

# Optimum Position of Outrigger Systems in Tall Building by Using Reinforced Concrete Shear Walls and Braces

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**ABSTRACT:** Tall building development has been rapidly increasing worldwide introducing new challenges that need to be met through engineering judgment. In modern tall buildings, lateral loads induced by wind or earthquake are often resisted by a system of coupled shear walls. But when the building increases in height, the stiffness of the structure becomes more important and introduction of outrigger system often used to provide sufficient lateral stiffness to the structure. The outrigger and is commonly used as one of the structural system to effectively control the excessive drift due to lateral load, so that, during small or medium lateral load due to either wind or earthquake load, the risk of structural and non-structural damage can be minimized.

In thispaper, a parametric study is performed on multi-storeyed building with and without outrigger systems, located in seismic zone IV. It is intended to describe the performance characteristics such as lateral displacement, time period, base shear etc. The study is carried out on a building with the help of different mathematical models considering shear walls and braces as an outrigger systems at different locations for improving the seismic performance of the building without any outrigger system. Analytical models represent all existing components that influence the mass, strength, stiffness and deformability of structure. The response spectrum analysis is carried out on all the mathematical 3D model using the software ETABS 2015 and the comparisons of these models are presented. Finally, the optimum location of outrigger system is suggested.

**KEYWORDS:** outriggers, tall building, shear wall, bracing

## I. INTRODUCTION

The outrigger and belt truss system is one of the lateral loads resisting system in which the external columns are tied to the central core wall with very stiff outriggers and belt truss at one or more levels. The belt truss tied the peripheral column of building while the outriggers engage them with main or central shear wall. The outrigger and belt truss system is commonly used as one of the structural system to effectively control the excessive drift due to lateral load, so that, during small or medium lateral load due to either wind or earthquake load, the risk of structural and non-structural damage can be minimized. For high-rise buildings, particularly in seismic active zone or wind load dominant, this system can be chosen as an appropriate structure.

Shear walls and braces are as an outrigger system are proved to be very effective in reducing response of buildings; hence their optimization is required to be checked for buildings. In the present work effect of outrigger system consisting of shear walls, braces etc. and their location in multistorey building is studied.

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## II. LITERATURE SURVEY

There are various authors who have worked on outrigger systems, some of them and their work is discussed below:

**Thejaswini R. M. et. al. (2015)** have carried out a comparative study and analysis of different lateral loadresisting structural systems to understand the realistic performance of the building during earthquake and under the excessive windpressure as well as to select structural system of tall building to stay in good condition with effect of gravity, live load and externallateral load, moment, shear force and torque with acceptable strength and stiffness. For this, modelled a geometrically irregular 14 storey RCC high rise building with different forms of structural system such as Rigid frame structure, Core wall structure, and Shear wall structure with different configurations of shearwall location, Tube structure and outrigger structure. Results of the analysis reveal that the values of displacement were less in tubestructure and outrigger structural system. Also stability of structurewillboost and the columns sway can be reduced by implementing L-shaped shear wall along the corners in geometrically irregular structure. When outrigger structural system is provided at a storywhich has maximum drift, it can perform as a maximum drift controller

**Alpana L. Gawate et.al. (2015)**, Research work focused on enhancement the lateral stiffness oftall buildings, because as the height of the building increases the core alone is not adequate to keep the drift within permissiblelimit. Therefore some other structural element is to be added in that building to take care of drift. Outriggers are the structuralsystem, which help in reducing the lateral drift increasing the stiffness of the structure by huge amount. The optimum location of the outrigger is found by considering few constraint conditions. The analysis have been performed on a 30 storied three dimensional model with various configurations of outrigger such as system with single and double outrigger by changing cross sectional dimensions of columns and thickness of shear wall. The said model was analyzed by response spectrum analysis as per Indian standard codes and following conclusion hasbeen drawn. When there was provision of only one outrigger, the system was not effective as concerning of drift. There was aremarkable change observed in the drift profile when two outriggers were provided. One important conclusion figured out from thisresearch is no story was found as soft story for all 9 trials made in model with two outriggers with changes in cross sectionaldimensions of columns and thickness of shear wall.

