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Comparison of Analysis and Design of Regular and Irregular Configuration of Multi Story Building in Various Seismic Zones

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Abstract: - The seismic performance of multi-story buildings is critically influenced by their structural configuration. This study presents a comparative analysis and design evaluation of regular and irregular reinforced concrete (RC) framed structures subjected to seismic forces across two seismic zones—Zone III (moderate) and Zone V (very severe)—as defined by IS 1893 (Part 1): 2016. The objective is to assess how geometric irregularities in plan and elevation impact structural response under dynamic loading conditions. Two G+17 RC buildings, one with regular configuration and another with irregularities (L-shaped plan and vertical mass/stiffness variation), were modeled and analyzed using ETABS 2017. The analysis was conducted using equivalent static and response spectrum methods, with parameters such as storey displacement, storey drift, base shear, stiffness, and modal time period evaluated. The results show that irregular configurations exhibit significantly higher lateral displacements, storey drift, and reduced stiffness compared to regular ones, especially under Zone V seismic conditions. Regular buildings demonstrated better seismic performance due to their uniform mass and stiffness distribution, leading to more predictable dynamic behavior.

Keywords: - Seismic Analysis, Regular and Irregular Buildings, Storey Drift, Displacement, Short Column Effect, Soil Type, Dynamic Analysis, Earthquake Engineering.

I. INTRODUCTION

In the present developing scenario, the construction of tall buildings has become a necessity due to rapid urbanization, population growth, and limited availability of land in major cities. As urban areas expand vertically rather than horizontally, the demand for high-rise and super-tall structures is continuously increasing across the world. This rapid development has significantly influenced the evolution of innovative structural systems, enabling buildings to reach greater heights with improved safety, efficiency, and functionality. The advancement in construction materials, especially reinforced concrete, along with modern analysis methods and construction technologies throughout the twentieth century, has made it possible to design and construct durable and stable tall buildings. Although there is no universally fixed definition of a tall building, the Council on Tall Buildings and Urban Habitat provides widely accepted criteria to classify such structures. According to CTBUH, a building can be considered tall based on several factors, including its height relative to the surrounding context, its slenderness ratio (proportion of height to base dimensions), and the incorporation of specific technologies associated with tall structures, such as advanced vertical transportation systems and lateral load-resisting mechanisms. For example, a 14-storey building may not be categorized as tall in cities like Chicago or Hong Kong, but it may be considered tall in smaller urban settings. From a structural engineering perspective, systems such as moment-resisting frames and shear walls are commonly used to resist gravity loads and provide basic lateral stability. However, as the height of a building increases, the influence of lateral loads—primarily wind and earthquake forces—becomes significantly more critical in design considerations.

These forces induce large displacements, storey drifts, and dynamic responses that can adversely affect the safety and serviceability of the structure. Therefore, controlling the effects of lateral loads becomes a key objective in the design of tall buildings. To address these challenges, structural systems incorporating reinforced concrete cores have been widely adopted. A concrete core, typically located at the center of the building, acts as a stiff vertical cantilever, providing substantial resistance against lateral forces caused by wind and seismic activity. This system effectively reduces deflection, enhances structural rigidity, and improves overall stability. In recent years, hybrid structural systems combining moment-resisting frames with concrete core walls have gained significant popularity. These frame-core systems offer both structural efficiency and economic advantages, making them a preferred choice for modern tall buildings. The integration of such advanced systems ensures improved performance under dynamic loading conditions while optimizing material usage and construction cost, thereby supporting the continued growth of tall building construction in the future.

