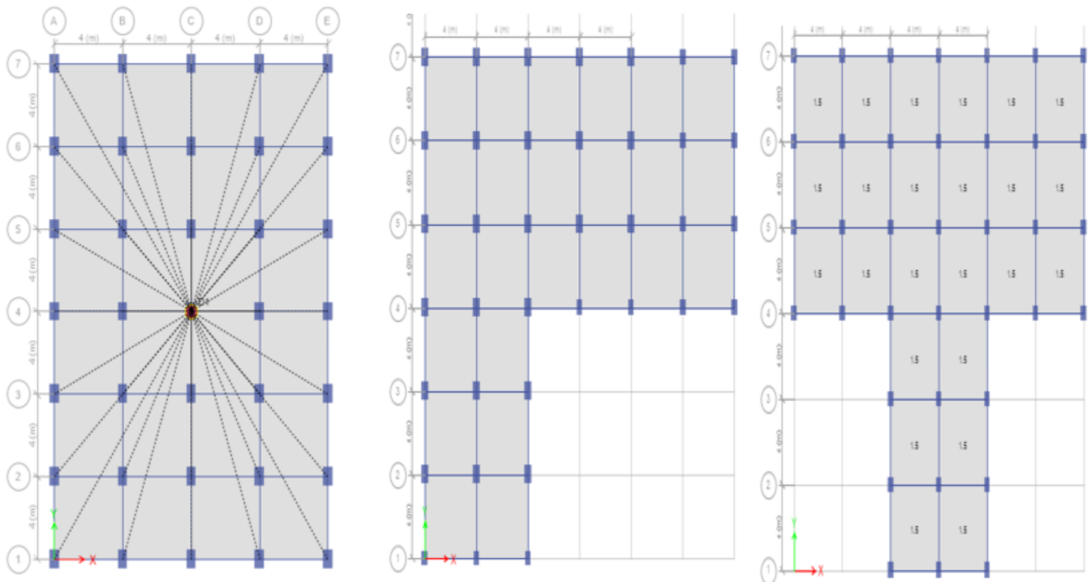
Table 1: Geometrical Configurations and Feature of Building

| Sr. No. | Parameters | Values |
|---|---|---|
| 1 | Material used | Concrete-M25 and M30 |
| 2 | Plan dimension | Reinforcement Fe-500Mpa |
| 3 | Height of each Story | 3.0m |
| 4 | Height of ground Story | 2.0m |
| 5 | Density of concrete | 25KN/m$^3$ |
| 6 | Poisson ratio | 0.2-concrete and 0.15-steel |
| 7 | Density of brick | 20KN/m$^3$ |
| 9 | Code of Practice adopted | IS456:2000, IS1893:2016 |
| 10 | Seismic zone for IS1893:2016 | III |
| 12 | Importance factor | 1.2 |
| 13 | Response reduction factor | 5 |
| 14 | Foundation soil | Medium |
| 15 | Slab thickness | 150mm |
| 16 | Wall thickness | 150mm |
| 17 | Floor Finish | 1KN/m2 |
| 18 | Live load | 3 KN/m2 |
| 19 | Earthquake load | As per IS 1893-2016 |
| 20 | Wind load | As per IS 875- 2015 |
| 24 | Model to be design | G+15 |
| 25 | Ductility class | IS1893:2016 SMRF |
| 27 | Basic wind speed (Vb) | 39 m/sec |

| | | |
|---|---|---|
| 28 | Terrain category | 3 |
| 29 | Risk coefficient | 1 |
| 30 | Topography factor | 1 |
| 31 | Parapet wall ht. | 0.9m |

## IV. RESULTS AND DISCUSSIONS

Building Plan



Software 3D Model of Building Plan with rectangular shaped shear wall Fig. shows the software 3D model of G+15 Story building with Rectangular, L-Shape and T-shape.