**Shivacharan K et.al. (2015)**, Analysis of the structure is carried out to study the behavior of outrigger and its efficiency for its optimum position at the first and second location. The three dimensional models of outrigger and belt truss system are subjected to wind and earthquake load, analyzed and compared to find the lateral displacement reduction related to the outrigger and belt truss system location. The present work is to study the use of outrigger and belt truss placed at different location subjected to wind and earthquake load. The design of wind load was calculated based on IS 875 (Part 3) and the earthquake load obtained using IS 1893 (Part-1): 2002. The location of outrigger and belt truss for reducing lateral displacement and building drift. To evaluate the performance of vertical irregularities of outrigger structure, a linear static analysis has been conducted by using ETABS2013.5. To achieve this objective, the vertical irregularities structures with 30 stories 7X7bay from 1st to 10th floor 5x5bay from 11th to 20th floor, 3x3bay from 21st to 30th floor with outriggers and belt truss at different stories were analyzed. Compression study of the displacement and drift of the structure is studied. Maximum Storey Shear and Axial Load of different columns are observed for the structure with first and second location of the outrigger.

From the available literatures, it is observed that, the tall buildingsare more vulnerable to earthquakes and become a cause of destruction. Hence to increase the seismic performance of such buildings, the use of outrigger systems such as shear wall, braces etc. are proposed in this present paper.

The aim of this paper is to improve the seismic performance of multistorey buildings after incorporations of outrigger systems of various types at various locations.

In this paper the seismic response of tall buildings with and without outrigger system such as shear walls, braces etc. are compared in terms of various parameters such as lateral displacement, base shear, time period etc.

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## III. MODELLING & ANALYSIS

### Building Description

The building considered is the commercial building having G+24 storeys. Height of each storey is 3m. The building has plan dimensions 12m x 12m and is symmetric in both orthogonal directions as shown in the Fig. 1. It is considered to be located in seismic zone IV and is built on hard soil. The size of columns is 500mm x 500mm. Size of beams is 300mm x 450mm in both transverse and longitudinal direction. Thickness of slab is 125mm. The unit weights of concrete and masonry are taken as 25 kN/m<sup>3</sup> and 20 kN/m<sup>3</sup> respectively. Live load intensity is taken as 3kN/m<sup>2</sup> for all floor level. Weight of floor finish is considered as 1.5 kN/m<sup>2</sup>. In the analysis special RC moment-resisting frame (SMRF) are considered. Thickness of shear walls as an outrigger system is considered as 230mm and size of brace considered as 300mmx300mm.

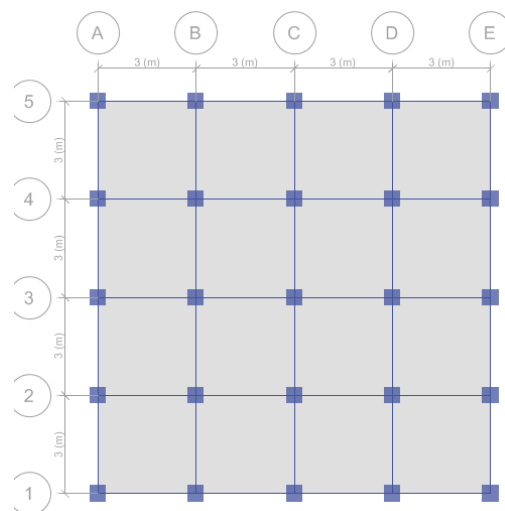


Fig 1: Plan of building

The building is modelled using the software ETABS. Response spectrum analysis is performed on the below mentioned 3D model. Beams and columns are modelled as two noded beam element with six DOF at each node. Slab is modelled as four noded shell element with six DOF at each node. In the modelling material is considered as an isotropic material.

The following models have been studied and presented in the paper.

Model I: Building without any Outrigger systems as shown in figure 2.

