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Comparative Seismic Analysis of Symmetric and Asymmetric RCC Buildings Using ETABS Under Equivalent Static Method

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Abstract: This study presents a comparative seismic analysis of symmetric and asymmetric RC buildings using the Equivalent Static Method as specified in IS 1893:2016. Two G+5 Storey RC buildings, one with a regular rectangular plan and the other with an L-shaped asymmetric configuration, were modeled and analyzed in ETABS software. Identical material properties, loadings, and structural dimensions were maintained for both models to isolate the impact of plan geometry. Key seismic response parameters that were studied included base shear, Storey shear, Storey drift, and Storey displacement. These parameters were evaluated under seismic loads applied in both X and Y directions. Results showed that the asymmetric structure experienced moderately higher responses, with an 8.13% increase in base shear and up to a 10.02% increase in top Storey displacement compared to the symmetric counterpart. Despite these increases, all values remained within the permissible limits outlined in IS 1893:2016. The findings emphasize the influence of plan irregularity on lateral seismic response and support the need for more advanced dynamic analyses in future studies.

Keywords: Seismic analysis, Equivalent Static Method, Symmetric & Asymmetric buildings, ETABS modeling, Storey drift and displacement

I. INTRODUCTION

The rapid population growth and urbanization in the recent decades have led to significant increase in the construction of multi-StoreyRC buildings even in seismically active areas. It is the utmost important to ensure the safety and stability of these buildings during earthquakes. Not only does the material strength and construction quality determine the seismic performance of a building, but also its geometry and configuration can have a significant impact on it.

One of the most critical factors influencing seismic behavior is structural symmetry. Symmetric buildings tend to have uniform distribution of mass and stiffness, which results in better performance during lateral loads. In contrast, asymmetric buildings often exhibit torsional responses and irregular displacement patterns, making them more vulnerable during seismic events.

This study aims to compare the seismic response of symmetric and asymmetric RC buildings using Equivalent Static Method as per IS 1893:2016. ETABS software is used for modeling and analysisof structures. Key seismic parameters such as base shear, Storey shear, Storey drift, and Storey displacement are evaluated and compared to understand how geometry influences earthquake performance.

The findings of this research will contribute to a better understanding of how building configuration affects seismic resistance and can help in making informed decisions during the planning and design phases of RCC structures.

II. METHODOLOGY

This study involves a complete seismic analysis using Equivalent Seismic method [as per IS 1893:2016] of two RC buildings One symmetric and one Asymmetric.

The procedure followed is detailed below: -

A. Model Development

1) Two G+5 RCC buildings were modeled: Symmetric and Asymmetric (L-shaped) with uniform bay dimensions i.e. 5mx5m.
2) Both models were created in ETABS 2018+ using identical structural parameters such as:

- Floor height: 3.5 m
- Beam size: 300 mm × 450 mm

- Column size: 450 mm × 600 mm
- Wall thickness: 230 mm (external), 150 mm (internal)
- Slab thickness: 125 mm
- Concrete Grade: M30
- Steel Grade: Fe500

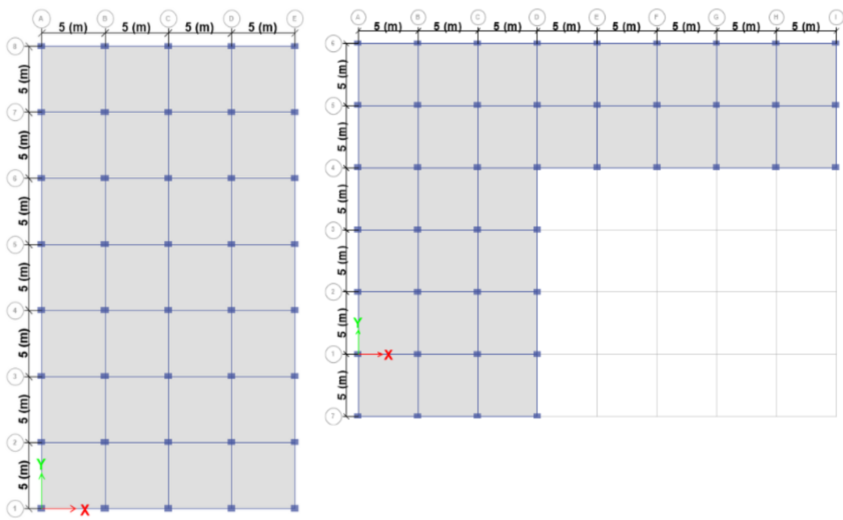

Fig. 1 Column Grid Plan of Symmetric (left) and Asymmetric (Right) RCC Buildings

B. Loading Considerations

1) Dead Load (DL) and Live Load (LL) applied as per IS 875 (Part 1 & 2).

