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Structural Analysis Of G+15 Building with Vertical Irregularities Using ETABS

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Abstract

Rapid urbanization and scarcity of land have led to the construction of high-rise buildings with complex architectural configurations. These configurations often [i]mass, stiffness, and geometry, which significantly influence the seismic performance of structures. This research presents a detailed seismic analysis of a G+15 reinforced concrete (RCC) building with vertical irregularities using ETABS software. Regular and vertically irregular building models are developed and analyzed using the Response Specturm Method and Time History Method in accordance with IS 1893 (Part 1):2016 and IS 456:2000. Key response parameters such as base shear, storey drift, lateral displacement, shear force, and bending moment are evaluated. The results demonstrate that vertical irregularities lead to increased seismic demand and deformation, particularly near irregular zones. The study emphasizes the importance of careful structural configuration and advanced analysis to ensure seismic safety of high-rise buildings.

Keywords: Vertical Irregularity; ETABS; G+15 Building; Seismic Analysis; Storey Drift; Base Shear

How to Cite This Article

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Introduction

Earthquakes are among the most destructive natural disasters, posing a serious threat to life and property, especially in seismically active regions. The performance of buildings during earthquakes depends largely on their structural configuration, material properties, and load-resisting systems. In recent years, rapid urban development has resulted in high-rise buildings with irregular architectural forms to meet functional and aesthetic requirements. Such buildings often possess vertical irregularities caused by sudden changes in mass, stiffness, or geometry along the height.

Vertical irregularities disrupt the uniform flow of seismic forces, leading to concentration of stresses and excessive deformation at certain levels. Past earthquake events have shown that buildings with irregular configurations are more vulnerable to damage compared to regular buildings. Therefore, understanding the seismic behavior of vertically irregular buildings is essential for safe and economical design. With the advancement of computer-based structural analysis tools, software such as ETABS has become widely used for modeling and analyzing complex multi-storey structures. This study focuses on evaluating the seismic response of a G+15 RCC building with vertical irregularities using ETABS.

Literature Review

Several researchers have studied the seismic behavior of vertically irregular buildings. Studies indicate that mass and stiffness irregularities significantly increase storey drift and displacement during seismic events. Researchers have also highlighted that setback irregularities cause sudden changes in lateral stiffness, resulting in higher bending moments and shear forces at irregular storeys. Comparative studies between regular and irregular buildings show that regular configurations perform better under seismic loading. The use of ETABS for seismic analysis has been proven effective due to its accuracy, user-friendly interface, and compliance with Indian Standard codes. The present study builds upon previous research by analyzing a G+15 RCC building with vertical irregularities and presenting detailed results based on code-compliant analysis.

Objective Of Study

The main objectives of this research are: - To model a G+15 RCC building with vertical irregularities using ETABS software - To perform seismic analysis using the Equivalent Static Method as per IS 1893:2016 - To evaluate seismic response parameters such as base shear, storey drift, displacement, shear force, and bending moment - To study the effect of vertical irregularity on the seismic performance of the building - To provide conclusions and recommendations for safer structural design

Methodology

The methodology adopted for the present study follows a systematic approach, starting from literature review to interpretation of results. The overall procedure is represented using a flow chart.

Flow chart of Methodology Literature Review

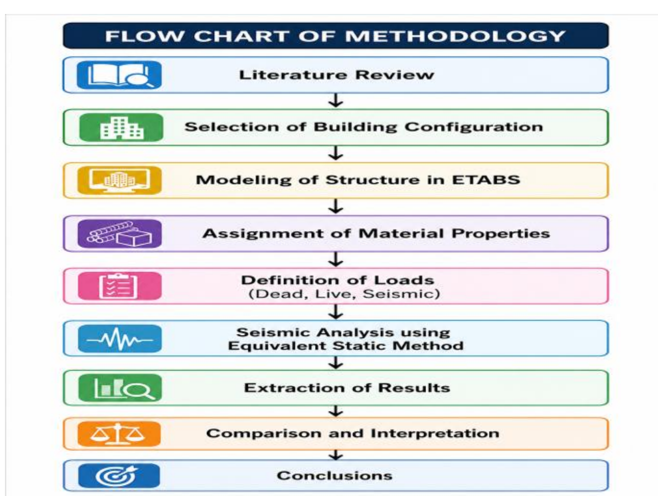


Fig. 1. *Flowchart of Research Methodology for Structural Analysis Using ETABS*

Building Description and Modeling

The building considered in this study is a G+15 reinforced concrete frame structure. The structure consists of beams, columns, and slabs designed as per Indian Standard codes. Vertical irregularity in the form of setback is introduced at higher storeys, resulting in a reduction of floor area along the height. The building is modeled in ETABS Ultimate

21.0 with appropriate material properties, section dimensions, and boundary conditions.