Model II: Building with External X Brace at 12th & 24th Storeys as shown in figure 3.

Model III: Building with External Shear Wall at 12th & 24th Storeys as shown in figure 4.

Model IV: Building with External X Brace at 8th, 16th & 24th Storeys as shown in figure 5.

Model V: Building with External X Brace at 8th, 16th & 24th Storeys as shown in figure 6.

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Model I: Building without any Outrigger systems:

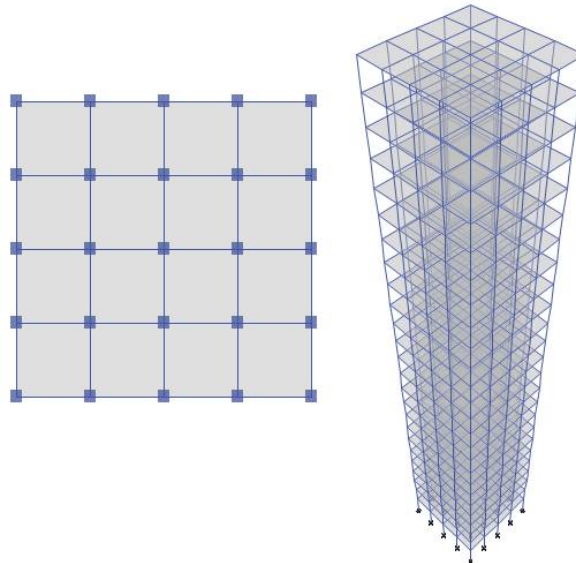


Figure 2: Building without any Outrigger systems (Model I)

Model II: Building with External X Brace at 12th & 24th Storey:

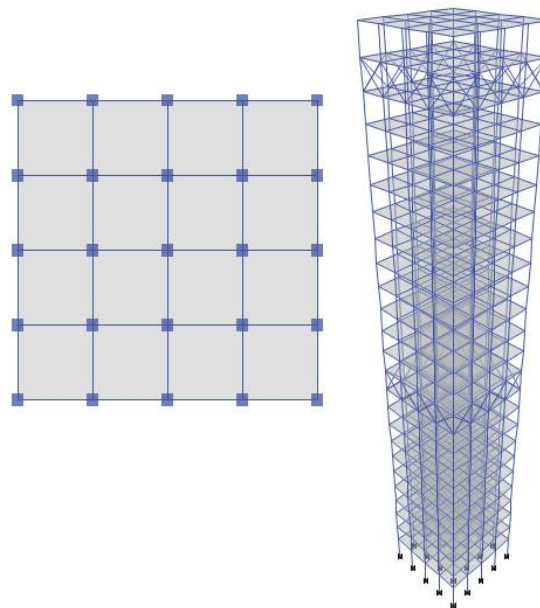


Figure 3: Building with External X Brace at 12th & 24th Storey (Model II)

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Model III: Building with External Shear Wall at 12th & 24th Storey:

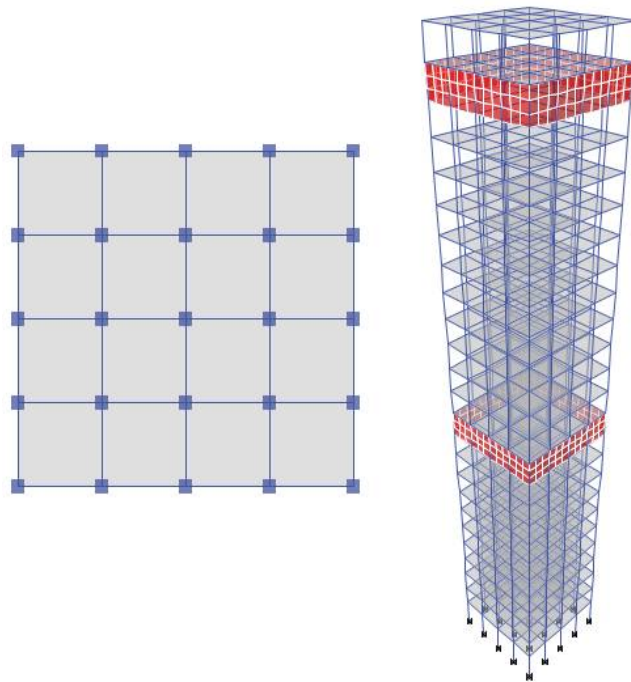


Figure 4: Building with External Shear Wall at 12th & 24th Storey (Model III)

