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SEISMIC ANALYSIS OF A G+10 BUILDING USING ETABS SOFTWARE

Avinash Joshi[1], Dacha Vaishnavi[2], Pendyala Sajan[2], Rayili Sruthi[2], Bachamgari Srija[2]

[1] Assistant Professor, Department of Civil Engineering, JNTUH University College of Engineering Sultanpur, Telangana, India
[2] B. Tech Student, Department of Civil Engineering, JNTUH University College of Engineering Sultanpur, Telangana, India

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ABSTRACT

The project report details a comprehensive investigation on the seismic analysis of a structure, utilizing the capabilities of ETABS for detailed analysis. The study aims to evaluate the seismic behavior of the structure and highlight the advantages of non-linear static analysis (Pushover Analysis) over linear static analysis. The building is initially analyzed using both linear and non-linear static methods, and the results are compared to demonstrate the superiority of non-linear analysis in capturing the structural response. The structure is then subjected to various irregularities, including soft stories at levels 3, 6, and 9, and mass irregularities (double live load) at the same levels. Non-linear analysis reveals that soft stories have a more significant impact on the structure's seismic behavior compared to mass irregularities. Key structural response parameters such as story displacement, story drifts, base shear, performance points (target displacements), performance levels, are examined in two lateral directions. Initially, the regular structure's performance levels indicate that the target displacement exceeds the limit value. However, enhancing the concrete grade reduces the target displacement to an acceptable level, deeming the structure safe. The target displacement value obtained from the push over analysis (in case of Retrofitted model) for the X-direction is 351.03 mm, and for the Y-direction, it is 363.02 mm. The target displacement values for both the x and y directions are still below the maximum displacement limit value of 0.02 x building height = 0.02 x 35.2 m = 0.704 m or 704 mm. The results showed that base shear value in the Y-direction (1972.52 KN) is greater than base shear value in X-direction (1945.94 KN). This indicates that the building's strong axis is in the X-direction and the weak axis is in the Y-direction. The revised configuration (modification in columns' size and orientation) ensures that the structure meets the desired performance objectives, with all hinges operating within acceptable limits (less than the collapse prevention state).

KEYWORDS: Linear Static Analysis, Push Over Analysis, Soft Stories, Mass Irregularity and Performance Levels

I. INTRODUCTION

Seismic analysis is crucial for ensuring building safety and integrity in earthquake-prone areas. It helps identify potential weaknesses, reducing collapse risk and saving lives. By designing structures that can withstand seismic forces, damage and economic losses can be minimized. Critical structures like hospitals and emergency services can remain operational post-earthquake. Compliance with seismic codes is often mandatory, and seismic analysis helps optimize design, balancing safety and cost. Overall, seismic analysis is essential for protecting lives and property in regions prone to earthquakes.

Urbanization in India has increased RC buildings with vertical irregularities like soft stories for stilt parking and mass irregularities from rooftop equipment, violating IS 1893:2016 stiffness and mass

Research Paper

limits. These irregularities cause drift concentration and story-mechanism failures as observed during Bhuj 2001 earthquake.

IS 1893:2016 adopts Linear Static and Response Spectrum Methods, which are force-based elastic procedures using Response Reduction Factor R. These methods assume uniform properties and cannot capture plastic hinge formation or collapse mechanisms in irregular frames, potentially yielding unconservative designs despite satisfying code drift limits.

Non-linear Static Pushover Analysis per FEMA 356 provides performance-based evaluation by generating capacity curves and assessing IO, LS, CP levels. ETABS implements this with ASCE 41-17 plastic hinges for Indian RC buildings.

Existing studies analyze soft story and mass irregularity separately. However, combined effects of soft story and mass irregularity at multiple levels on FEMA 356 performance points remain unquantified for IS 1893:2016 G+10 frames.

Comparative evaluation of Linear vs pushover methods and basic retrofitting via concrete grade and column modification for achieving IO performance is also limited. This study analyzes a Zone II G+10 frame through push over analysis considering irregularities.

OBJECTIVES

The objectives of this project are as follows-

1. To provide a comprehensive understanding how linear analysis results differ from non-linear analysis results.
2. To investigate the effect of vertical irregularities (soft stories and mass irregularities) at different story levels on different parameters such as displacement, base shear, drift.
3. To evaluate the performance point of the structure to understand Performance Discrepancies.
4. To analyse the effect of enhancing concrete grade on seismic performance and impact of increasing the column size on the structural capacity.

II. METHODOLOGY

The methodology of this project focuses on evaluating the seismic performance of reinforced concrete buildings with vertical irregularities using ETABS software. The entire process is carried out in a systematic manner to ensure accurate modeling, analysis, performance evaluation, and comparison of results.