2) Seismic Loads generated using **Equivalent Static Method** as per IS 1893:2016.

- Zone: IV (factor = 0.24)
- Importance Factor (I): 1.0
- Response Reduction Factor (R): 5.0 (SMRF)
- Soil Type: Medium (Type II)
- Damping: 5%

3) Seismic load cases applied in both X and Y directions (EQX and EQY).

C. Load Combinations:

1) Load combinations defined as per IS 1893 and IS 875 (Part 5). Focus was on unfactored combinations for analysis purposes.

- DL + LL
- DL + EQX
- DL - EQX
- DL + EQY
- DL - EQY
- DL + LL + EQX
- DL + LL - EQX
- DL + LL + EQY

- DL + LL – EQY

D. Analysis:
- Linear Static Analysis was performed in ETABS for both models.
- Since the Scope was limited to Analysis and Comparison of results, no design checks were made.

E. Result Parameters Evaluated:
- Base Shear

$$V_b = \frac{Z.I.S_a}{2.R}.W$$

Where:
- V_b= Design Base Shear
- Z = Zone factor
- I = Importance factor
- S_a=Average response acceleration coefficient (from spectral response curves)
- R= Response reduction factor
- W= Seismic Weight of the building

- Storey Shear
- Storey Drift
- Storey Displacement

III. RESULTS& DISCUSSION

A comparative linear static Seismic analysis was conducted to evaluate the seismic performance of symmetric and asymmetric RC buildings in ETABS using Equivalent Static Method of Seismic analysis as directed in IS1893:2016.The Results were evaluated by comparing and analyzing 4 key response parameters: Base Shear, Storey Shear, StoreyDrift, and Storey Displacement under Seismic loading in both X and Y directions [EQX & EQY].

A. Base Shear

The total horizontal Force transferred which is transferred from super structure to the foundationduring an earthquake is represented by base shear. It is an essential parameter for assessing global lateral force demand.

TABLE I

Base Shear Values Under EQX And EQY for Symmetric and Unsymmetric Buildings

BASE SHEAR			
	EQX	EQY	% INCREASE
Symmetric	1573.1708	1486.2791	8.13%
Asymmetric	1701.2716	1515.6936	1.98%

An 8.13% and 1.98% increase in base shear in X and Y direction respectively was observed in the asymmetric model. We can say that the increase is attributed to plan irregularity, which induces torsional response and amplifies the lateral demand, particularly in primary loading direction.

B. Storey Shear

Storey Shear indicates the cumulative lateral force acting on each floor level which increases from top to bottom because of accumulation of inertial mass was we move down on the structure.

TABLE II

Storey Shear Values Under EQX And EQY for Symmetric and Unsymmetric Buildings

STOREY SHEAR DUE TO SEISMIC LOADS		
Storey	Elevation (m)	Shear (kN)

		X-Direction (EQX)		Y-Direction (EQY)	
		Symmetrical	Asymmetrical	Symmetrical	Asymmetrical
Storey 7	23	453.663	487.483	428.606	434.307
Storey 6	19.5	923.486	996.837	872.479	888.100
Storey 5	16	1239.790	1339.756	1171.313	1193.612
Storey 4	12.5	1432.847	1549.056	1353.706	1380.082
Storey 3	9	1532.928	1657.558	1448.259	1476.748
Storey 2	5.5	1570.304	1698.079	1483.570	1512.849
Storey 1	2	1573.171	1701.272	1486.279	1515.694
Base	0	0	0	0.000	0.000

In the X-direction, the base Storey shear increased from 1573.17 kN (symmetric) to 1701.27 kN (asymmetric), a rise of 128.1 kN. In the Y-direction, the increase was from 1486.28 kN to 1515.69 kN, a rise of 29.41 kN. The difference is more prominent at lower Storeys, which confirms the torsional amplification due to eccentric mass distribution in the asymmetric plan.

C. Storey Drift

TABLE III

Storey Drift Values Under EQX And EQY for Symmetric and Unsymmetric Buildings

StoreyDrift due to Seismic loads					
Storey	Elevation (m)	Drift			
		X-Direction (EQX)		Y-Direction (EQY)	
		Symmetrical	Asymmetrical	Symmetrical	Asymmetrical
Storey 7	23	0.000414	0.000428	0.000381	0.000443
Storey 6	19.5	0.000677	0.000692	0.000677	0.000746
Storey 5	16	0.000897	0.000916	0.000911	0.000993
Storey 4	12.5	0.001032	0.001055	0.001057	0.001148
Storey 3	9	0.001067	0.001089	0.001117	0.001202
Storey 2	5.5	0.000907	0.000918	0.001015	0.001061
Storey 1	2	0.000358	0.000357	0.000409	0.00042
Base	0	0	0	0	0

Storey drift is a crucial factor in seismic analysis, as it measures the relative horizontal movement between two consecutive floors. Excessive drift can lead to damage to structural and non-structural components, such as columns, walls, partitions, and finishes. As per IS 1893:2016, the maximum permissible drift is 0.004 times the Storey height, which equals 14 mm for a floor height of 3.5 meters.