Model IV: Building with External X Brace at 8th, 16th & 24th Storey:

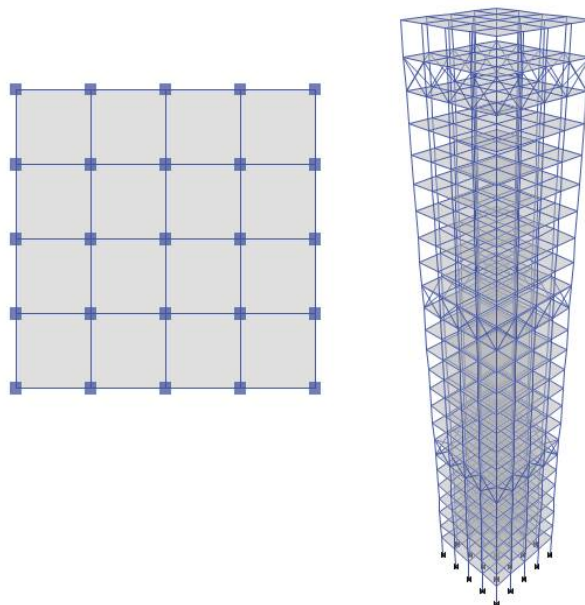


Figure 5: Building with External X Brace at 8th, 16th & 24th Storey (Model IV)

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Model V: Building with External X Brace at 8th, 16th & 24th Storey:

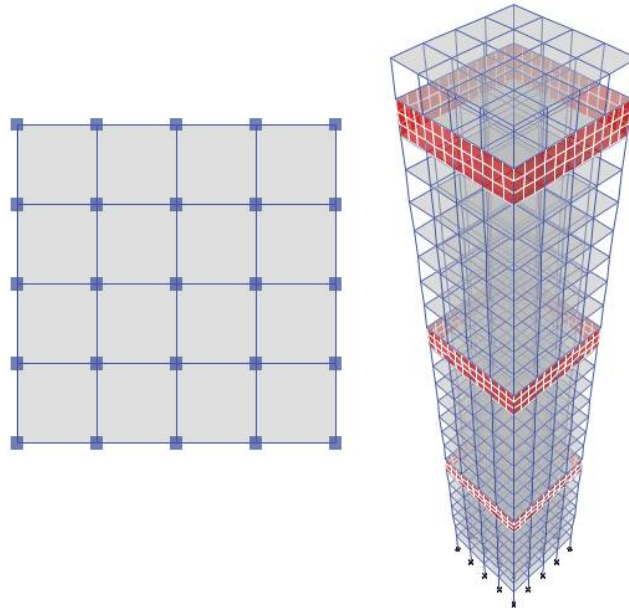


Figure 6: Building with External shear walls at 8th, 16th & 24th Storey (Model IV)

## IV. RESULT & DISCUSSION

As discussed above, there are total five models under consideration, out of which first model is without incorporation of any outrigger systems. In other four models, RC shear walls and braces are used at various positions to improve seismic performance of such type of building. For comparison purpose, lateral displacement of top storey, time period and base shear etc. are chosen.

### Lateral displacement at top storey

Large displacement occurs in case of without outrigger system building (Model I). It is seen that the use of X bracing at 12th & 24th Storey (Model II), use of peripheral shear walls at 12th & 24th Storey (Model III) and use of peripheral shear walls at 8th, 16th & 24th Storey (Model IV) reduces the displacement up to 4.3%. The building with use of External X Brace at 8th, 16th & 24th Storey (Model V) reduces the displacement up to 9.5%.