II. METHODOLOGY

The methodology of the present study is developed on a detailed comparative analysis of regular and irregular multi-storey building configurations subjected to different seismic conditions in India. The entire investigation is carried out in accordance with the provisions of IS 1893 (Part 1): 2016 along with other relevant Indian Standards such as IS 456:2000 and IS 875. The primary objective of this methodology is to evaluate and compare the seismic performance of buildings having regular and irregular configurations under varying seismic intensities, considering key response parameters such as storey displacement, storey drift, base shear, natural time period, and overall structural behaviour. Irregularities in building structures play a significant role in influencing seismic performance. During earthquake excitation, structural failure is often initiated at weak zones created due to discontinuities in geometry, abrupt changes in mass and stiffness, and vertical or plan irregularities. Such structures are categorized as irregular buildings and are generally more vulnerable to seismic forces due to uneven distribution of lateral loads and complex dynamic response. In contrast, regular buildings possess uniform distribution of mass and stiffness along both plan and elevation, resulting in better stability and predictable performance under seismic loading. For the purpose of this study, G+17 reinforced concrete (RC) frame structures are considered. Two main building configurations are selected: one representing a regular structure with uniform geometry and stiffness distribution, and the other representing an irregular structure incorporating vertical irregularities in terms of mass and stiffness. Both configurations are analyzed under two different seismic zones of India, namely Zone III (moderate seismic risk) and Zone V (very severe seismic risk), to understand the variation in structural response with increasing seismic intensity. The structural modelling and analysis are carried out using advanced finite element software such as ETABS or STAAD Pro. Each model is subjected to Dead Load, Live Load, and Seismic Load as per the codal provisions. Seismic analysis is performed using the Response Spectrum Method, which is suitable for evaluating dynamic response of multi-storey buildings. The seismic input parameters such as zone factor, importance factor, and response reduction factor are assigned based on the selected seismic zone and building characteristics. The analytical procedure involves systematic steps including modelling of both regular and irregular buildings with identical height, plan dimensions, and loading conditions to ensure a fair comparison. Material properties and sectional dimensions are assigned as per relevant Indian Standards. Seismic loads are applied considering appropriate design parameters, and the analysis is executed to determine critical structural responses such as fundamental natural time period, lateral displacement, storey drift, base shear, and variation in storey stiffness along the height of the building. After completing the analysis, the results are extracted and compared in detail. Key performance indicators such as maximum storey displacement, inter-storey drift, modal time periods, base shear at foundation level, and stiffness variation are evaluated for both configurations in different seismic zones. Comparative graphical representations are prepared to clearly illustrate the differences in seismic behaviour between regular and irregular structures. This comprehensive methodological approach helps in understanding the influence of geometric irregularities on seismic performance and provides valuable insights for structural engineers and designers. The study ultimately assists in selecting appropriate building configurations and design strategies to ensure safety, stability, and economic efficiency of structures located in different seismic zones.

Table 3.1: Data Required for Modeling for G+17 Storey Building

Sr. No.	Component	Dimension (mm)
1	Beam	230 × 500
2	Column	550 × 550
3	Slab Thickness	150

