

Parametric study of High Rise building with Outrigger belt truss system and Passive dampers

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Abstract

Tall buildings are rapidly increasing around the world, owing to the rise of the land value and the developments in the construction technology. As buildings increase in height, it becomes more important to ensure adequate stiffness against lateral forces. In order to limit the wind drift to acceptable limit and to maintain human comfort with optimum utilization of material, the outrigger and belt truss structural system is developed. The Outrigger and Belt trussed system is the one of the lateral load resisting systems that can provide significant drift control for tall buildings. The aim of present study is to understand the behavior of 40 storied high rise building with and without outrigger and belt truss system. To find the effective outrigger and belt truss system by varying geometry and material of the outrigger and belt truss system. The optimum location of outrigger is found out for the two outrigger and belt truss system to minimize the response of the building. The parameter consider are top storey displacement, storey drift, base shear, time period, base moment of shear wall. Modelling and analysis of the building for the study is carried out using ETABS software.

Keywords: *Outrigger, Belt truss, Lateral loading, Response spectrum, ETABS*

INTRODUCTION

Tall structures in the modern sense began to appear over a century ago advancement in structural engineering and technology will continuously extend the height limit. However, for greater heights, the resistance of the core systems to bending caused by overturning becomes progressively inefficient. In India, the common high-rise building structural system is shear-wall frame structure. But the outrigger and belt truss system is new structural system for high rise buildings. Shear wall frame structure is the representative structure for up to 25 storied buildings, and shear wall - frame plus outrigger structure can be used up to 60 storied buildings. The savings in steel tonnage and cost can be significant in high-rise buildings if certain techniques are employed to utilize the full capacities of the structural elements.

Outrigger and belt truss system

Outrigger systems have been historically used by sailing ships to help resist the wind forces in their sails, making the tall and slender masts stable and strong. The outrigger and belt truss system is one of the lateral loads resisting system in which the external columns are tied to a reinforced-concrete or braced steel frame main core with very stiff horizontal cantilever members at one or more levels commonly referred to as “outriggers”