Objectives → ETABS Model Generation → Analysis of Buildings for Different Cases → Performance Evaluation and Retrofitting → Presentation and comparison of results in the form of graphs and tables → Results and Conclusion.

GEOMETRY-

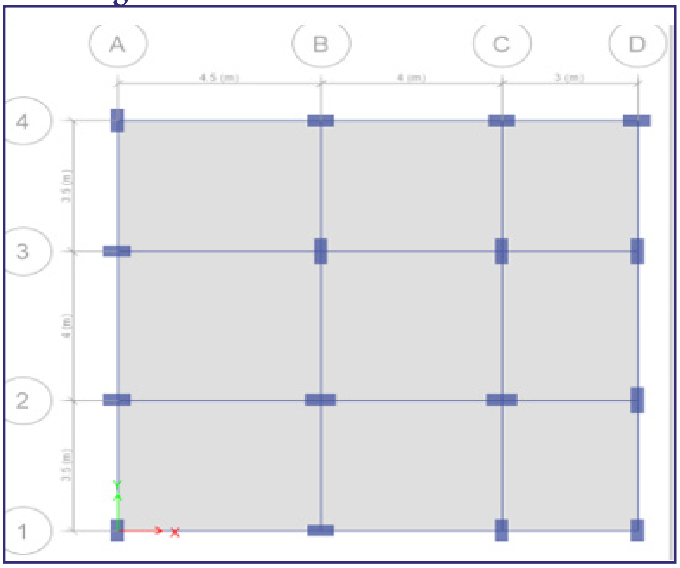
The following table shows the geometrical, material and seismic parameters used-

Table 1: Geometry, materials and Seismic Parameters

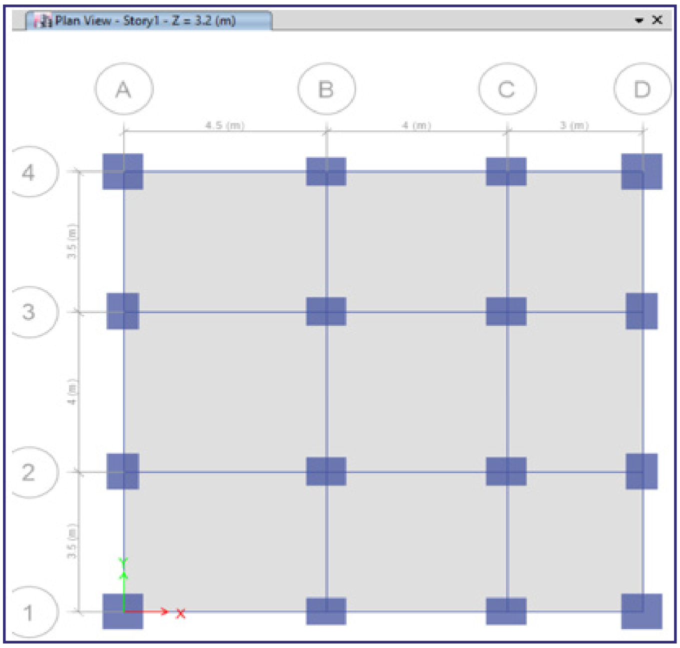
PARAMETER	VALUE
Building Details	
No. of Stories	G+10
Plan dimension	11.5 m x 11 m
Total Height	35.2 m
Story Height	3.2 m
Structural Members	
Beam Size	300 mm x 600 mm
Initial Column Size	300 mm x 600 mm 300 mm x 680 mm
Final Column Size	700 mm x 900 mm 900 mm x 900 mm
Slab Thickness	220 mm
Material Properties	
Grade of Concrete (Initial)	M30
Grade of Concrete (Final)	M40-Beams & Slabs M45-Columns
Grade of Rebar	HYSD 500
Density of Concrete	25 KN/m3
Density of Infill	18 KN/m3
Gravity Loads	
Floor Finish	1 KN/m2
Live Load	2 KN/m2
Seismic Parameters	
Seismic Zone	III
Zone Factor, Z	0.16
Soil Type	Soft

Importance Factor, I	1
Response reduction factor, R	5
Irregularity Details	
Soft Story Location	Levels 1,3,6,9
Soft Story Method	Removing Wall loads @ 1,3,6 and 9 levels.
Mass Irregularity Location	Levels 3,6,9
Mass Irregularity Method	Double live loads- 3,6 and 9 levels

Fig. 1: Plan Views of G+10 RC Frames



(a) Regular Building Configuration With initial Column Sizes



(b) Ground Floor plan after retrofitting showing final column sizes and orientation