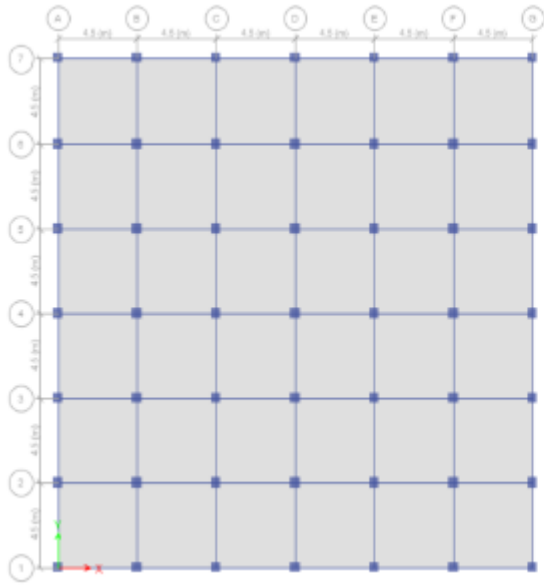


Figure 3.1 Regular Building

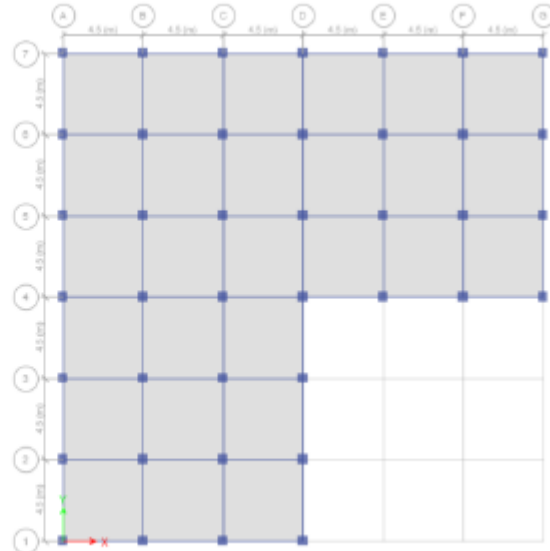


Figure 3.2 Irregular Building



Figure 3.3 Regular Building



Figure 3.4 Irregular Building

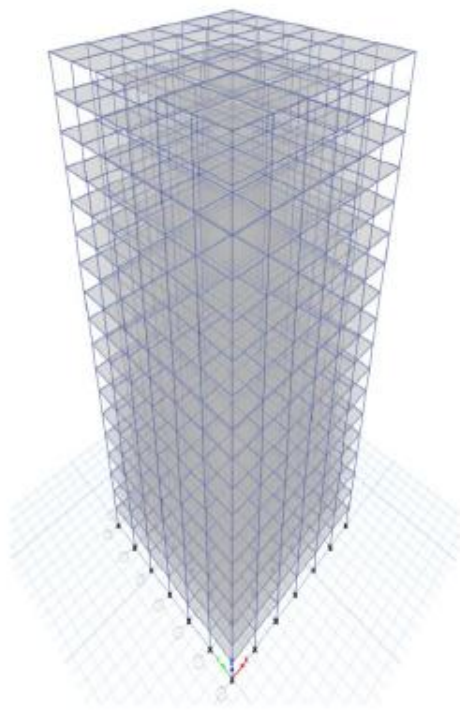


Figure 3.5 Regular Building

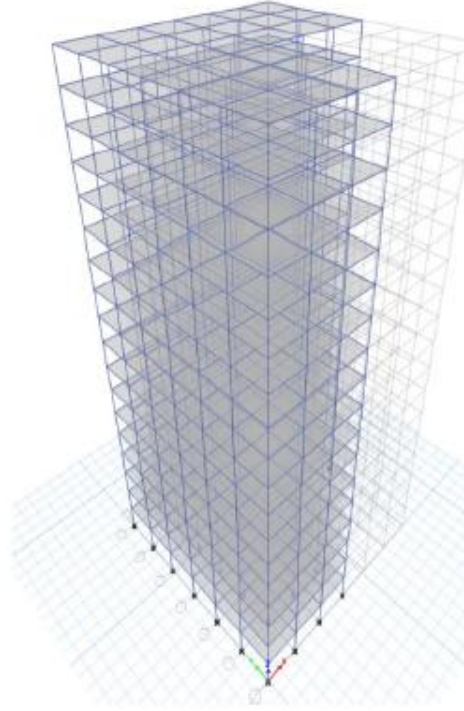


Figure 3.6 Irregular Building

Modelling of Structure in ETABS 2017:

The modelling of the structure in this study is carried out using ETABS 2017, which is one of the most widely used software tools for analysis and design of multi-storey building structures. The structural system considered is a conventional reinforced concrete (RCC) beam–column frame, where beams and columns act as the primary load-resisting components. This type of structural configuration is commonly adopted in building construction due to its simplicity, efficiency, and ease of analysis. The main objective of modelling is to develop accurate analytical models of both regular and irregular G+17 storey RCC buildings and to evaluate their structural performance under seismic loading conditions as per IS 1893 (Part 1): 2016. In this study, it is assumed that the material properties of concrete remain uniform throughout all structural components for consistency in comparison.

The modelling procedure is carried out systematically in ETABS using the following steps:

Step 1: Formation of Grid Lines

Grid lines are created based on the required plan dimensions of the building. These grids define the spacing and alignment of structural elements such as columns and beams. Proper grid formation ensures accurate geometry and uniformity in modelling.

Step 2: Assignment of Material and Section Properties

Material properties such as grade of concrete and reinforcement are defined as per relevant Indian Standards. Section properties for beams, columns, and slabs are assigned based on the design requirements. These properties include cross-sectional dimensions, stiffness parameters, and material characteristics.

Step 3: Modelling of Structural Elements

The structural model is developed by drawing beams, columns, and slabs using the predefined section properties in ETABS.

Procedure:

- Go to: Draw → Beam/Column/Slab
- Select the required section property
- Draw structural elements as per grid layout

This step results in a complete 3D analytical model of the building structure.

Step 4: Analysis of RCC Structure (Linear Dynamic Method)

The seismic analysis of the structure is carried out using the Response Spectrum Method, which is a linear dynamic analysis technique suitable for multi-storey buildings.

Procedure for Linear Dynamic Analysis:

1. Define Response Spectrum Function
 - o Go to: Define → Functions → Response Spectrum
 - o Input spectral data as per IS 1893:2016 based on the selected seismic zone
2. Define Mass Source
 - o Go to: Define → Mass Source
 - o Assign mass contributions from dead load and a percentage of live load
3. Assign Diaphragm
 - o Go to: Assign → Shell → Diaphragm
 - o Assign rigid diaphragm to floor slabs to ensure proper lateral load distribution
4. Define Load Cases
 - o Go to: Define → Load Cases → Add New
 - o Select Response Spectrum method
 - o Specify direction of loading (X and Y directions)
5. Run Analysis
 - o Go to: Analyze → Select Analysis Cases → Run Analysis
 - o Perform analysis to obtain structural response parameters

III. RESULTS AND DISCUSSION

Table 4.1: Modal Time Period for Regular & Irregular Building

Mode	Zone V – Regular Building	Zone V – Irregular Building	Zone III – Regular Building	Zone III – Irregular Building
1	2.056	2.051	2.056	2.051
2	2.056	2.050	2.056	2.050
3	1.845	1.867	1.845	1.867
4	0.672	0.669	0.672	0.669
5	0.672	0.669	0.672	0.669
6	0.606	0.612	0.606	0.612
7	0.387	0.383	0.387	0.383
8	0.387	0.383	0.387	0.383
9	0.353	0.354	0.353	0.354
10	0.266	0.263	0.266	0.263
11	0.266	0.262	0.266	0.262
12	0.243	0.243	0.243	0.243

Table 4.2: Storey Displacement for Regular & Irregular Building

Storey	Zone V – Regular Building	Zone V – Irregular Building	Zone III – Regular Building	Zone III – Irregular Building
Terrace	47.244	49.242	20.997	21.885
Story 16	46.435	48.273	20.638	21.455
Story 15	45.244	46.929	20.108	20.857
Story 14	43.658	45.191	19.404	20.085
Story 13	41.712	43.093	18.539	19.152
Story 12	39.450	40.680	17.533	18.080
Story 11	36.916	37.995	16.407	16.887



Story 10	34.151	35.083	15.178	15.593
Story 9	31.196	31.984	13.865	14.215
Story 8	28.086	28.735	12.483	12.771
Story 7	24.855	25.372	11.047	11.276
Story 6	21.532	21.925	9.570	9.744
Story 5	18.146	18.424	8.065	8.189
Story 4	14.720	14.896	6.542	6.621
Story 3	11.280	11.369	5.014	5.053
Story 2	7.862	7.881	3.494	3.503
Story 1	4.546	4.522	2.020	2.010
GL	1.598	1.570	0.710	0.698