3d Model Symmetrical and Unsymmetrical

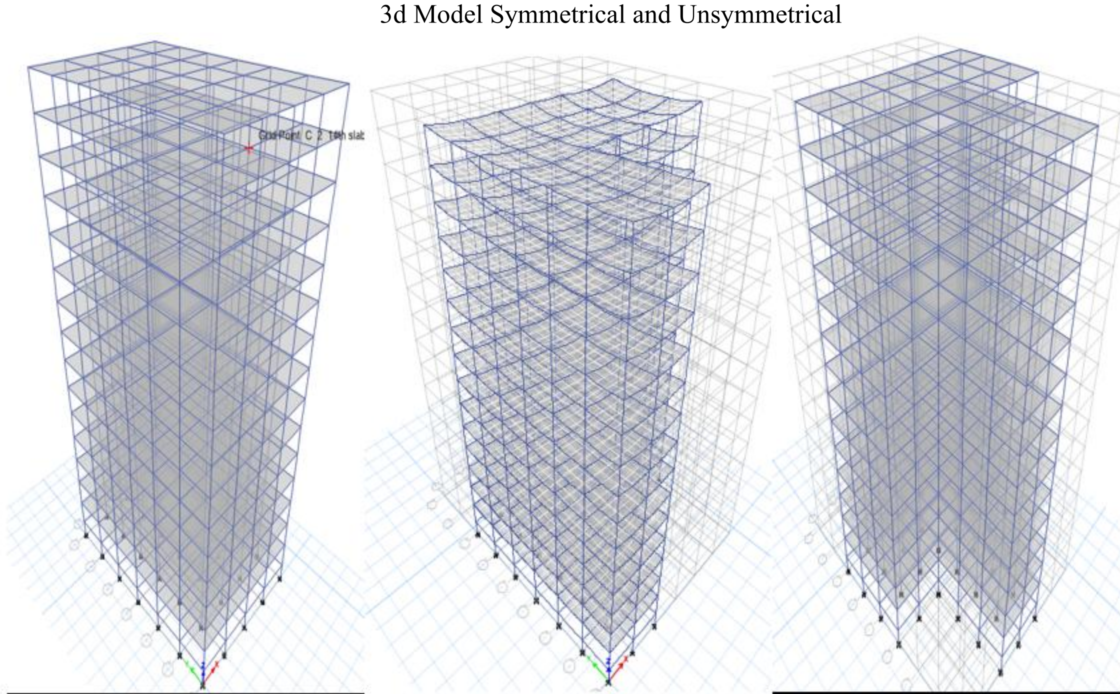
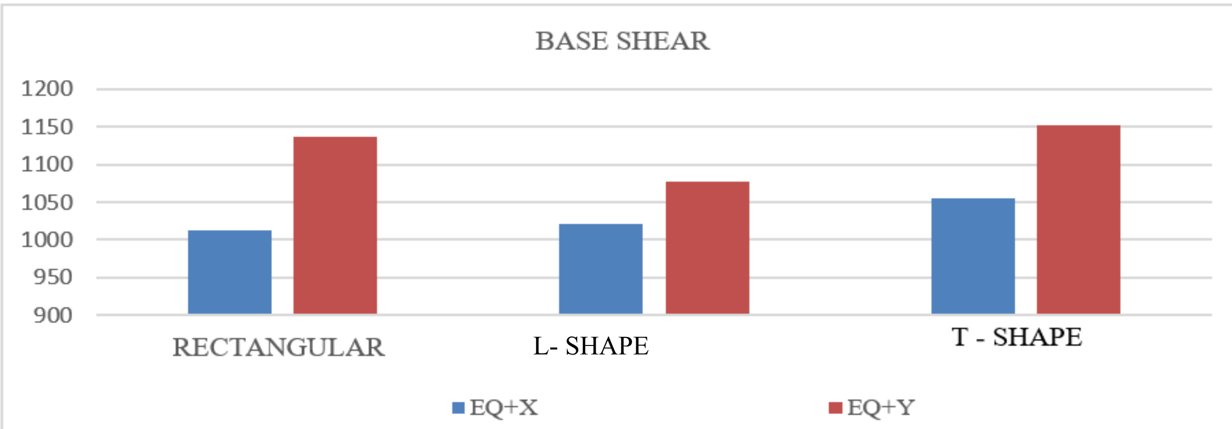


Table 2 Base Shear Results for Symmetrical and Unsymmetrical Shape of Building I.e. Rectangular, L-Shape and T-Shape in Earthquake Zone- III.

