# Steel Outrigger Bracing System Position Optimization for High Rise Construction

**Piyush Jaiswal[1] Lavina Talwale[2]**
[1]M. Tech Scholar [2]Assistant Professor
[1,2]Department of Civil Engineering & Applied Mechanics
[1,2]Shiv Kumar Singh Institute of Technology & Science, Indore College, Indore, M.P., India

*Abstract*— The outrigger bracing system provides the solution to control excessive drift and displacement in high rise buildings. It consists of the outrigger bracings or the outrigger trusses which connects the central core of the building with the peripheral columns and the peripheral columns relate to one another through the belt trusses. In this study, the conventional structural model having the central core of reinforced concrete and the models with outrigger at top, top and 0.75H, top and 0.5H and top and 0.25H where H is the total height of the building are modeled for the 20, 40 and 60 storey building heights. The main objective of the study is to determine the optimum location of the outrigger system. ETABS 2017 software package is used for the modeling and analysis of this study. The models are analyzed by three methods, Equivalent Static Method, Response Spectrum Method and the Non-Linear Time History Analysis and results are compared in terms of the maximum top displacement, storey drift, base shear, moment in the core, axial forces in peripheral column, roof acceleration, roof velocity and time period of the structure. The results obtained from different analyses suggests that the optimum location of the outrigger bracing system for high rise building is at the top and mid height of the building for which the top displacement and drift is minimum. The outrigger structures are stiffer than the conventional structures and hence time period decreases. The top and 0.5H model of outriggers showed the maximum decrease in moment at the base of the central core and the maximum increase in axial forces in peripheral columns because they are engaged with central core and forms a tension compression couple that resists external loadings.

***Keywords:*** Truss Bridge, IRC loading

## I. INTRODUCTION

The demand for the high-rise buildings has been increased rapidly in the recent times owing to the rise in population and decrease in the available land. The advancements in the engineering techniques and technological advancements have made it possible to develop super high-rise structures with perfection and safety. There is a trend of constructing tall and more slender structures owning to the aesthetic demands and more essentially because of the small land area available due to the raise in land prices and rapid urbanization. The tall buildings are more subjected to the lateral loads due to wind and seismic forces and hence must be designed accordingly to resist any lateral loadings. In the design of high rise buildings, the requirements of strength and stiffness must be adequately met and the lateral displacements and drift arising due to the seismic and wind loads must be properly controlled in order to avoid the structural as well as nonstructural damages. For this purpose, various types of the structural systems emerged over the ages which are briefly described.

### *A. Outrigger System*

It has been found through various research that the shear wall when used alone provides resistance effectively only upto a certain height and beyond that it becomes uneconomical when compared with the benefit it provides. Thus, there is necessity of some other more efficient structural system offering more stiffness and strength to the high-rise structures against wind and seismic loadings and also considering the economy criteria. The outrigger bracing system provides more stiffness to tall buildings against the lateral displacement and drifts without paying any extra cost on the steel and proves to be very economical solution for the drift control.

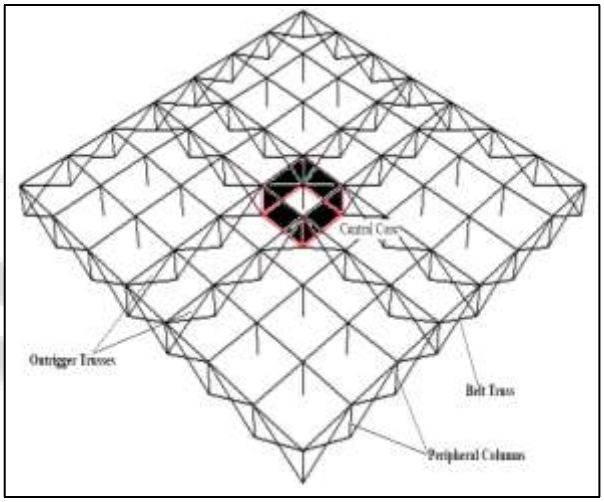


Fig. 1: Component of Outrigger system

## II. OBJECTIVE OF STUDY

The following are the objectives of the current study-

- To study the concept of outrigger structural system and examine the response of the same using the linear and nonlinear methods of analysis.
- To vary the location of outrigger bracings with belt trusses along the height of structure and find out the best location of outrigger system in terms of performance, least lateral displacement, and economic consideration.
- To compare the results in terms of storey drift, storey shear, top storey displacement, and roof velocity and acceleration of outrigger system with the conventional framed structural system.
- To compare the moment in the central core and axial forces in the peripheral columns of the outrigger system models with that of the conventional models.

## III. METHODOLOGY

In this study comparison of outrigger system and conventional structure under seismic as well as gravity loading is worked out, and concept of outrigger structural system is studied. To achieve the objective of this study the methodology used is as follows.

- Review the existing literature and various standards on outrigger structural system.
- Selection of the building's geometry and Seismic zone.
- Calculation of loads on building using Indian Standard Codes.
- Formation of load combination as per IS: 1893 (Part I): 2016
- Preliminary member sections are assumed and modeling of conventional frame with central core and conventional frame with central core and outrigger system is done by using ETABS 2017 software.
- The models are of 20, 40 and 60 storey height.
- The position of one outrigger is kept fixed at top and other one is varied along the height as 0.25H, 0.5H and 0.75H where H is height of structural model.
- The linear static and linear dynamic analysis is done to find out parameters like displacement, inter storey drift, moment in core, base shear, time period and axial force in the peripheral column.
- The results are compared with nonlinear dynamic analysis i.e., Time History Method.
- The efficiency of outrigger system is found out based on above parameters and the optimum location of outrigger for which displacement and drift is least found.
- In the end, the number of outriggers bracing systems is also increased one by one and a comparative study of the subsequent reduction in lateral displacement is done.

The data used in this study is summarized below.

| | |
|---|---|
| