Performance Evaluation of Unsymmetrical High-Rise Building with Different Types of Structural Techniques for Critical Load Condition

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Abstract— Presently, high rise buildings are generally constructed with a central core that helps transfer the load to the foundation. The frame tube and tube in tube structure have been commonly used in high rise buildings too. As per modern load conditions, columns take care of all gravity load and transfer it to the foundation and lateral load is resisted by tube structure, bracing system, outrigger system and by using other techniques. In this paper, various techniques are used to investigate the resist critical lateral load condition for unsymmetrical high-rise buildings. Various parameters like Story Drift, Lateral Displacement, Base Shear, and Story Displacement are reviewed for different types of structures used in unsymmetrical high-rise buildings. To perform a comparative study of various type structures, different models were developed by using ETABS software.

Index Terms— Tube in tube, tube in frame, frame structure with bracing system, outrigger system.

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1 Introduction

Due to rapid development of population and metro cities, high rise structures are a necessity to meet the demands. The limitation of land and increasing rate of urbanization led to feasibility for an expansion in the vertical direction. The primary purpose of all structure systems used in the building type of structure is to support gravity load but in high rise and tall structures there is an impact of lateral load such as earthquake, wind and gravity loads. Earlier structures were only being considered for gravity load but in recent years increase in height, change in load condition and revision of IS codes, we must consider and take care of lateral load with utmost care. Lateral forces resulting from wind and seismic activity now dominate the design considerations. Lateral displacement of such buildings must be strictly controlled. There are different types of structure systems such as framed tube structure, tube in tube structure, braced frame structure, bundled tube structure, mega tube structure and outrigger frame system that can be used to enhance the lateral resisting capacity of tall buildings.

2 Type of Structure

2.1 Frame tube Structure

In this type of structure, the columns are placed on the periphery of the building with a core wall. In frame tube structure, columns take care of all gravity load and core wall resists the shear force and lateral load. This type of structure is widely used and considered in common practices. The system is a logical extension of moment resisting frame whereby the beam and column stiffness are increased dramatically by reducing the clear span dimension and increasing the member depth.

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2.2 Tube in Tube Structure

In this type of structure, a group of tubes is placed at a particular location with a core tube in the periphery of the column. The exterior and interior tubes are designed to act together. The exterior tube is resisting the bending moment due to the lateral load whereas the shear force is resisted by the core tube or interior tube.

2.3 Braced Frame Structure

Braced frame structure is an improvement of tubular structural system. Made by cross bracing the frame with X bracing over many stories with the diagonals of braces connected to the column. The bracing system can resist all lateral load due to earthquake and wind load. As a result, the structure behaves under lateral load more like a braced frame reducing bending in the member of frame. Nowadays braced frame structure is the most representative structure system for tall and high-rise buildings.

2.4 Frame Structure with Outrigger system

Outrigger is a rigid horizontal structure that is truss or beam which is connected to the core wall and outer columns of a building to improve strength and overturning stiffness. Through connection the moment arm of the core will be increased which led to higher lateral stiffness of the system. Wall frame outrigger is one of the most efficient of economic structure in tall building. The structure is subjected to horizontal force, wall and outrigger truss take care of it and gravity force resist by column.

3 Objective

- To determine the effect of lateral load on unsymmetrical high-rise building with frame tube structure, tube in tube structure, braced frame structure and frame structure with outrigger system.

- Comparative analysis between frame tube structure, tube in tube structure, braced frame structure and frame structure with outrigger system.
- To study the lateral story displacement, story drift, and base shear for frame tube structure, tube in tube structure, braced frame structure and frame structure with outrigger system.
- Results compared between the all four types of unsymmetrical high-rise structure.
- To rectify the most vulnerable building among the models considered for lateral load condition.

4 Methodolgy

A G+43 story unsymmetrical high-rise building was considered in this study. Four models were modelled and analyzed using ETABS Software. Typical floor plan and elevation is shown below.

