Static & Dynamic Analysis of Multistory Structural system with varying outrigger belt truss System

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***Abstract*— Advances in engineering and technology, the development of high-strength structural materials, an increase in population, a lack of available land area due to rising land prices, and rapid urbanization have all contributed to the development of high-rise buildings in the modern era. High-rise buildings are the most vulnerable to lateral loadings caused by wind and seismic forces. The trend toward taller and slender structures necessitates the development of structural systems that can withstand lateral loads effectively and affordably. Outrigger bracing is a solution for controlling excessive drift and displacement in high-rise buildings. It is made up of outrigger bracings or outrigger trusses that connect the central core of the building to the peripheral columns, and the peripheral columns are connected to one another via belt trusses. In this study, the conventional structural model with a reinforced concrete central core and models with outriggers at the top, top and 0.75H, top and 0.5H, and top and 0.25H where H is the total height of the building are modelled for building heights of 20, 40, and 60 stores. The primary goal of the research is to determine the best location for the outrigger system. This study's modelling and analysis are carried out using the ETABS 2017 software package. The models are analyses using two methods: the Equivalent Static Method, the Response Spectrum Method, and the results are compared in terms of maximum top displacement, storey drift, base shear.**

Keywords—outrigger system, Multistory, Response spectrum analysis

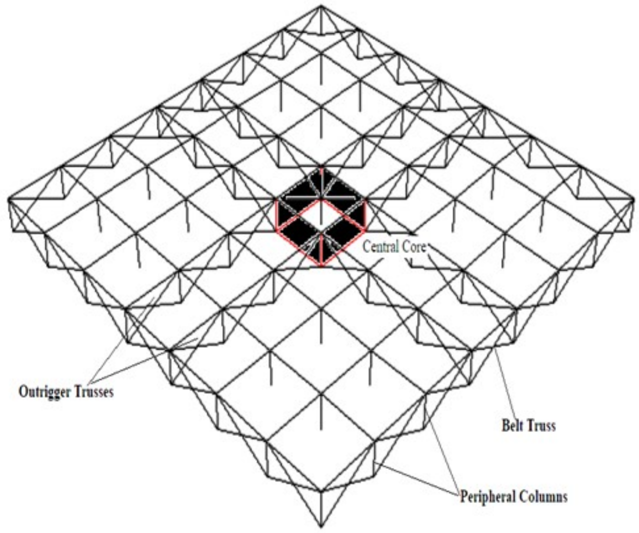
I. Introduction

Because of the increase in population and decrease in available land, the demand for high-rise buildings has risen rapidly in recent years. Engineering techniques and technological advancements have enabled the development of super high-rise structures with precision and safety. There is a trend toward taller and more slender structures due to aesthetic demands and, more importantly, the limited land area available as a result of rising land prices and rapid urbanisation. Tall buildings are more vulnerable to lateral loads caused by wind and seismic forces, and thus must be designed to withstand any lateral loadings.

Previously, structural elements were primarily designed to withstand gravity loads. However, thanks to advances in structural engineering and the development of high-strength materials and analysis techniques, structures can now be designed for multiple functions, and structural elements can now be used more efficiently to resist lateral loads as well. Because tall structures, particularly slender structures, are vulnerable to lateral forces such as wind and earthquake, a suitable structural system must be chosen based on the structure's slenderness ratio, stiffness requirements, drift control, and other factors.

Tall building structural design is governed by lateral stiffness, so structural systems in tall buildings have evolved to produce higher lateral stiffness more efficiently. In general, perimeter tube type structures with diagonals, such as braced tubes and diagrids, are very efficient among the various structural systems developed for tall buildings.

Various studies have discovered that when used alone, the shear wall provides effective resistance only up to a certain height, after which it becomes uneconomical when compared to the benefit it provides. As a result, a more efficient structural system is required to provide more stiffness and strength to high-rise structures against wind and seismic loadings while also meeting economic criteria. The outrigger bracing system provides more stiffness to tall buildings against lateral displacement and drifts without incurring additional steel costs, proving to be a very cost-effective drift control solution. The outrigger system is made up of outrigger bracings or outrigger trusses that connect the core of the building to the columns on the periphery, and the peripheral columns are linked together by belt trusses.



The outrigger connecting the core to the peripheral column could be made of very stiff outrigger reinforced concrete beams or steel trusses, and the belt could be made of deep concrete beams or steel trusses. The core can also be constructed with stiff steel trusses or a reinforced concrete section. The core can be in the middle of the structure, with outriggers extending from the centre to the perimeter columns on all four sides, or it can be eccentrically located on one side.

