Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 06, June - 2025

Study of High-Rise RC Building with a Vertical Irregularity using Response Spectrum Method

Mrs. Deepika R, Mr. Manjunath V,
Assistant Professor,

Bablu Kumar Das, Pradip Kumar Chaudhary, Roshan Kumar Das, Dipen Pradhan
Student, Department of Civil Engineering,
Sri Krishna Institute of Technology
Bangalore, India

Abstract— **High-rise reinforced concrete (RC) buildings with vertical irregularities exhibit complex dynamic behavior under seismic and wind loads. Vertical irregularities, such as setbacks, soft stories, and mass discontinuities, significantly influence structural response, altering stiffness, strength distribution, and overall stability. This study investigates the impact of vertical irregularities on the dynamic characteristics of high-rise RC buildings using numerical modeling and dynamic analysis. Modal analysis, response spectrum analysis, and time-history analysis are employed to evaluate natural frequencies, mode shapes, inter-story drift, and base shear. Results indicate that vertical irregularities lead to amplified dynamic responses, increasing vulnerability to seismic forces. Strategies for mitigating adverse effects, such as structural retrofitting and optimized design approaches, are also discussed. The findings contribute to improved design guidelines for resilient high-rise structures in seismically active regions.**

Keywords—**Response spectrum method; vertical irregularity; RC Structure.**

I. INTRODUCTION

An Earthquake is a natural and unexpected disaster characterized by the shaking of the earth's surface, often resulting in significant loss of life and property. Despite extensive studies and research on earthquakes, it remains difficult to completely prevent structural damage or failure during such shaking. Earthquakes can cause damage due to factors such as irregular building design, the presence of soft stories, insufficient lateral strength, and the interaction between the structure and the ground.

Various types of vertical irregularities are commonly found in modern buildings. During an earthquake, these irregularities can cause a building to collapse due to discontinuities in geometry, mass, and stiffness. These discontinuities are known as irregular systems. Vertical irregularities are a major cause of structural failures during earthquakes. Earthquakes are among the most dangerous natural disasters, causing both economic and human losses. Most of these losses result from building collapses or damages. In addition to vibrations, earthquakes can also lead to secondary hazards such as landslides, floods, and fires. Therefore, it is crucial to design structures that can resist earthquake forces effectively.

For an irregular structure to perform well during an earthquake, a building must possess four essential attributes: a simple and regular configuration, and adequate lateral strength, stiffness, and ductility. Buildings with simple, regular geometry and uniformly distributed mass and stiffness—both in plan and elevation—experience significantly less damage compared to those with irregular configurations. According to IS Code 1893 (Part 1):2002, a building is classified as irregular if it meets one or more of the criteria specified in Tables 4 and 5 of the standards.

The coverage area of a building is influenced by its plan irregularities. Common types of irregular building plans include L-shape, U-shape, Plus-shape, and O-shape configurations. A building is considered irregular when two adjacent sides are not orthogonal to each other. The main types of plan irregularities and vertical irregularities are:

1. Torsional Irregularity
2. Re-entrant Corners
3. Diaphragm Discontinuity
4. Out-of-Plane Offsets
5. Non-Parallel Structural Systems

Vertical irregularities, there are

1. Stiffness (Soft storey and extreme soft storey)
2. Mass,
3. Vertical Geometric,
4. In-Plan Discontinuity in Vertical Elements Resisting Lateral Force,
5. Discontinuity In Capacity- Weak Storey.

II. SOFT STOREY

A soft storey is one of the major causes of structural failure during seismic activity. It is categorized as a stiffness irregularity under vertical irregularities. In modern construction, it is common to design high-rise buildings with an open ground floor used for parking or other utilities. These buildings are typically designed as framed structures, where the upper floors are infilled with masonry walls. These walls increase the stiffness of the upper floors against lateral loads, while the open ground floor remains relatively flexible, resulting in what is termed a soft storey.

According to IS 1893:2002 (Part 1), a soft storey is defined as a storey whose lateral stiffness is less than 70% of the stiffness of the storey above, or less than 80% of the average lateral stiffness of the three storeys above.

To ensure structural safety, the code provides the following recommendations for buildings with soft storeys (refer to Page 27 of IS 1893:2002):

- Special provisions should be made to enhance the lateral strength and stiffness of the soft storey.
- Structural members should be designed based on the results of a dynamic analysis.
- After completing the analysis, the beams and columns in the soft storey should be designed to resist at least 2.5 times the calculated moments and shear forces.
- Additionally, shear walls should be provided symmetrically on both sides of the building, and these walls should be designed to resist 1.5 times the lateral storey shear force.