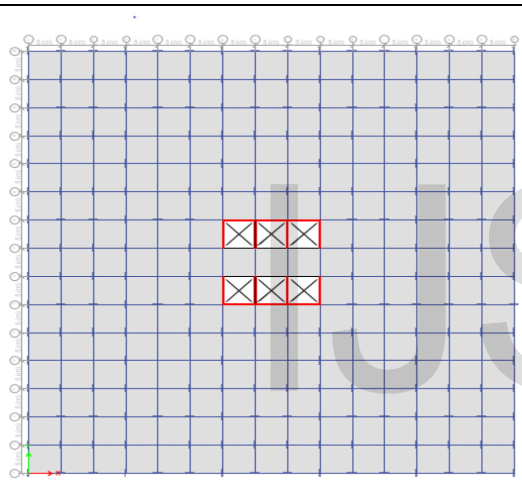

Fig. 1. Plan of Model

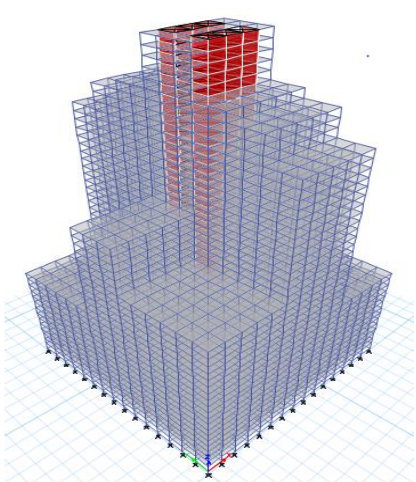

Fig. 2. 3D View of Model

5 Modelling and Anaylsis

5.1 Frame tube Structure

- Tube in tube structure.
- Frame structure with outrigger system.
- Braced frame structure.
- Frame tube structure.

5.2 Input Parameter

A G+43 high rise building with asymmetric plan modeled in this study. Material properties of each element are discussed below. Four models were analyzed and effect due to static and dynamic earthquake load was determine.

TABLE 1
Input Parameter

Sr no.	Particular	Dimension
1	Floor dimension X-direction	75 m
2	Floor dimension Y-direction	75 m
3	Spacing between frame	5 m
4	Beam size	230 mm X 600 mm
5	Column size	300 mm X 1500 mm

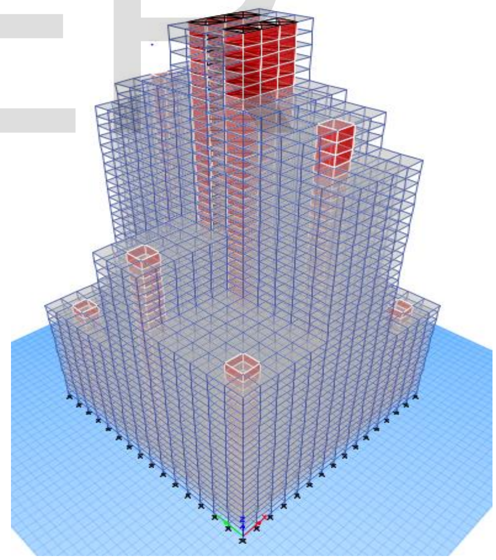

Fig. 3. 3D View of Tube in Tube structure

ISSN 2229-5518

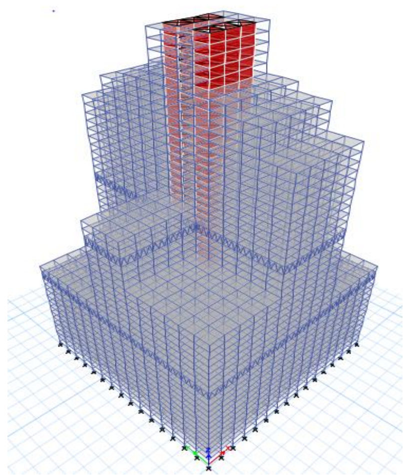

Fig. 4. 3D View of Frame Structure with Outrigger System

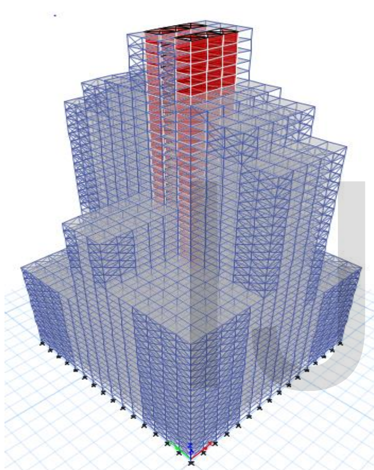

Fig. 5. 3D View of Braced Frame Structure

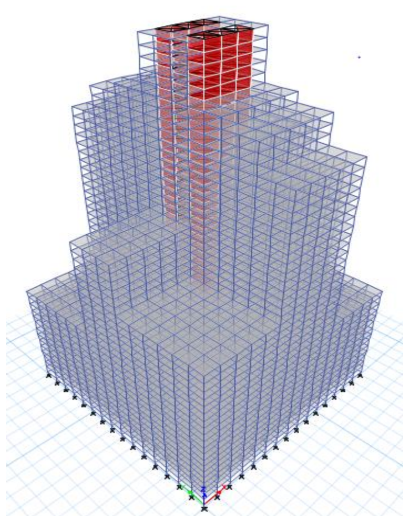

Fig. 6. 3D View of Frame Tube Structure

TABLE 2
MATERIAL PROPERTIES

Sr no.	Particular	Dimension
1	Concrete	M:40
2	Steel	Fe 500
3	Youngs modulus of steel Es	210000 MPa
4	Youngs modulus of concrete Ec	31622.77 MPa
5	Yield stress of steel	500 MPa
6	Ultimate strain	0.0035