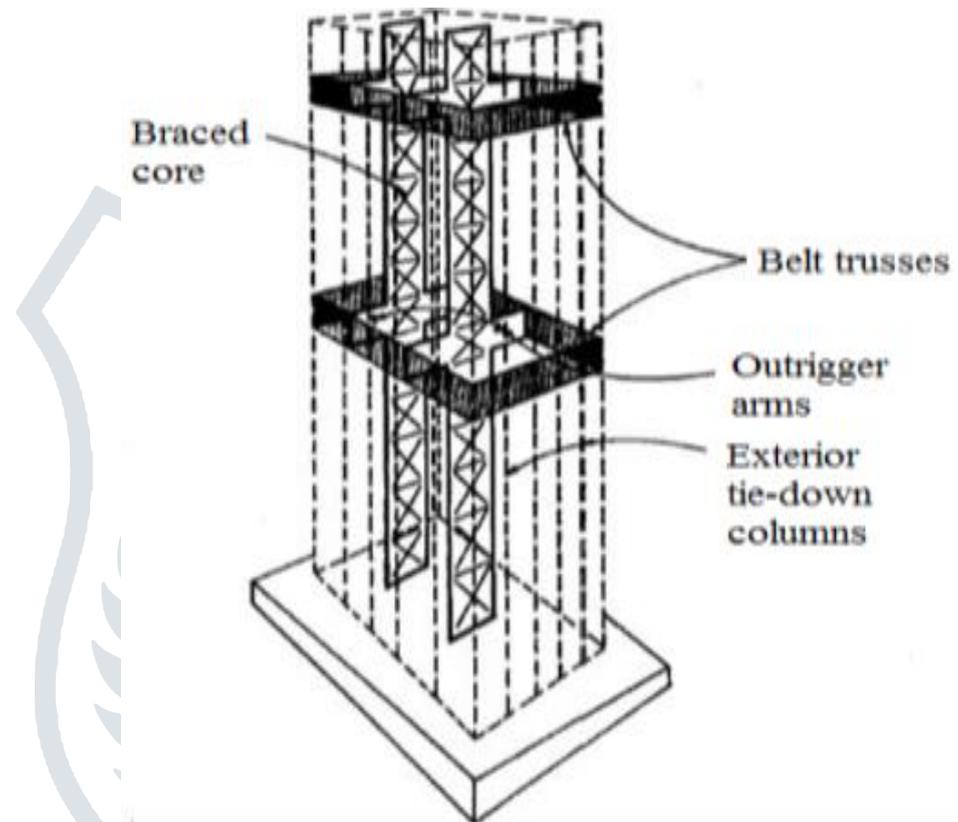


Fig. 1. The outrigger and belt truss system

The outriggers are generally in the form of trusses in steel structures, or walls in concrete structures, that effectively act as stiff headers inducing a tension-compression couple in the outer columns. Outrigger systems is mostly used against wind loading and it can lead to very efficient use of structural materials by mobilizing the axial strength and stiffness of exterior columns to resist part of the overturning moment produced by lateral loading.

Belt trusses are often provided to distribute these tensile and compressive forces to a large number of exterior frame columns. The belt trusses also help in minimizing differential elongation and shortening of columns.

CLASSIFICATION OF OUTRIGGER SYSTEM

On the basis of connection to the core there are two types of outrigger truss;

- 1) Conventional Outrigger system
- 2) Virtual Outrigger system

Conventional Outrigger System:

In the conventional outrigger system, the outrigger truss is connected directly to shear walls at the core and with columns at the periphery of the building. The intermediate columns between the external columns and the shear walls are connected with outrigger truss. The outrigger can be applied simultaneously at multiple floors simultaneously. The outrigger truss connected to the core and external columns converts the moment in core to vertical couple in columns.

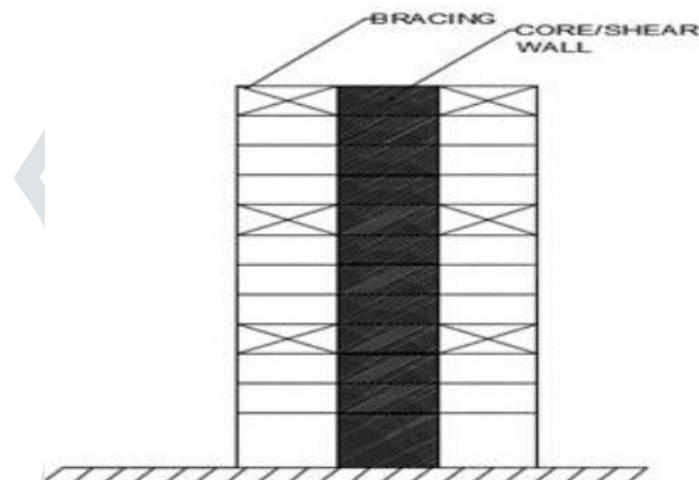


Fig. 2. Building with conventional outrigger

Belt Trusses as Virtual Outriggers

The floor diaphragm action restrict the rotation of the core is resisted by the floor diaphragms at the top and bottom of the belt trusses which results in conversion of moment in core into a horizontal couple in the floor, which in turn is transferred to the inclined bracings which then shift their forces to the vertical columns supporting it. The lateral load resisting system consists of shear wall core, external columns, belt truss bracings and floor diaphragm action. The belt truss is connected to the external columns; belt truss is bracing that are connected to the external column which tie down the periphery of the building.

MODELLING PARAMETERS

A 40 storied building model has been considered for this study. Building plan size is 40m×40m. The total height of building is 140m with a typical floor to floor height of 3.5m. Columns are spaced at 8m Centre to center in both direction. The plan view of the building is represented in Figure. 3.

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1) Material properties

Concrete	- M40
Reinforcement	- Fe500
Steel	- Fe345

2) Sectional properties

Columns	- 1200 mm x 1200 mm 1000 mm x 1000 mm 900 mm x 900 mm 800 mm x 800 mm
Beam	- 400 mm x 700 mm
Outrigger	- 450 mm outer diameter, 100 mm thick
Belt truss	- 300 mm outer diameter, 75 mm thick
Slab	- 150 mm thick
Shear wall	- 150 mm thick

3) Loadings

Super dead load	- 1.5 KN/m ²
Live load	- 3 KN/m ²
Zone factor	- 0.16
Soil Type	- II
Importance factor	- 1
Response reduction factor	- 5
Basic wind speed	- 39 m/s