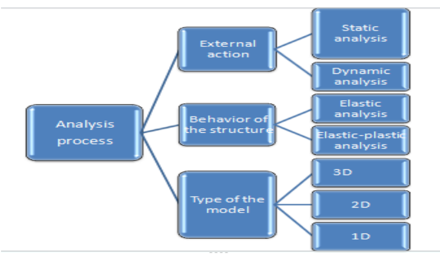
III. OBJECTIVE OF WORK

This project work deals with an analytical study of a Stiffness irregularity i.e., soft storey behavior of a simple high-rise building under the dynamic loads. Tall building is considered having stiffness irregularity, i.e. making different floors as a soft storey and masonry wall is used for stiffening the other floors.

Building will be modeled and designed using ETAB V2022 software and dynamic analysis are carried out. The main parameters are focused on time period, storey drifts, storey displacement, storey stiffness.

A. Methodology

Seismic analysis can be performed on the basis of an external action, behavior of the structure, materials, and type of the structural model selected.



B. Problem Description

Structural details

- 50m X 30m with (G+15) Floors
- 1st, 5th and10th Floors are made soft storey.
- Soft storey was created by varying height of the storey and neglecting infill wall effects
- Total Height- 46.5m (Height of bottom Soft Storey-4.5 and typical story height -3m)

TABLE I. DETAILS OF MODEL

Sl No	*Description*	*Details*
1	Storey Height	Base 4.5m & Typical 3m
2	Materials	Fe 415, M20 & Masonry
3	Codes	IS 456:2000, IS 875-1987 (Part II) - Live Loads/ Design Loads, IS 1893 (Part 1) 2002- For Earthquake Designing
4	Load Details Live Load Super Dead Load	 Typical Floor 2kN/m^2 Terrace Floor 1.5 kN/m^2 Typical Floor 1kN/m^2 Terrace Floor 0.7 kN/m^2

Earthquake Load (X And Y Direction)

Earthquake loads are calculated as per seismic co-efficient method as suggested in IS 1893-(Part 1) – 2002. According to the IS Code 1893, the Indian Sub-Continent has been divided into four seismic zone. Zone II is zone of “Low Seismic Risk”, Zone III is of “Moderate seismic Risk”, Zone IV is of “Severe Seismic Risk”, & Zone V is of “Very Severe Seismic Risk”.

TABLE II. EARTHQUAKE LOAD DETAILS

Sl No	*Description*	*Values*
1	Zone factor (Zone II)	0.1
2	Zone factor (Zone III)	0.16
3	Importance factor	1
4	Response reduction	5
5	Soil type	III

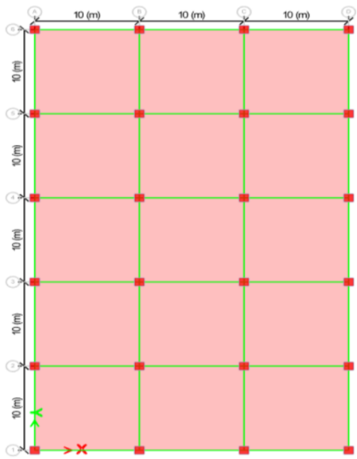


Figure 1: Plan view

Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 06, June - 2025

C. Model Details and Analysis

For analysis purpose, soft storey conditions considered at different storey level included with Infill walls as given below

Model 1: Soft storey at 1st/ Ground Floor and other floors having infill walls.

Model 2: 5th floor having soft storey effect with others as infill walls.

Model 3: Building with soft storey effect at 10th floor and remaining floor are infill walls.

All these models are analyzed under earthquake loading (Zone II & Zone III) following IS 1893:2002 code.