In this study, drift was assessed independently in both directions, i.e., X-direction for EQX and Y-direction for EQY. It was observed that the maximum Storey drift occurred in the Third Storey for both models, which is expected due to the natural distribution of mode shapes and stiffness.

When comparing both models, the asymmetric building displayed higher drift ratios. The increase in drift for the asymmetric structure was around **2.06%** in the X-direction and **7.61%** in the Y-direction when compared to the symmetric model. Although the values remained well within the code limits, this increase highlights the influence of irregular building geometry on lateral deformation.

In real-life applications, higher drift in asymmetric buildings could mean greater susceptibility to cracking in walls, misalignment of frames, and more stress on expansion joints. While not alarming at low-rise levels, this difference can become critical in high-rise or performance-based design scenarios.

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D. Storey Displacement

Storey displacement refers to the absolute lateral movement of a floor level relative to the base. Unlike drift, which is inter-Storey movement, displacement gives an overall sense of how much the structure sway during an earthquake. High displacements are typically associated with lower lateral stiffness and greater flexibility, particularly in taller or irregular buildings.

TABLE IV
Storey Displacement Values Under EQX And EQY for Symmetric and Unsymmetric Buildings

Storey displacement due to Seismic loads									
Storey	Elevation (m)	Displacement (mm)							
		Symmetrical				Asymmetrical			
		EQX				EQX			
		X-Dir	Y-Dir	X-Dir	Y-Dir	X-Dir	Y-Dir	X-Dir	Y-Dir
Storey 7	23	18.179	0	0	18.849	18.544	0.908	0.773	20.401
Storey 6	19.5	16.731	0	0	17.517	17.047	0.819	0.692	18.853
Storey 5	16	14.361	0	0	15.148	14.627	0.683	0.574	16.243
Storey 4	12.5	11.223	0	0	11.961	11.423	0.518	0.431	12.767
Storey 3	9	7.61	0	0	8.262	7.731	0.34	0.279	8.751
Storey 2	5.5	3.885	0	0	4.359	3.923	0.171	0.137	4.545
Storey 1	2	0.715	0	0	0.818	0.714	0.031	0.025	0.839
Base	0	0	0	0	0	0	0	0	0

For both models, lateral displacement increased gradually from the base to the top Storey, forming a near-linear pattern, which is typical in static analysis. The asymmetric structure recorded slightly higher displacement values in both directions.

Specifically, under EQX loading, the top-Storey displacement increased from 18.18 mm in the symmetric model to 18.85 mm in the asymmetric model, reflecting a 3.69%increase. In the Y-direction, the top displacement increased more significantly from 18.54 mm to 20.40 mm, marking a 10.02% rise.

These differences, though within safe limits, suggest that the asymmetric structure is marginally more flexible. In practical terms, this could impact façade performance, expansion of joint behavior, and even serviceability under repeated minor quakes. While these results are not extreme, they reaffirm the need for careful attention to geometry during the early design stage of a building.

E. Summary

- Asymmetry led to an increase of up to 8.13%.
- A rise of up to 128.1kN (8.13%) was observed in Storey shears for asymmetric building
- Though within the IS 1893 limits, the Storey drift values in asymmetric model were increased up to 7.6%.
- Up to 10% more sway was observed in the asymmetric model. Which indicated decreased stiffness and increased torsional effects.

IV. CONCLUSION

A comparative analysis of seismic performance of symmetric and asymmetric RC buildings using equivalent stative method as per IS 1893:2016 was concluded in this study. Modeling and analysis were done in ETABS software, maintaining consistent geometric, material, and loading parameters for both structures to solely concentrate the results for Plan configuration (Symmetry).

The results demonstrate that:

- The asymmetric building consistently exhibited higher base shear, Storey drift, and Storey displacement across both seismic directions (EQX and EQY).

- The increase in base shear ranged up to 8.13%, and top Storey displacement showed a maximum increase of 10.02%, indicating that irregularity amplifies lateral seismic response.
- Despite the increased response in the asymmetric model, all critical parameters remained within the permissible limits defined by IS 1893:2016, confirming the adequacy of the Equivalent Static Method for regular low-rise structures.

Thus, while plan asymmetry affects seismic performance, its impact remains moderate in Mid-rise buildings under static analysis. However, attention to configuration during planning remains essential, particularly for performance-critical structures in high seismic zones.