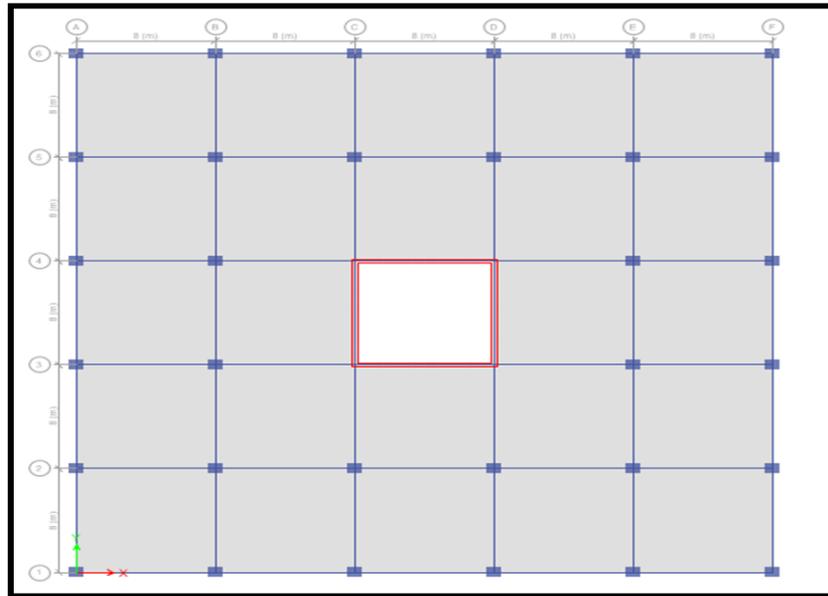


Fig. 3. Plan of Building

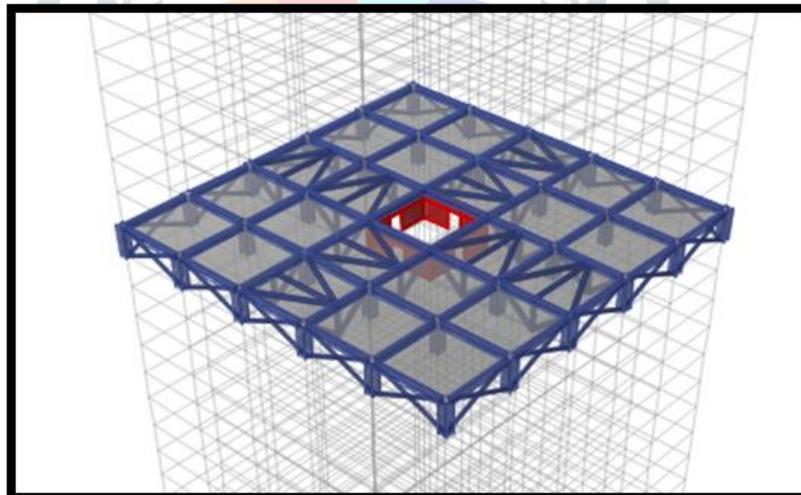


Fig. 4. 3D View of Vertical and Horizontal Truss

The designation of the analytical model are as follows:

- Without - 40 storey building with shear wall only
- With RCC O & B - 40 storey building with RCC outrigger and belt truss
- With steel O & B - 40 storey building with vertical STEEL outrigger and belt Truss
- Vertical and Horizontal O&B - 40 storey building with STEEL outrigger and belt Truss in vertical and horizontal

ANALYSIS OF THE BUILDING

For static behavior purpose the analysis is carried out for lateral wind load conforming to IS-875-part3 (1987) and equivalent static analysis for seismic in accordance with IS 1893-2002 has been carried out. For dynamic behavior purpose response spectrum analysis is carried out using ETABS. The core wall and slab has been modeled as thin shell element. To find the most effective outrigger and belt truss system and to find optimum location by providing outrigger and belt truss at one third and at one half height of building analysis has been carried out using above analytical method.

RESULTS AND DISCUSSION

The results obtained from analysis are compared and discussed as follows.

Base shear

From the figure 5. It is observed that base shear is increase maximum 1.25% if we compare building with vertical and horizontal outrigger and belt truss with building without outrigger and belt truss system. Also figure 5. Indicate that whether we provide outrigger and belt truss system at one third or one half height base shear value does not change.