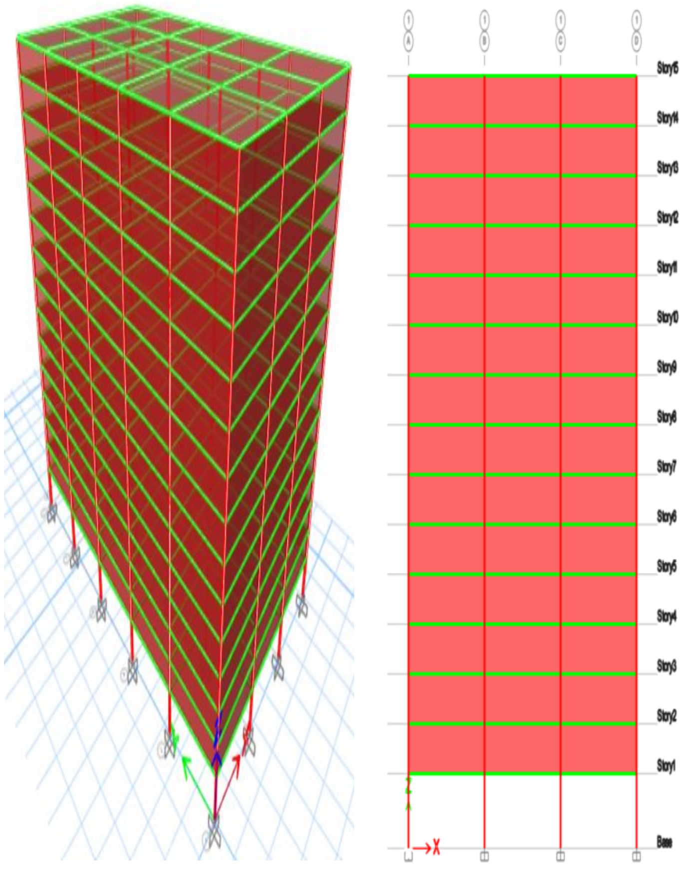


Figure 2: 3D and Elevation view of Model, ground floor open and rest all filled with infill walls

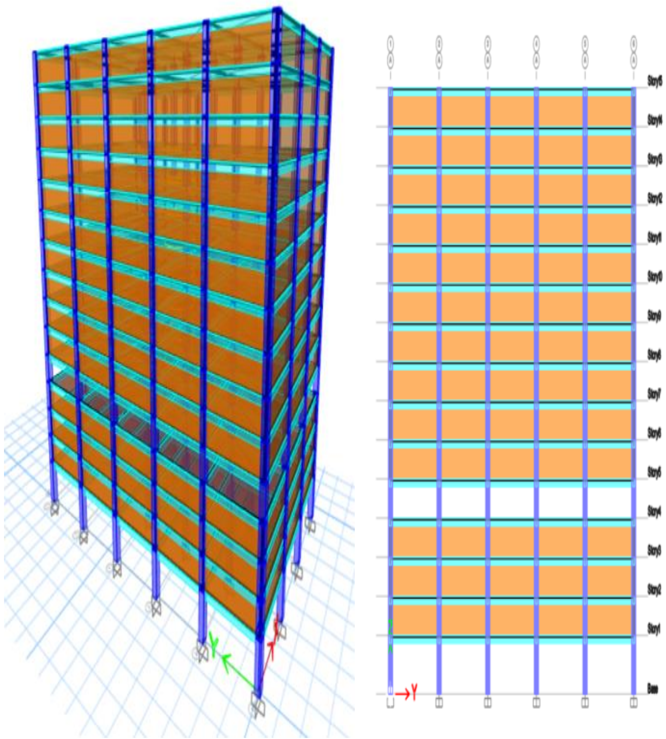


Figure 3: 3D and Elevation view of Model, 5th floor open and rest all filled with infill walls

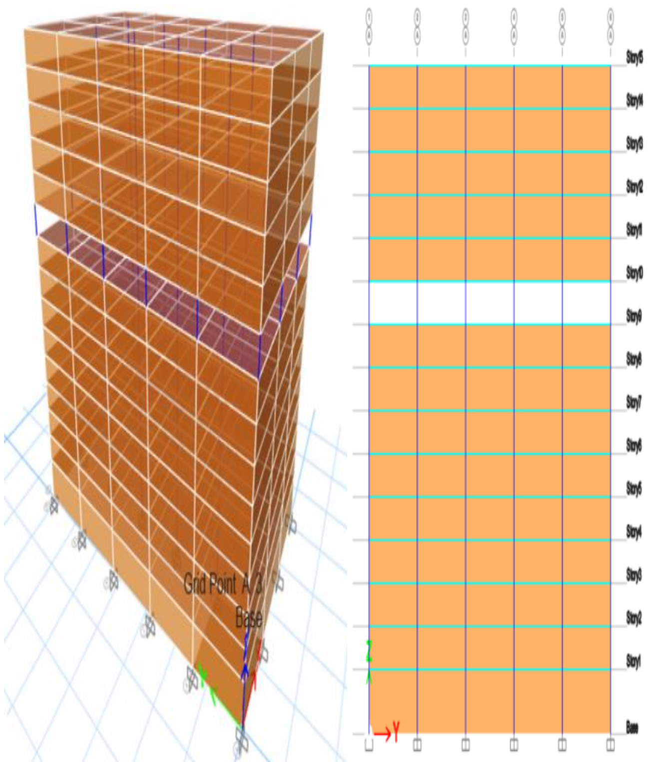


Figure 4: 3D and Elevation view of Model, 10th floor open and rest all filled with infill walls