V. LIMITATIONS & FUTURE SCOPE

While the current study offers valuable insight into the influence of plan symmetry on seismic response, several limitations are acknowledged:

- The analysis was limited to G+5 RCC buildings. High-rise or irregular-height buildings may exhibit more pronounced dynamic behavior.
- The Equivalent Static Method, though code-compliant, does not account for torsional irregularities, mode shapes, or frequency-dependent response.
- No design checks or ductility detailing were performed, as the focus remained on comparative response analysis.
- Future studies may consider:
- Using Response Spectrum Analysis or Time History Analysis for more accurate representation of dynamic behavior and torsional effects.
- Evaluating different irregularity types (e.g., vertical, mass irregularity).
- Incorporating material nonlinearity and performing pushover or performance-based design.
- Such investigations will enhance the understanding of structural behavior under real earthquake scenarios and support more resilient design practices.

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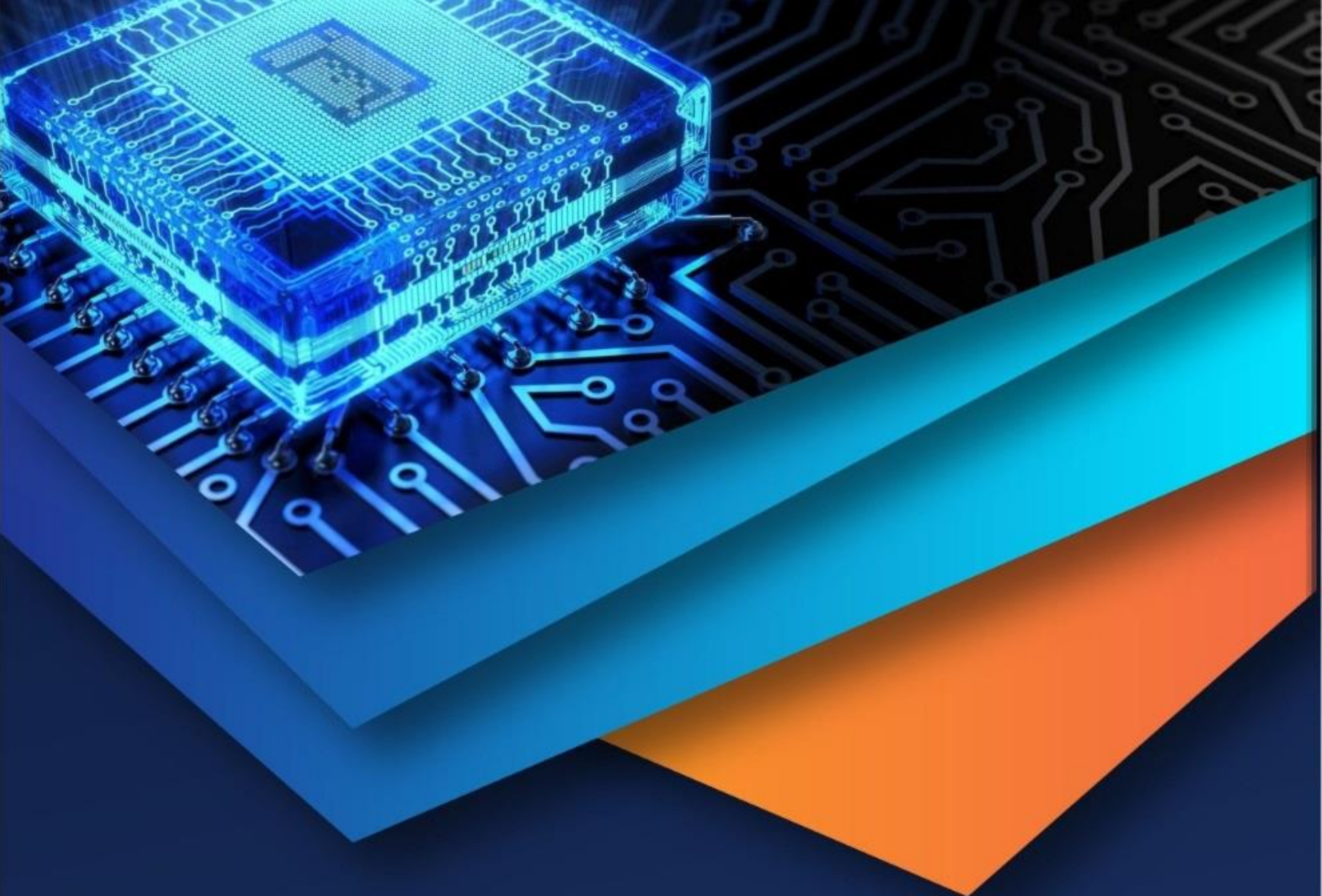

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