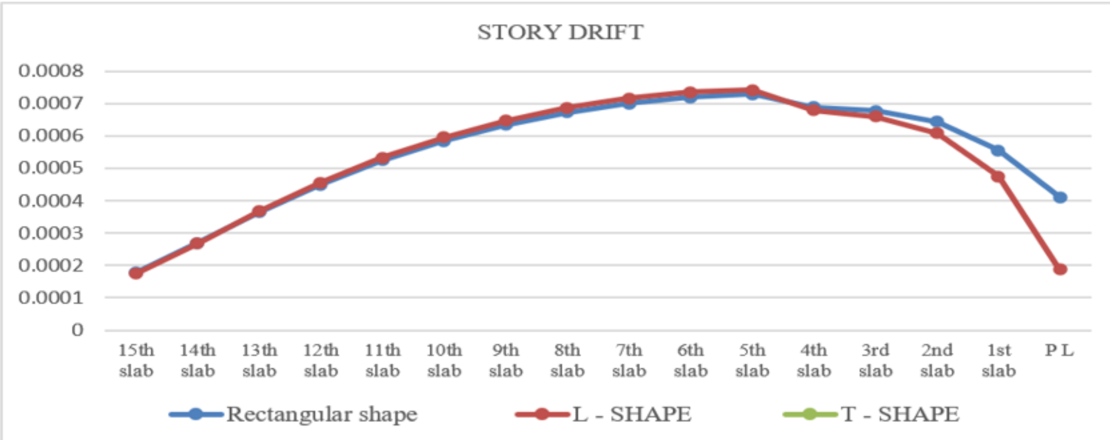
| TABLE: Auto Seismic - IS 1893:2002 | | | | | | | |
|---|---|---|---|---|---|---|---|
| Load Pattern | Z | Soil Type | I | R | Base Shear | Base Shear | Base Shear |
| | | | | | kN | kN | kN |
| | | | | | Rectangular | L-Shape | T-shape |
| EQ+X | 0.16 | II | 1.2 | 5 | 1012.2624 | 1021.2022 | 1055.0471 |
| EQ-X | 0.16 | II | 1.2 | 5 | 1012.2624 | 1021.2022 | 1055.0471 |
| EQ+Y | 0.16 | II | 1.2 | 5 | 1136.7367 | 1076.7746 | 1152.3127 |
| EQ-Y | 0.16 | II | 1.2 | 5 | 1136.7367 | 1076.7746 | 1152.3127 |




Graph 1 Base Shear Vs. Symmetrical and Unsymmetrical Shape of Building I.e. Rectangular, L-Shape and T-Shape in Earthquake Zone- III.

Table 3 Story Drift Results for Symmetrical and Unsymmetrical Shape of Building I.e. Rectangular, L-Shape and T-Shape in Earthquake Zone- III.

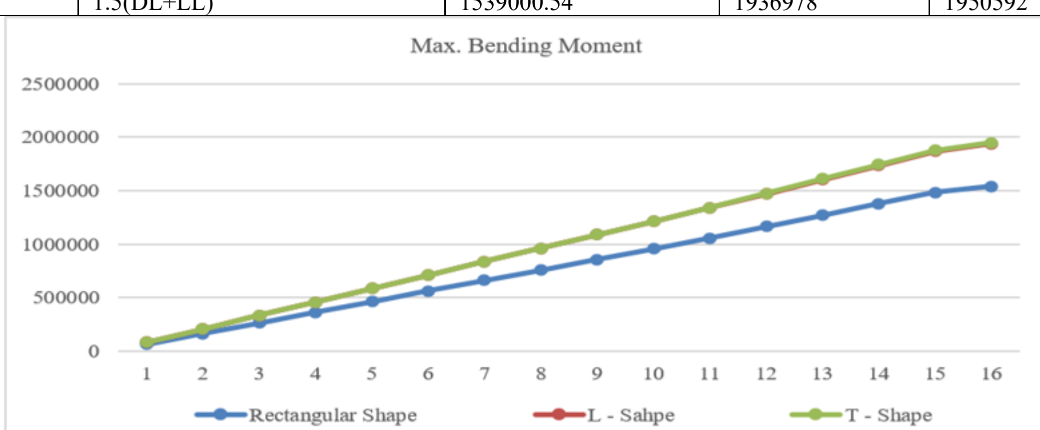
| TABLE: Story Drifts | | | | |
|---|---|---|---|---|
| Story | Load Case/Combo | Drift | Drift | Drift |
| | | Rectangular | L-Shape | T-shape |
| 15th slab | EQ+X | 0.000158 | 0.000178 | 0.000174 |
| 14th slab | EQ+X | 0.000251 | 0.000269 | 0.000268 |
| 13th slab | EQ+X | 0.000349 | 0.000364 | 0.000367 |
| 12th slab | EQ+X | 0.000437 | 0.00045 | 0.000456 |
| 11th slab | EQ+X | 0.000512 | 0.000524 | 0.000533 |
| 10th slab | EQ+X | 0.000575 | 0.000585 | 0.000596 |
| 9th slab | EQ+X | 0.000625 | 0.000634 | 0.000647 |
| 8th slab | EQ+X | 0.000665 | 0.000672 | 0.000687 |
| 7th slab | EQ+X | 0.000694 | 0.0007 | 0.000716 |
| 6th slab | EQ+X | 0.000714 | 0.000719 | 0.000735 |
| 5th slab | EQ+X | 0.000724 | 0.000729 | 0.000742 |
| 4th slab | EQ+X | 0.000661 | 0.000689 | 0.000679 |
| 3rd slab | EQ+X | 0.000646 | 0.000678 | 0.00066 |
| 2nd slab | EQ+X | 0.000599 | 0.000643 | 0.000609 |
| 1st slab | EQ+X | 0.000472 | 0.000556 | 0.000475 |
| P L | EQ+X | 0.000189 | 0.000411 | 0.000187 |