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 06, June - 2025

Story	Response Sepctrum in Y direction					
	Displacement					
	Zone II			Zone II		
	1st floor open	5th floor open	10th floor open	1st floor open	5th floor open	10th floor open
15	1.917	23.134	0.664	77.671	37.015	26.576
14	1.897	22.911	0.651	76.873	36.658	26.053
13	1.875	22.661	0.635	75.963	36.257	25.404
12	1.849	22.382	0.615	74.939	35.811	24.6
11	1.821	22.076	0.594	73.803	35.321	23.756
10	1.791	21.742	0.561	72.557	34.788	22.436
9	1.757	21.382	0.28	71.205	34.211	11.209
8	1.721	20.999	0.246	69.753	33.598	9.85
7	1.683	20.581	0.22	68.204	32.93	8.786
6	1.643	20.176	0.19	66.568	32.281	7.605
5	1.6	19.609	0.161	64.847	31.375	6.422
4	1.565	15.704	0.135	63.416	25.127	5.407
3	1.537	14.194	0.106	62.291	22.71	4.248
2	1.506	13.902	0.074	61.036	22.243	2.986
1	1.407	13.07	0.042	57.032	20.912	1.664

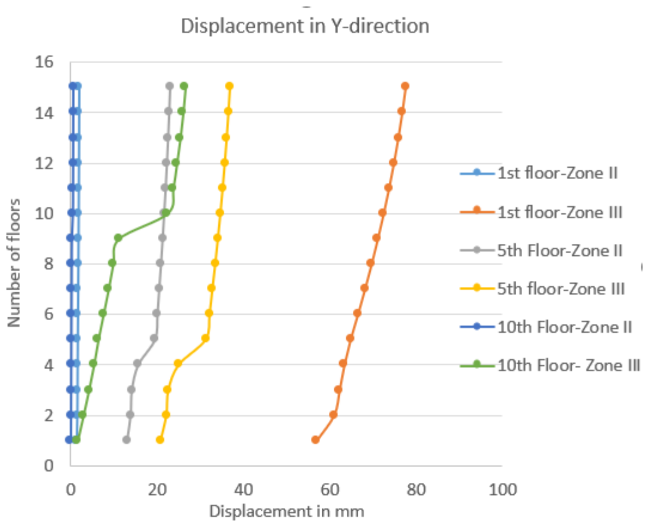


Figure 5: Maximum Displacement in Y-direction in zone II & zone III

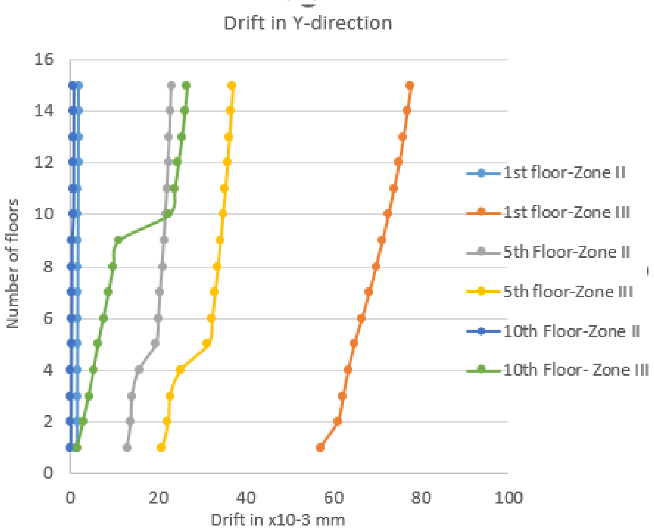


Figure 6: Maximum Drift in Y-direction in zone II & III

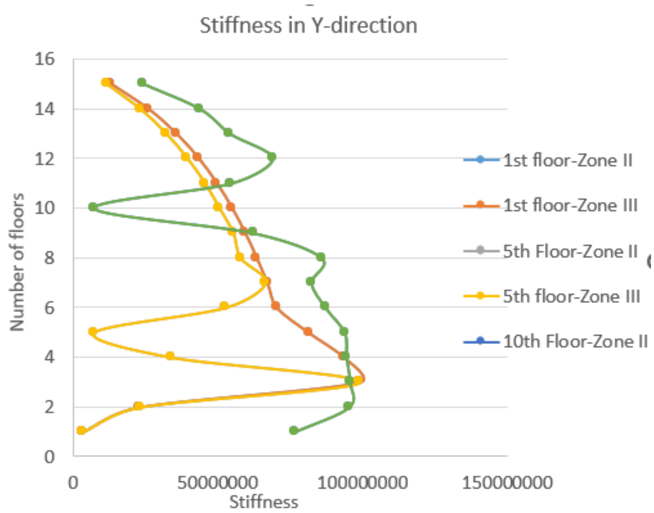


Figure 7: Maximum Stiffness in Y-direction in zone II & III

IV.CONCLUSION

- The bare frame exhibits significant displacement, increasing the risk of deflection during an earthquake. Therefore, incorporating lateral load-resisting elements is crucial to reduce the risk of structural failure.
- The model with an open 5th floor in seismic Zone II shows greater displacement compared to other models with different soft storey levels, indicating a higher likelihood of failure during seismic activity.
- The model with an open ground floor in seismic Zone III also exhibits higher displacement relative to other configurations, suggesting increased vulnerability during an earthquake.
- The presence of a soft storey causes a sudden increase in drift at that level. Storeys with infill walls offer higher stiffness, whereas bare frames lack the necessary rigidity.
- Infill walls with openings perform poorly compared to solid infill walls. However, a limited percentage of openings (e.g., 25%) can be included without significantly compromising the structure's earthquake resistance.
- The conventional design approach—which assumes that frames carry loads and infill walls serve only as dividers—may be inadequate in high seismic zones, especially in structures with soft storey effects such as an open ground floor.