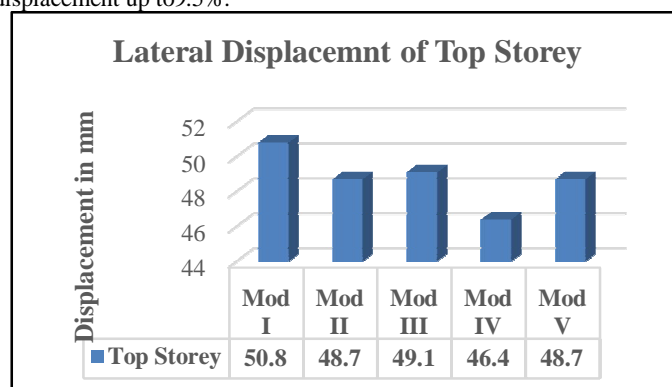


Fig 11: Comparison of lateral displacement

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### Base shear

There is no considerable change in Base shear of model II (Building with External X Brace at 12th & 24th Storey), model III (Building with External Shear Wall at 12th & 24th Storey), model IV (Building with External X Brace at 8th, 16th & 24th Storey). For model V (Building with External Shear Wall at 8th, 16th & 24th Storey), base shear is reduce to 8% of model I (Building without any Outtrigger system).

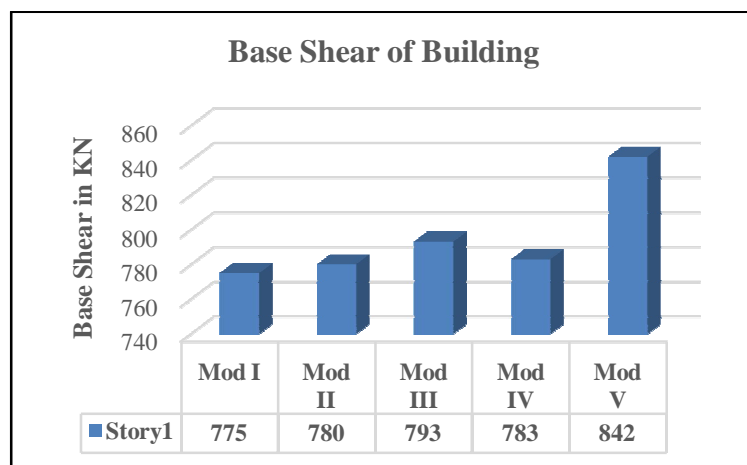


Fig 15: Comparison of Base shear

### Time period and frequency

It is observed that the time period of vibration is more for Model I (Building without any Outtrigger system). While it is considerably reduced for models II, III, IV, and V. Period of vibration is found to be minimum for Model V (Building with External X Brace at 8th, 16th & 24th Storey)