TABLE 3
LOAD CONSIDERATION

Sr no.	Load type	Value
1	Live load	2 kN/m2
2	Floor finish load	1.5 kN/m2
3	230 mm Thik Wall load	13.8 kN.m

TABLE 4
SEISMIC PARAMETER

Sr no.	Load type	Value
1	Seismic zone	III
2	Zone factor	0.16
3	Response reduction factor, R	5
4	Soil type	II
5	Important factor	1.2

TABLE 4
WIND PARAMETER

Sr no.	Load type	Value
1	Wind speed (Vb)	39 m/s
2	Terrain category	2
3	Risk co-efficient (K1)	1
4	Topography (K3)	1
5	External co-efficient	0.8
6	Internal co-efficient	0.5

6 RESULTS

The results found plotted to get actual behavior of structure and judge the objective of study. The result and their significance discussed here briefly.

6.1 Lateral Displacment

From the results studied, we can observe that when the G+43 story models are subjected to a dynamic earthquake in X-direction the maximum top story displacement of the structure with conventional SMRF system is observed to be 490.56 mm while 386.54 mm in tube in tube structure. 351.48 mm in frame structure with outrigger system and minimum displacement observed in braced frame structure which is 226.37 mm. Hence, a reduction up to 40% is achieved by introducing X-bracing at the end of structure. Similarly, a reduction of up to 35-40% is observed due to application of seismic force along Y-direction by using bracing system as compared to conventional system.

ISSN 2229-5518

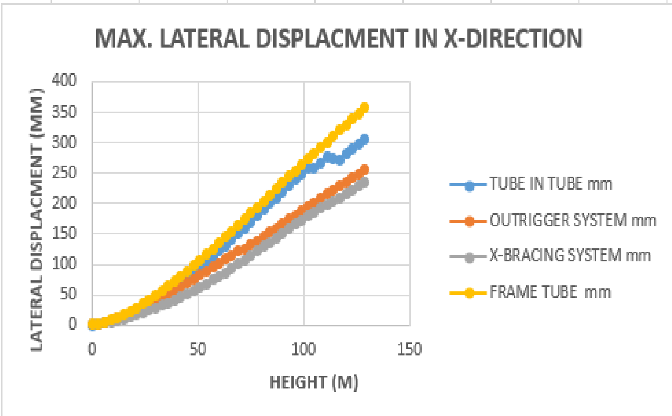

Fig. 7. Max. Lateral Displacment in X-direction

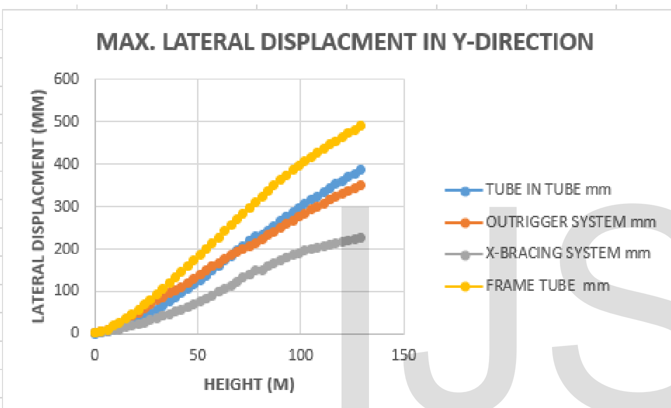

Fig. 8. Max. Lateral Displacment in Y-direction

6.2 Base Shear

A small increase is seen in base shear when structure is subjected to earthquake load. This small increase in base shear along both directions is due to the increase in self weight of outrigger truss and X-bracing system.