- Soft storeys must be carefully evaluated, and adequate stiffness should be ensured through the use of shear walls or bracing systems.
- The placement and arrangement of infill walls play a vital role in reducing the soft storey effect and improving overall structural performance.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 06, June - 2025

REFERENCES

[1] Krishna Prasad Chaudhary, "Response spectrum analysis of irregular shaped high rise buildings under combined effect of plan and vertical irregularity using csi etabs" IOP Conference Series Earth and Environmental Science 889(1):012055

[2] Ugalde D, Lopez-Garcia D and Parra P F 2020 Fragility-based analysis of the influence of effective stiffness of reinforced concrete members in shear wall buildings Bull. Earthq. Eng. 18 2061–82

[3] Sunagar P, Dharek M S, Nruthya K, Sreekeshava K S, Nagashree B and Ramegowda R S 2020 Non-Linear Seismic Analysis of Steel Plate Shear Wall Subjected to Blast Loading IOP Conference Series: Materials Science and Engineering vol 955, ed K N P V Vasudevan M. Soundara B. (IOP Publishing Ltd)

[4] Apurva Arjun Gaikwad, D. A. B. P. (2019). Seismic Analysis of Low Rise, Mid Rise, and High Rise Rcc Structure on Sloping Ground. International Research Journal of Engineering and Technology.

[5] Magdy Nagy Hanna, Hesham Tahoon, Sayed Mahmoud, "Seismic Response Evaluation of Moment-Resisting-Frame Multi-Story Buildings with Soft Story" International Journal of Civil and Structural Engineering Research, Vol. 3, Issue 1, pp: (118-127)

[6] Mukesh Soni, Danish Khan " Shear Walls for Strengthening of Multistory Buildings with Soft Story" IJSRD - International Journal for Scientific Research & Development, Vol. 3, Issue 07, 2015 | ISSN (online): 2321-0613

[7] Anirudh Raajan, V., Balaji, G. C., & Vasavi, V. (2021). Response spectrum analysis of a G+4 building with mass irregularity on a sloped surface. IOP Conference Series: Materials Science and Engineering, 1070(1).

[8] IS:1893 (part1)-2016 Criteria for earthquake resist design of structure.

[9] IS:13920-2002Code practice for ductile detailing of structure.

[10] IS:456-2000 Code practice for plane and reinforced concrete.

[11] IS 875 Part-2Code of practice for design loads (other than earthquake) for buildings and structures.