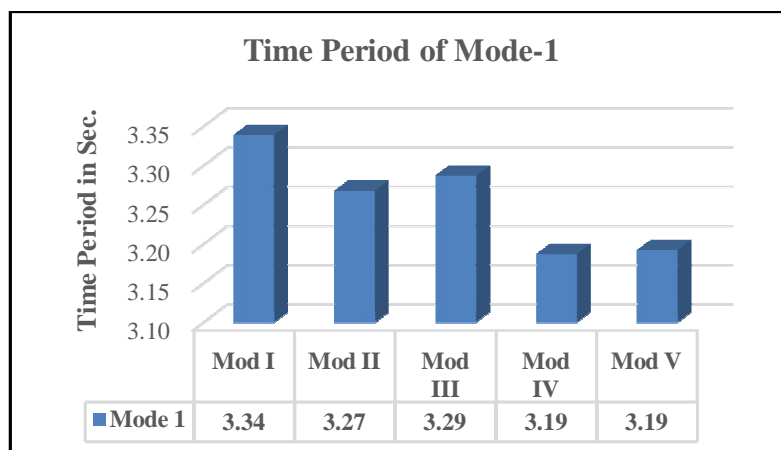


Fig 16: Comparison of time period for first modes

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## V. CONCLUSION

Based on the analysis results following conclusions are drawn

- The use of outrigger system in high-rise buildings increase the stiffness and makes the structural form efficient under lateral load.
- X Bracings and shear walls as certain refuge floors can be used as an outrigger systems.
- Outrigger system as an X bracing at peripheral of building on 12th & 24th Storey reduces top storey displacement by 4.5%. There is negligible change in time period of building and base shear of building.
- Outrigger system as a shear walls at peripheral of building on 12th & 24th Storey reduces displacement by 3.5%. There is negligible change in time period of building and base shear of building.
- Outrigger system as an X bracing at peripheral of building on 8th, 16th & 24th Storey reduces displacement by 9.5%. There is negligible change in time period of building and base shear of building.
- Outrigger system as a shear walls at peripheral of building on 8th, 16th & 24th storey reduces displacement by 4.5%. Also there is reduction in time period of building by 5% and in base shear by 8%.
- The optimum type of outrigger is Model V i.e. Building with External X Brace at 8th, 16th & 24th Storey).

## REFERENCES

- [1] Thejaswini R.M. And Rashmi A.R.: "Analysis and Comparison of different Lateral load resisting structural Forms" International Journal of Engineering Research & Technology (IJERT) Vol. 4 Issue 7, July – 2015
- [2] Po Seng Kian, Frits TorangSiahaan: "The use of outrigger and belt truss system for high-rise concrete buildings"
- [3] N. Herath, N. Haritos, T. Ngo & P. Mendis: "Behaviour of Outrigger Beams in High rise Buildings under Earthquake Loads", Australian Earthquake Engineering Society 2009
- [4] Kiran Kamath, N. Divya, Asha U Rao: "A Study on Static and Dynamic Behavior of Outrigger Structural System for Tall Buildings", Bonfiring International Journal of Industrial Engineering and Management Science, Vol2, No 4, December 2012
- [5] Alpana L. Gawate J.P. Bhusari: "Behaviour of outrigger structural system for high-rise building", International Journal of Modern Trends in Engineering & Research, e-ISSN No.:2349-9745, Date: 2-4 July, 2015
- [6] VijayaKumariGowda M R and Manohar B C: "A Study on Dynamic Analysis of Tall Structure with Belt Truss Systems for Different Seismic Zones", International Journal of Engineering Research & Technology (IJERT) Vol. 4 Issue 8, August – 2015
- [7] Kiran Kamath, Shashikumar Rao and Shruthi : "Optimum Positioning of Outriggers to Reduce Differential Column Shortening Due to Long Term Effects in Tall Buildings", International Journal of Advanced Research in Science and Technology, Volume 4, Issue 3, 2015, pp.353-357.
- [8] Abbas Haghollahi, Mohsen BesharatFerdous and Mehdi Kasiri: "Optimization of outrigger locations in steel tall buildings subjected to earthquake loads", 15th world conference of earthquake engineering 2012.
- [9] Shivacharan K, Chandrakala S , Karthik N M: "Optimum Position of Outrigger System for Tall Vertical Irregularity Structures", IOSR Journal of Mechanical and Civil Engineering, Volume 12, Issue 2 Ver. II (Mar - Apr. 2015), PP 54-63
- [10] Abdul Karim Mulla and Shrinivas B.N: "A Study on Outrigger System in a Tall R.C. Structure with Steel Bracing", International Journal of Engineering Research & Technology (IJERT) Vol. 4 Issue 7, July – 2015
- [11] Dr. S. A. Halkude, Mr. C. G. Konapure and Ms. C. A. Madgundi: "Effect of Seismicity on Irregular Shape Structure" International Journal of Engineering Research & Technology (IJERT) Vol. 3 Issue 6, June – 2014
- [12] Mr.Gururaj B. Katti and Dr. BasavrajBaapgol: "Seismic Analysis of Multistoried RCC Buildings Due to Mass Irregularity By Time History Analysis", International Journal of Engineering Research & Technology (IJERT) Vol. 3 Issue 6, June – 2014