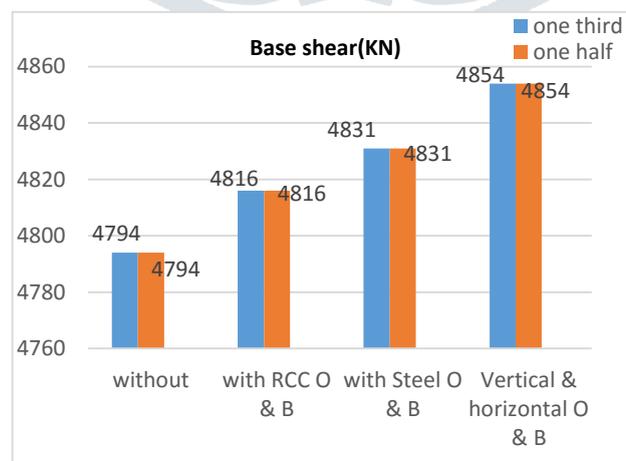


Fig. 5. Base shear of building for different model

Time period

Figure 6. Shows variation of time period for different model of 40 storey building. From the figure 6. It is observed that time period is decrease maximum 22% if we compare building without outrigger and belt truss with building with vertical and horizontal outrigger and belt truss system.

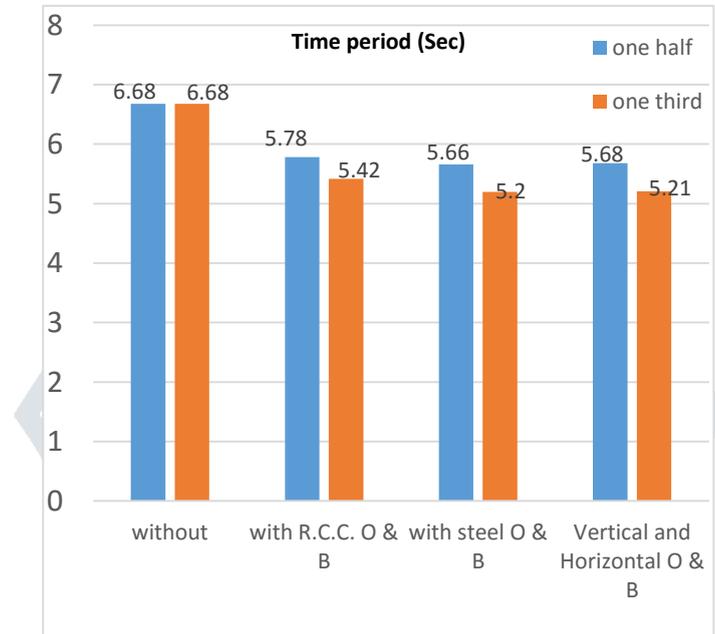


Fig. 6. Time period of building for different model

Top storey displacement

The following figure 7 shows the variation of top storey displacement and from the figure 7 it is observed as follows: Top storey displacement is decrease as we provide various outrigger and belt truss system. Also figure 7 indicate that top storey displacement is decrease maximum 1.25% if we compare building without outrigger and belt truss with building with vertical and horizontal outrigger and belt truss system at one third height.

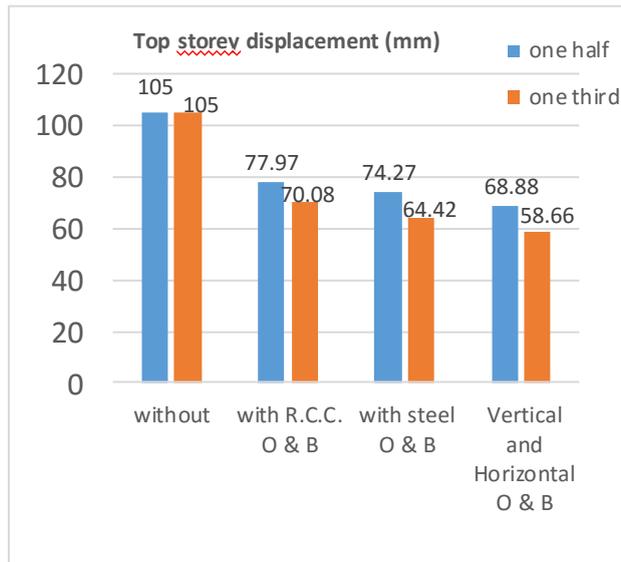


Fig. 7. Top storey displacement of building for different model

Maximum storey drift

Figure 8. Shows variation of Maximum storey drift for different model of 40 storey building. From the figure 8. It is observed that maximum storey drift is decrease maximum 39.37% if we compare building without outrigger and belt truss building with vertical and horizontal outrigger and belt truss.