Material properties such as grade of concrete and steel are assigned as per IS 456:2000. The base of the structure is assumed to be fixed. Dead load and live load are applied as per IS 875, while seismic loads are calculated according to IS 1893 (Part 1):2016. The Equivalent Static Method is used to evaluate seismic forces acting on the building.

Structural Analysis

The seismic analysis is carried out using ETABS, and various response parameters are obtained for evaluation. The analysis focuses on understanding the distribution of internal forces and deformation patterns along the height of the building.

Shear Force Distribution

The shear force distribution obtained from ETABS indicates that maximum shear forces occur at the lower storeys due to the accumulation of seismic forces. Vertical irregularity causes variation in shear force distribution, especially near setback levels.

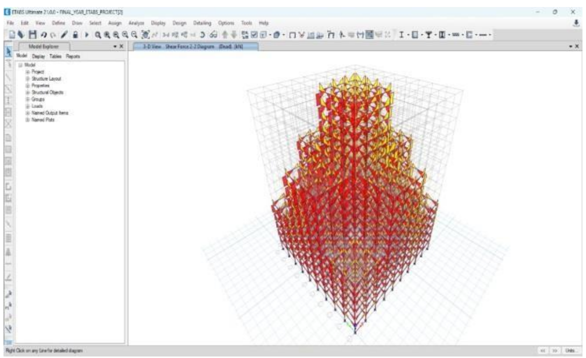


Fig. 2. *3D shear force diagram from ETABS*

3D shear force diagram from ETABS framed structure consisting of beams, columns, and slabs. Vertical setback irregularity is introduced at upper storeys reducing floor area. Material properties are assigned as per IS 456:2000. Loads are

Bending moment distribution

The bending moment diagram shows higher moment values at irregular storeys where stiffness changes abruptly. This increase in bending moment highlights the need for proper reinforcement detailing at such locations.

3D Bending Moment Diagram from ETABS assigned as per IS 456:2000. Loads are applied according to IS 875 and seismic parameters per IS 1893:2016.

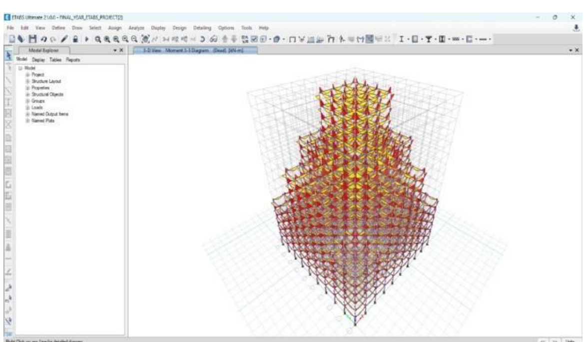


Fig. 3. *3D Bending Moment Diagram from ETABS*

The building considered is a G+15 RCC framed structure consisting of beams, columns, and slabs. Vertical setback irregularity is introduced at upper storeys reducing floor area. Material properties are assigned as per IS 456:2000. Loads are applied according to IS 875 and seismic parameters per IS 1893:2016.

Lateral Displacement

Lateral displacement increases with height, reaching maximum at the top storey. The presence of vertical irregularity results in increased displacement compared to a regular building configuration.

3D Displacement Diagram from ETABS obtain internal force distribution and deformation response. Key parameters studied include shear force, bending moment, storey displacement, and drift variation along building height.

Seismic analysis is conducted in ETABS to obtain internal force distribution and deformation response. Key parameters studied include shear force, bending moment, storey displacement, and drift variation along building height.