Table 4.3: Storey Drift for Regular & Irregular Building

Storey	Zone V – Regular Building	Zone V – Irregular Building	Zone III – Regular Building	Zone III – Irregular Building
Terrace	0.00027	0.000323	0.00012	0.000143
Story 16	0.000397	0.000448	0.000176	0.000199
Story 15	0.000529	0.000579	0.000235	0.000257
Story 14	0.000649	0.000699	0.000288	0.000311
Story 13	0.000754	0.000804	0.000335	0.000358
Story 12	0.000845	0.000895	0.000375	0.000398
Story 11	0.000921	0.000971	0.000410	0.000431
Story 10	0.000985	0.001033	0.000438	0.000459
Story 9	0.001037	0.001083	0.000461	0.000481
Story 8	0.001077	0.001121	0.000479	0.000498
Story 7	0.001108	0.001149	0.000492	0.000511
Story 6	0.001129	0.001167	0.000502	0.000519
Story 5	0.001142	0.001176	0.000508	0.000523
Story 4	0.001146	0.001176	0.000510	0.000523
Story 3	0.001139	0.001163	0.000506	0.000517
Story 2	0.001105	0.001120	0.000491	0.000498
Story 1	0.000983	0.000984	0.000437	0.000437
GL	0.000533	0.000523	0.000237	0.000233

Table 4.4: Storey Stiffness for Regular & Irregular Building

Storey	Zone V – Regular Building	Zone V – Irregular Building	Zone III – Regular Building	Zone III – Irregular Building
Terrace	346372.589	244153.116	346372.589	244153.116
Story 16	471338.315	345256.962	471338.315	345256.962
Story 15	511112.940	381424.461	511112.940	381424.461
Story 14	529005.688	398805.353	529005.688	398805.353
Story 13	539312.193	409157.057	539312.193	409157.057

Story 12	546267.473	416257.148	546267.473	416257.148
Story 11	551471.753	421616.900	551471.753	421616.900
Story 10	555688.543	425981.874	555688.543	425981.874
Story 9	559345.458	429778.289	559345.458	429778.289
Story 8	562715.321	433281.528	562715.321	433281.528
Story 7	565996.544	436693.076	565996.544	436693.076
Story 6	569370.558	440194.577	569370.558	440194.577
Story 5	573101.968	444036.007	573101.968	444036.007
Story 4	577864.379	448809.094	577864.379	448809.094
Story 3	585985.994	456465.984	585985.994	456465.984
Story 2	606707.076	474549.722	606707.076	474549.722
Story 1	683818.323	538275.140	683818.323	538275.140
GL	1261918.470	1003565.585	1261918.470	1003565.585

CONCLUSION

Based on the detailed comparative analysis of regular and irregular G+17 multi-storey RCC buildings under different seismic zones, the following conclusions are drawn in accordance with the provisions of IS 1893 (Part 1): 2016:

1. The study clearly indicates that structural configuration plays a crucial role in determining the seismic performance of buildings. Regular buildings, due to their uniform distribution of mass and stiffness, exhibit more stable and predictable behaviour under seismic loading. In contrast, irregular buildings show comparatively higher vulnerability due to discontinuities in geometry, stiffness, and mass, which lead to complex dynamic responses.
2. From the modal analysis results, it is observed that the natural time periods of both regular and irregular buildings are nearly similar for lower modes, indicating comparable global stiffness. However, slight variations in higher modes suggest that irregularity influences the dynamic characteristics of the structure, making it more sensitive to seismic excitation.
3. The storey displacement results reveal that irregular buildings experience higher lateral displacement compared to regular buildings in both Zone III and Zone V. This difference becomes more significant in Zone V (very severe seismic zone), indicating that irregular structures are more susceptible to large lateral movements under strong earthquake forces. Maximum displacement is observed at the top storey (terrace level), which gradually decreases towards the base in both cases.
4. Similarly, storey drift values are consistently higher in irregular buildings compared to regular buildings. Although the drift values are within permissible limits, the increased drift in irregular structures indicates a higher risk of damage to non-structural elements and reduced overall serviceability. The drift increases from the base to mid-height and then reduces towards the top, showing typical structural behaviour under lateral loads.
5. The study of storey stiffness shows that regular buildings possess higher stiffness at all levels compared to irregular buildings. Irregular structures exhibit reduced stiffness due to discontinuities, which results in greater deformation under seismic loads. It is also observed that stiffness increases towards the base of the building in both configurations, which enhances overall stability.
6. Furthermore, the effect of seismic zone is clearly evident from the results. Buildings located in Zone V experience significantly higher displacement and drift compared to those in Zone III due to higher seismic intensity. This highlights the importance of proper structural design and configuration selection based on seismic zoning.

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