III. RESULTS

CASE 1. Displacement and Drift Comparison for different cases-

Table 2. Maximum Story Displacements

Case	Max Story Displacement (mm)	
	X-direction	Y-direction
Linear Static	117.4	134.44
Non Linear Static	205.08	215.99
Soft Story Structure	216.732	224.788
Mass irregular Structure	209.894	217.853

Table 3: Maximum Story Drifts

Case	Max Story Drift	
	X-direction	Y-direction
Linear Static	0.004527	0.005054
Non Linear Static	0.011656	0.011839
Soft Story Structure	0.012269	0.012267
Mass irregular Structure	0.011942	0.011948

Table 4: Story Displacement comparison

Comparison	% Increment	
	X-direction	Y-direction
Linear vs. Non-linear	74.7%	60.7%
Regular vs. Soft Storey Structure	5.7%	4.1 %
Regular vs. Mass irregular Structure	2.3%	0.9%
Mass irregular Structure	0.011942	0.011948

Table 5: Story Drift comparison

Comparison	% Increment	
	X-direction	Y-direction
Linear vs. Non-linear	157.477%	149.679%
Regular vs. Soft Storey Structure	5.26%	3.615%
Regular vs. Mass irregular Structure	2.454 %	0.92 %
Mass irregular Structure	0.011942	0.011948

CASE 2. Performance based evaluation of Regular model and Retrofitted model

Table 6: Performance Levels Comparison for regular vs. Retrofitted modified model

Parameter	Regular model		Retrofitted model	
	Push X	Push Y	Push x	Push Y
No. of Steps	32	41	8	8
Total Hinges	1760	1760	1760	1760
No. of Hinges in different stages				
A-IO	1702	1710	1618	1622
IO-LS	48	48	142	138
LS-CP	0	0	0	0
>CP	10	2	0	0

Table 7: Performance Point Results in case of Retrofitted model

Parameter	Values	
	Push X	Push Y
Base Shear	1945.9376 kN	1972.5188 kN
Displacement	351.03 mm	363.023 mm

IV. DISCUSSIONS

1. In Case of comparison of Linear vs. Non- Linear Results,

a. The Maximum Story Displacement is increased by 74.686% in the X-direction and by 60.654% in the Y-direction.

b. The Maximum Storey Drift is increased by 157.477 % in the X-direction and by 149.679 % in the Y-direction.

2. In Case of comparison of Regular Model vs. Model with Soft Stories,

a. The maximum story displacement is increased by 5.68 % in the X-direction and 4.076 % in the Y-direction.

b. The maximum story drift is increased by 5.26 % in the X-direction and 3.615 % in the Y-direction.

3. In Case of comparison of Regular Model vs. Mass Irregular Model,

a. The maximum story displacement is increased by 2.346 % in the X-direction and 0.864 % in the Y-direction.

b. The maximum story drift is increased by 2.454 % in the X-direction and 0.92% in the Y-direction.

4. Retrofitting by increasing column size and changing orientation resulted in all hinges within the life safety level.

V. CONCLUSION

1. The maximum storey displacement is significantly 1.74 times in X-direction and 1.601 times in Y-direction higher in non-linear analysis compared to linear analysis, indicating potential non-linear behaviour under load.
2. The effect of introducing soft storeys noticeably increases maximum storey displacements by 5.8% (X-direction) and 3.92% (Y-direction) on average. This indicates soft storeys have a significant impact on structural deformation, emphasizing the need to manage stiffness distribution for better seismic performance.
3. The effect of mass irregularity on the structure is minimal. The displacements increase by 2.734 % (X-direction) and 1.085 % (Y-direction) on average. This indicates a noticeable magnification of lateral deformation due to the uneven mass distribution takes place. The effect of mass irregularities on the structure is less when compared to structure with soft stories.
4. The target displacement value obtained from the push over analysis (in case of Retrofitted model) for the X-direction is 351.03 mm, and for the Y-direction, it is 363.02 mm. The target displacement values for both the x and y directions are still below the maximum displacement limit value of 0.02 x building height = 0.02 x 35.2 m = 0.704 m or 704 mm.
5. The results showed that base shear value in the Y-direction (1972.52 KN) is greater than base shear value in X-direction (1945.94 KN). This indicates that the building's strong axis is in the X-direction and the weak axis is in the Y-direction.
6. The revised configuration (modification in columns' size and orientation) ensures that the structure meets the desired performance objectives, with all hinges operating within acceptable limits (less than the collapse prevention state).

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- IS 875 (PART 1) -2015 : Dead Loads- Unit weights of Building materials and stored materials.
- IS 875(PART 2) -2015 : Imposed loads