Seismic analysis is conducted in ETABS to obtain internal force distribution and deformation response. Key parameters studied include shear force, bending

Result And Discission

The results obtained from the analysis clearly show that vertical irregularities significantly influence the seismic response of the building. Increased storey drift and displacement are observed near irregular zones, making these regions more susceptible to damage during earthquakes. The bending moment and shear force values are also higher at setback levels, indicating stress concentration. These findings emphasize the importance of avoiding abrupt changes in stiffness and mass distribution in high-rise buildings.

MODEL 1

For Response Spectrum Analysis in Zone III

Table 1. Base reaction

Case	**FX**	**FY**
RSX	80501.5455	0.0013
RSY	0.0017	80501.5456

Table 2. Storey Drift

Storey	**X Direction**	**Y Direction**
15	0.00329	0.00329
14	0.005123	0.005123
13	0.006853	0.006853
12	0.008086	0.008086
11	0.007431	0.007431
10	0.004022	0.004022
9	0.004847	0.004847
8	0.005886	0.005886
7	0.006818	0.006818
6	0.006817	0.006817
5	0.005614	0.005614
4	0.005916	0.005916
3	0.006386	0.006386
2	0.006757	0.006757

1	0.006957	0.006957
P	0.004625	0.004625

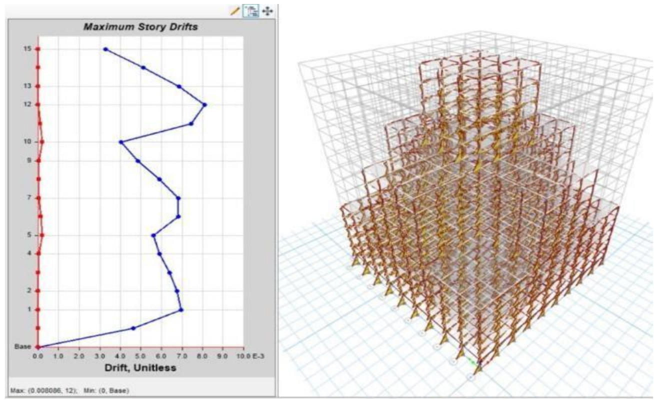


Fig. 4. *Storey Drift*

From Table 2, the Maximum and Minimum story drifts in X-direction are found as 0.006957;10 at storey 1 and 0.00329 at storey 15. Maximum and Minimum story drifts in Y-direction are found as 0.006957-91 from Ground to storey and 0.00329-64 at storey 15.

Table 3. Story Shear

Storey	X Direction (VX)	Y Direction (VY)
15	3087.1131	3087.1132
14	6421.0565	6421.0568
13	9370.9409	9370.8407
12	11876.4724	11876.4719
11	13942.1454	13942.1456
10	21528.5397	21528.5418
9	29824.3780	29824.3779
8	37475.3828	37475.3806
7	44271.3388	44271.3386
6	50133.7385	50133.7406
5	58271.7107	58271.7100
4	65686.9628	65686.9609
3	71854.9232	71854.9230
2	76642.7020	76642.7037
1	79836.0513	79836.0508
Ground	80501.5455	80501.5446

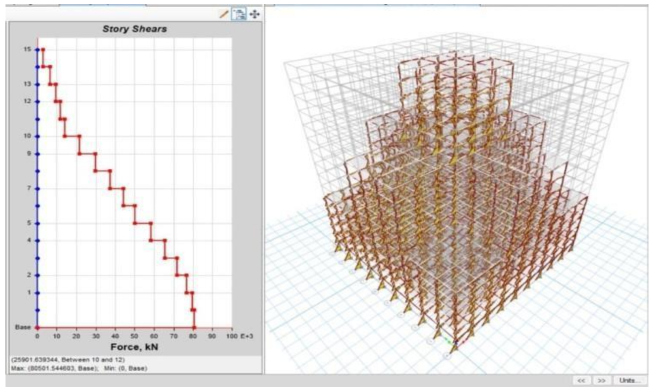


Fig. 5. *Storey Shear*

From Table 3, the Maximum and Minimum values of story shears in X direction are found as 0.0018(KN) at Ground and 0.0006(0KN) at storey 15. Maximum and Minimum story shears in Y direction are found as -6421.0568(KN) at storey 15 and -0.0012(KN) at Ground. Base shear is maximum at base.