II. OBJECTIVE

The objectives of the study are:

- To investigate the concept of an outrigger structural system and its response using both static and dynamic analysis methods.
- Vary the location of outrigger bracings with belt trusses along the height of the structure to determine the best outrigger system location in terms of performance, lateral displacement, and cost.
- To compare the results of the outrigger system with the conventional framed structural system in terms of storey drift, storey shear, top storey displacement, and roof velocity and acceleration.

III. METHODOLOGY

In this study, a comparison of an outrigger system and a conventional structure is made under seismic and gravity loading, and the concept of an outrigger structural system is investigated. The following methodology was used to achieve the study's goal:

- Examine existing literature and standards related to outrigger structural systems.
- Geometry and seismic zone of the building are chosen.
- Using Indian Standard Codes, calculate the loads on the building.
- Load combination formation according to IS: 1893 (Part I): 2016
- Preliminary member sections are assumed, and ETABS 2017 software is used to model a conventional frame with central core and a conventional frame with central core and outrigger system.
- The models are 20 storeys, 40 storeys, and 60 storeys tall.
- One outrigger is fixed at the top, while the other is moved along the height as 0.25H, 0.5H, and 0.75H, where H is the structural model's height.
- Parameters such as displacement, inter-storey drift, moment in core, base shear, time period, and axial force in the peripheral column are determined using linear static and linear dynamic analysis.
- On the basis of the above parameters, the efficiency of the outrigger system is determined, as well as the optimum location of the outrigger for the least amount of displacement and drift.

Modelling and Analysis

The goal of this project is to investigate the use of outrigger and belt truss in various locations that are subjected to wind and earthquake loads. IS 875 (Part 3) was used to calculate the wind load, and IS 1893 was used to calculate the earthquake load (Part-1). To perform the analysis, the ETABS software programme is chosen. The current research is limited to multi-story symmetrical reinforced concrete (RC) buildings. For all models, the bay width is kept constant in two horizontal directions. The live load on the floors is 3 kN/m2. For the floor finishes, a floor load of 1.5 kN/m2 is applied to all slab panels on all floors.

The data used in this study is summarized below:

Number of storeys	30 storeys
Plan area	38.5 m x 38.5 m
Storey height	3 m
Spacing of columns	5.5 m
Grade of concrete	M40
Grade of steel	Fe415
Size of columns	600 mm x 600 mm
Size of beams	230 mm x 600 mm
Slab thickness	150 mm

IV. RESULT

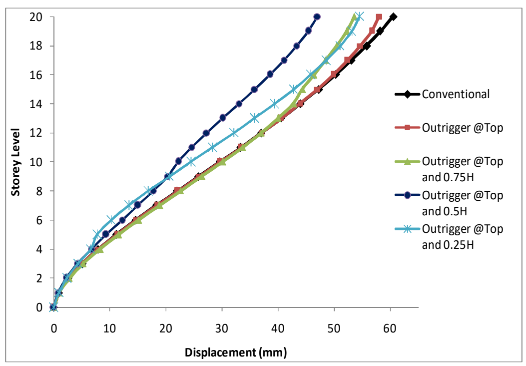


Figure 1 Storey displacements of 20 storey models

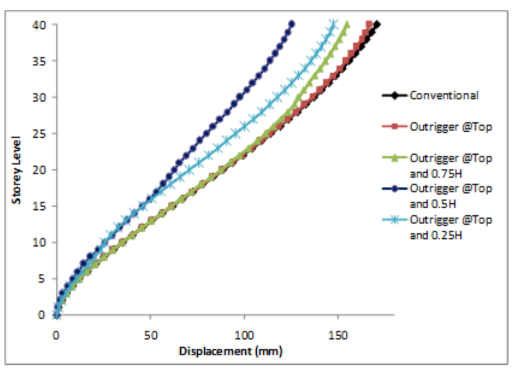


Figure 2 Storey displacements of 40 storey models

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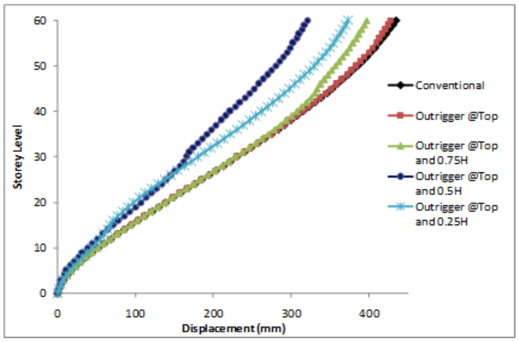