Graph 2 Story Drift Vs. Symmetrical and Unsymmetrical Shape of Building I.e. Rectangular, L-Shape and T-Shape in Earthquake Zone- III.

Table 4 Story Force Results for Symmetrical and Unsymmetrical Shape of Building I.e. Rectangular, L-Shape and T-Shape in Earthquake Zone- III.

| Table: Story Forces | | | | |
|---|---|---|---|---|
| Story | Load Case/Combo | MX | MX | MX |
| | | kN-m | kN-m | kN-m |
| | | Rectangular | L-shape | T-shape |
| 15th slab | 1.5(DL+LL) | 64300.23 | 81755.53 | 81755.53 |
| 14th slab | 1.5(DL+LL) | 163570.86 | 207467.1 | 207467.1 |
| 13th slab | 1.5(DL+LL) | 262841.49 | 333178.6 | 333178.6 |
| 12th slab | 1.5(DL+LL) | 362112.12 | 458890.1 | 458890.1 |
| 11th slab | 1.5(DL+LL) | 461382.75 | 584601.6 | 584601.6 |
| 10th slab | 1.5(DL+LL) | 560653.38 | 710313.2 | 710313.2 |
| 9th slab | 1.5(DL+LL) | 659924.01 | 836024.7 | 836024.7 |
| 8th slab | 1.5(DL+LL) | 759194.64 | 961736.2 | 961736.2 |
| 7th slab | 1.5(DL+LL) | 858465.27 | 1087448 | 1087448 |
| 6th slab | 1.5(DL+LL) | 957735.9 | 1213159 | 1213159 |
| 5th slab | 1.5(DL+LL) | 1057006.53 | 1338871 | 1338871 |
| 4th slab | 1.5(DL+LL) | 1163547.882 | 1471020 | 1473947 |
| 3rd slab | 1.5(DL+LL) | 1270089.234 | 1603169 | 1609023 |
| 2nd slab | 1.5(DL+LL) | 1376630.586 | 1735318 | 1744099 |
| 1st slab | 1.5(DL+LL) | 1483171.938 | 1867468 | 1879175 |
| P L | 1.5(DL+LL) | 1539000.54 | 1936978 | 1950592 |




Graph 3 Story Force vs. Symmetrical and Unsymmetrical Shape of Building I.e. Rectangular, L-Shape and T-Shape in Earthquake Zone- III.

## V. CONCLUSION

In the present study, Relative Analysis of RCC Building G+15 Story with different shape of building i. e. rectangular shape, Inverted L-shape and T-shape of building. The structures are analyses for earthquake zone III with medium soil and Results Compare. It has been made on different structural parameters viz. Base Shear, Story Shear, Max. Bending Moment, Max. Story Force and Story Drift etc. Grounded on the analysis results following conclusions are drawn.

Base Shear Decreases with Height – Generally, as building height increases, the base shear values tend to decrease. This happens because taller buildings have a higher natural period, which reduces the seismic forces acting at the base.

Variation Among Categories (R, T, L) – If the graph shows different categories (e.g., R, T, L), their differences suggest that structural configuration or material properties impact how seismic forces are distributed. Some structures may absorb or dissipate seismic forces more effectively.

Higher Base Shear for Shorter Buildings – The G+15 structure likely has the highest base shear because shorter buildings tend to be stiffer, leading to greater seismic force attraction. This is a common trend in earthquake engineering.

Structural Stability Considerations – A well-balanced decrease in base shear values with height suggests that the structural design effectively manages lateral forces, possibly through damping systems or flexible structural elements.

Design Considerations – Higher drift values at greater heights emphasize the need for structural stability measures. If the drift values exceed permissible limits, modifications in design (e.g., increased stiffness, better load distribution) may be required to ensure safety and serviceability.

Category Comparison (R, T, L) – The "T" and "L" categories show higher bending moments compared to "R" at each height level. This suggests that these structural configurations (T and L) might experience more flexural stress due to their design or load distribution.

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