MODEL II

For Response Spectrum Analysis in Zone II

Table 4. Base reaction

Case	**FX**	**FY**
RSX	80501.5456	0.0012
RSY	0.0018	80501.5446

Table 5. Storey drift

Storey	**X Direction**	**Y Direction**
15	0.00329	0.00329
14	0.005123	0.005123
13	0.006853	0.006853
12	0.008086	0.008086
11	0.007431	0.007431
10	0.004022	0.004022
9	0.004847	0.004847
8	0.005856	0.005856
7	0.006518	0.006818
6	0.006817	0.006817
5	0.005614	0.005614
4	0.005916	0.005916
3	0.006386	0.006386
2	0.006757	0.006757
1	0.006957	0.006957
P	0.004625	0.004625

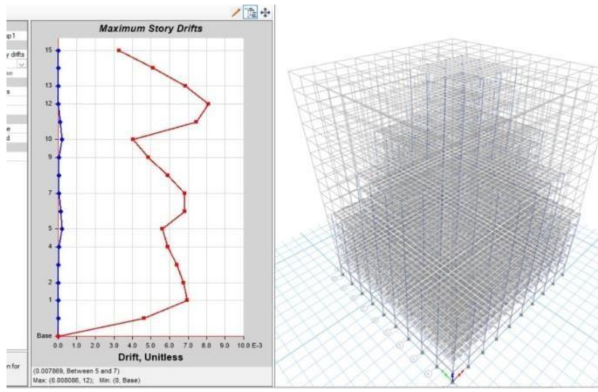


Fig. 6. *Storey drift*

From Table 5, the Maximum and Minimum values of Story drift in X direction are found as 0.008086 at storey 12 and 0.00329 at storey 15. Maximum and Minimum values of Story displacement in Y direction are found as 0.008086 from storey1 to storey 9 and 0.00329 at storey 15.

Table 6. Story Shear

Storey	X Direction (VX)	Y Direction (VY)
15	3087.1131	3087.1132
14	6421.0565	6421.0568
13	9370.8409	9370.8407
12	11876.4724	11876.4719
11	13942.1454	13942.1456
10	21528.5397	21528.5418
9	29824.3780	29824.3779
8	37475.3828	37475.3806
7	44271.3388	44271.3386
6	50133.7385	50133.7406
5	58271.7107	58271.7100
4	65686.9628	65686.9609
3	71854.9232	71854.9238
2	76642.7020	76642.7037
1	79836.0513	79836.0508
Ground	805001.5455	80501.5446

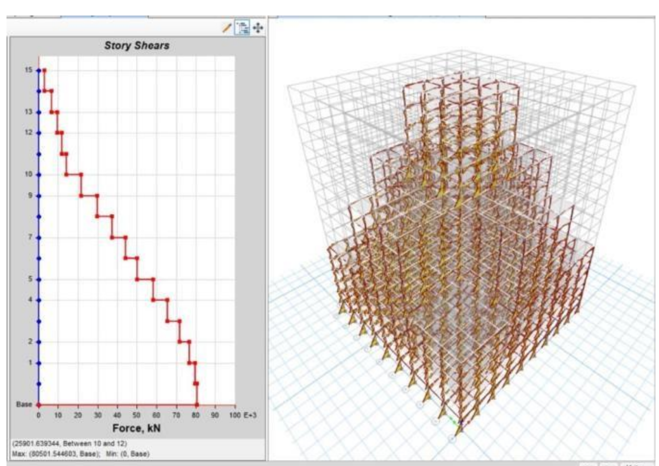


Fig. 6. *Storey Shear*

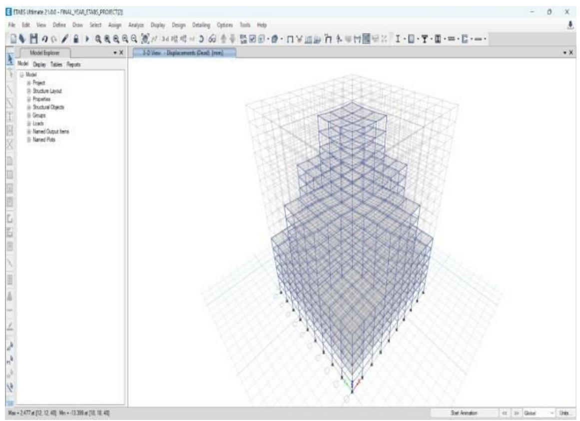
From Table 6, the Maximum and Minimum values of Story shear in X direction are found as 80501.5455 at storey Ground and 3087.1131 at 15 Storey. Maximum and Minimum values of Story shear in Y direction are found as 3087.1132 at storey 15 and 0.0013 at Ground.