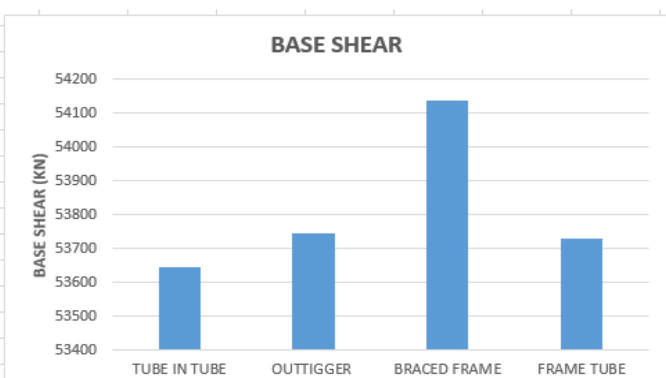

Fig. 9. Base Shear

6.3 Story Drift

From the results studied after a 129 m high rise building is subjected to seismic load along X-direction, it is noted that story drift at 48 m level and 77 m level is reduced by 48% to 52 % due to outrigger truss at 0.4 h and 0.6h. However, story drift is less in braced frame structure compare to tube in tube structure, and frame tube structure.

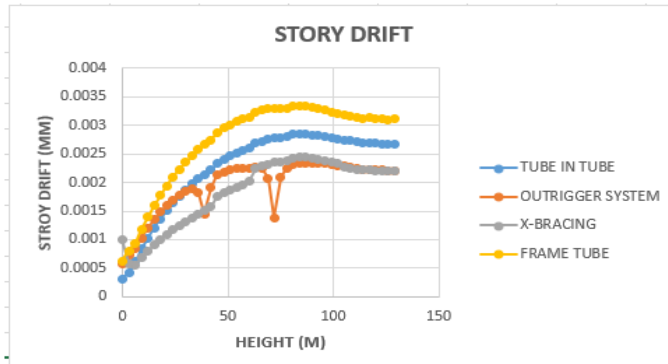

Fig. 10. Story Drift

6.4 Time Period

From the results, it is observed that providing X-bracing at the end of structure reduces the time period as compared to tube in tube structure, frame structure with outrigger system and frame tube structure. In mode-I, there is a reduction of about 15% to 20% in the time period of the X-bracing system compared to other three structures.

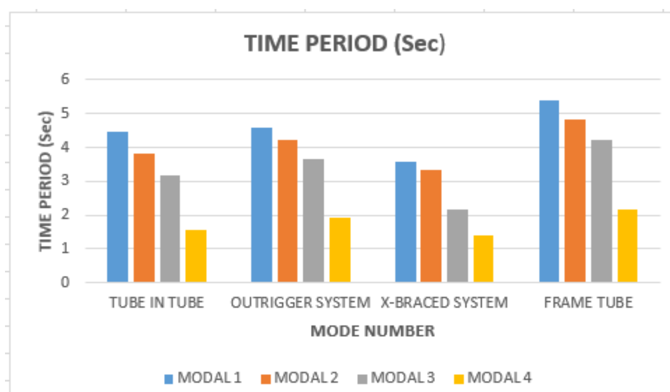

Fig. 10. Time Period

7 Conclusion

The analysis of four different types of structure were carried out using the ETABS software. The behavior of each model is studied, and the results are tabulated. The various parameters like lateral displacement, Base shear, Story drift and natural time period have been studied for dynamic analysis method. The results of all models are observed, and the most suitable model is selected by comparing the results of each model.

- From the modular investigation it can be inferred that lateral displacement of braced frame structure decreases by 40% due to introduction of X-bracing system in frame structure. Lateral displacement is less than tube in tube structure, Frame structure with outrigger system and frame tube structure.
- There has been a small increase in base shear in the X-bracing system. This is due to the addition of self-weight of X-Bracing in the structure. Similarly, base shear is greater in the outrigger system compared to frame tube structure and tube in tube structure due to additional self-weight of the outrigger system.
- Time period considerably decreases by 15% to 20% due to introduction of X-bracing in frame structure. Time period in braced frame structure is comparatively less than tube in tube structure, frame structure with outrigger system and frame tube structure.
- From the results studied, when a 129 m high rise building is subjected to seismic load along X-direction, it noted that the story drifts at 48 m level and 77 m level are reduced by 48% to 52 % respectively due to outrigger truss at 0.4 h and 0.6h. However, story drift is less in braced frame structure compared to tube in tube structure, and frame tube structure.
- After comparisons. it is found that braced frame structure performs better in dynamic load condition compared to tube in tube structure, frame structure with outrigger system and frame tube structure.
- From the comparison of analysis results, braced frame structure is recommended as a better structure system of high-rise building than other the three types of structure.
- Hence, provision of a X-bracing position in an appropriate location is advantageous for better performance in dynamic load condition.

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