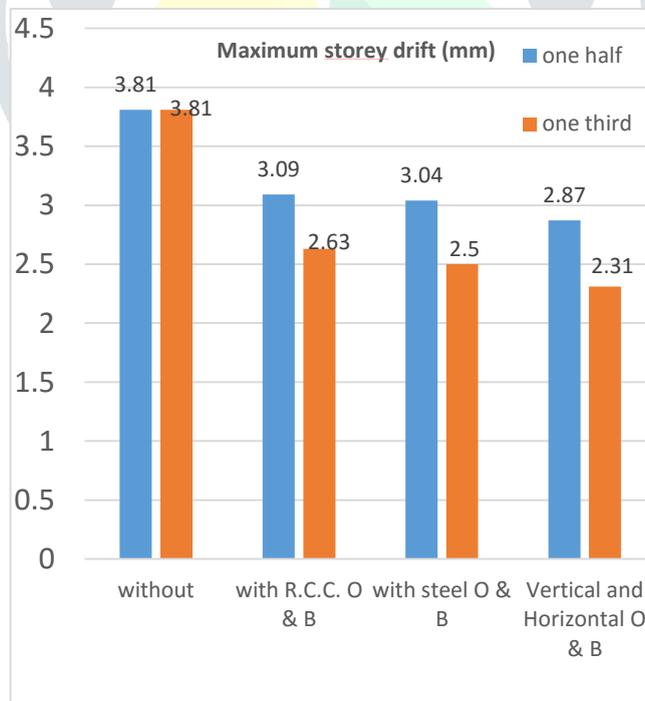


Fig. 8. Maximum storey drift of building for different model

Base moment of shear wall

The following figure 9 shows the variation of base moment of shear wall and from the figure 9 it is observed as follows: Base Moment of shear wall is decrease as we provide various outrigger and belt truss system. Also figure 7 indicate that Base moment of shear wall is decrease maximum 16.77% if we compare building without outrigger and belt truss with building with vertical and horizontal outrigger and belt truss system at one third height.

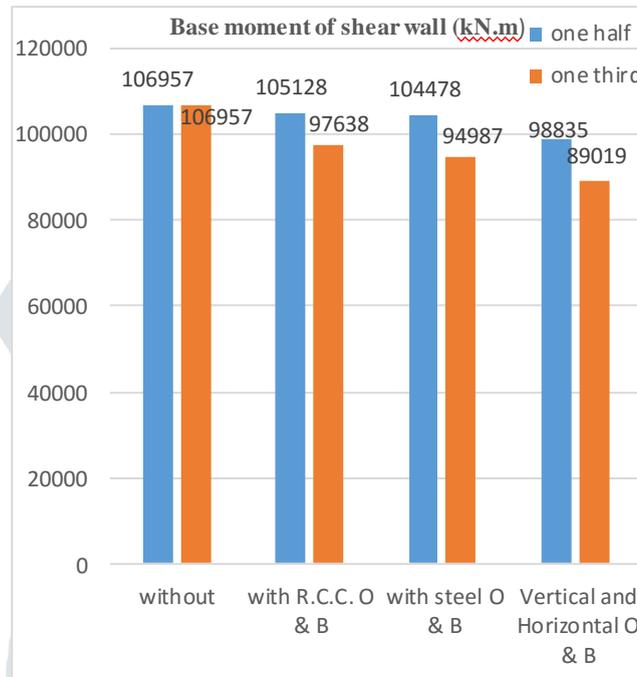


Fig. 9. Base moment of shear wall for different model

CONCLUSIONS

- The use of outrigger and belt truss structural systems in high-rise buildings increases the stiffness and makes the structural form efficient under lateral load.
- Overall, vertical and horizontal steel outrigger and belt truss system is found to be efficient in comparison to concrete and vertical steel outrigger and belt truss system.
- By providing steel outrigger and belt truss system at one third height base moment of shear wall reduced up to 16.77%.
- When two outrigger and belt truss used in building optimum location is at 2/3rd and 1/3rd height.

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