Figure 3 Storey displacements of 60 storey models

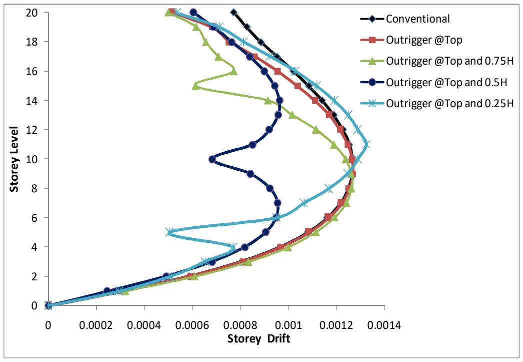

Figure 4 Storey drift of 20 storey models

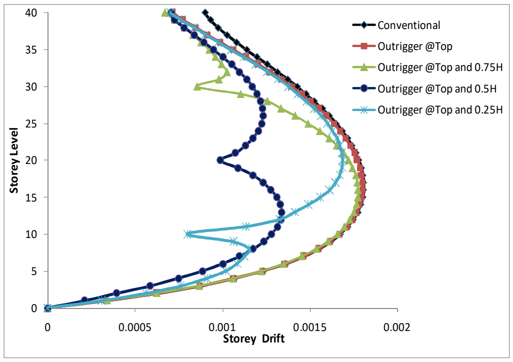

Figure 5 Storey drift of 40 storey models

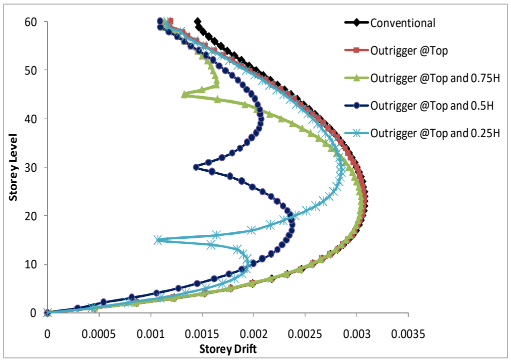

Figure 6 Storey drift of 60 storey models

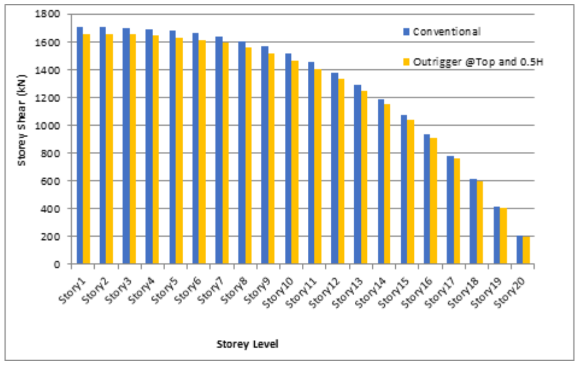

Figure 7 Storey shear of 20 storey models

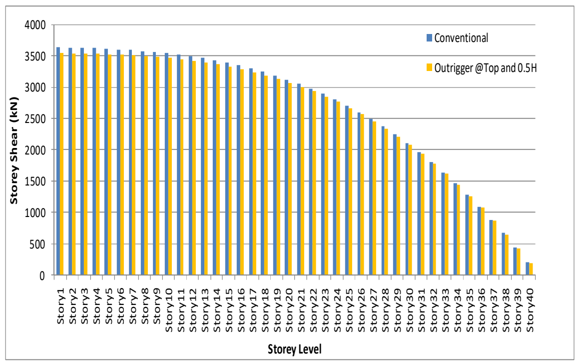

Figure 8 Storey shear of 40 storey models

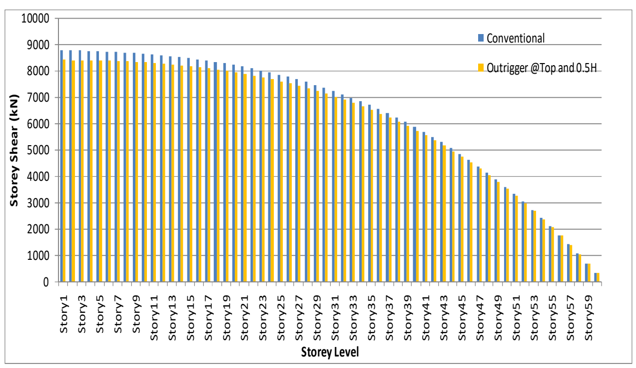

Figure 9 Storey shear of 60 storey models

V. CONCLUSION

- The best location for an outrigger system is at the top and 0.5 times the structure's height. Providing outriggers at this location results in a significant reduction in lateral displacement and drift.

- The Equivalent Static Method reduces lateral displacement by 22.3 percent, 26.5 percent, and 26.3 percent for 20, 40, and 60 storey structural models with outrigger at top and 0.5H, respectively.

- The Response Spectrum Method reduces lateral displacement by 18.53 percent, 30.45 percent, and 28.73 percent for 20, 40, and 60 storey structural models with outrigger at top and 0.5H, respectively.

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