Detail Etabs Modeling Procedure (Step-By-Step)

The structural model of the G+15 RCC building was created using ETABS Ultimate software by following a systematic modeling procedure. This section explains the complete ETABS (commonly referred to as STABS in practice) process adopted in this study.

Grid and Storey Definition

Initially, the grid system was defined based on the architectural plan. Storey data including storey height and number of floors (G+15) were defined to represent the vertical configuration of the building accurately.



Material Properties

Material properties for concrete and reinforcement steel were defined as per IS 456:2000. The grade of concrete and steel were selected to meet strength and durability requirements.

Section Properties

Beam, column, and slab sections were defined with appropriate dimensions. Columns were assigned larger dimensions at lower storeys to resist higher loads, while reduced sizes were provided at upper storeys.

Modeling of Vertical Irregularity

Vertical irregularity in the form of setback was introduced by reducing floor area at higher storeys. This change resulted in sudden variation of stiffness and mass along the building height.

Load Definition and Assignment

Dead load and live load were assigned as per IS 875 (Part 1 and Part 2). Seismic load parameters were defined according to IS 1893 (Part 1):2016 including seismic zone factor, importance factor, response reduction factor, and soil type.

Load Combinations

Appropriate load combinations were generated automatically as per IS codes to ensure safety under different loading conditions.

Sesmic Analysis Procedure

The Equivalent Static Method was adopted to evaluate seismic forces acting on the structure. The total base shear was calculated and distributed along the height of the building based on storey mass and height. The analysis was

performed to obtain internal forces and displacement responses.

Interpretation Of Etabs Output Results

Storey Drift Analysis

Storey drift values were checked against permissible limits specified in IS 1893:2016. It was observed that maximum drift occurs near the irregular zones.

Storey Shear

Storey shear distribution shows higher values at lower floors due to accumulation of seismic forces. Irregularity causes non-uniform distribution of shear forces.

Time Period

The natural time period of the structure increased due to vertical irregularity, indicating increased flexibility of the building.

Comparative Study and Discussion

A comparative assessment between regular and irregular configurations indicates that irregular buildings experience higher deformation and internal forces. This highlights the need for careful planning and detailing of vertically irregular structures.

Practical Design Consideration

- Avoid sudden stiffness and mass variation Strengthen columns near irregular zone
- Provide adequate ductile detailing
- Perform dynamic analysis for critical structures

Advantages Of Using ETABS

- Accurate 3D modeling
- Easy visualization of results
- Code-compliant seismic analysis
- Efficient handling of high-rise buildings

Limitation Of Study

- Only Equivalent Static Analysis is considered
- Soil–structure interaction is neglected
- Wind effects are not included

Applications Of Study

- Design of high-rise RCC buildings
- Academic and research applications
- Seismic safety assessment

Environmental And Safety Aspects

Proper seismic design reduces structural damage, enhances occupant safety, and minimizes economic losses during earthquakes.

Next Steps and Future Source

Future work may include Response Spectrum Analysis and Time History Analysis for more accurate seismic response evaluation. The study can be extended to different seismic zones and soil conditions. Advanced techniques such as base isolation and dampers may also be incorporated.

Final Conclusion

The study concludes that vertical irregularities significantly influence seismic behavior of high-rise RCC buildings. ETABS proves to be a powerful tool for modeling and analyzing such structures. Proper structural planning, uniform stiffness distribution, and code-compliant analysis are essential for ensuring seismic safety. Based on the seismic analysis of the G+15 RCC building with vertical irregularities, the following conclusions are drawn: - Vertical irregularities increase seismic demand and structural deformation - Buildings with setback irregularities show higher bending moments and shear forces - ETABS is an effective tool for analyzing complex high-rise structures - Uniform distribution of mass and stiffness improves seismic performance

References

Indian Standard Codes (IS 456:2000, IS 1893:2016, IS 875) and various peer reviewed research papers related to seismic analysis of vertically irregular buildings were referred in this study.

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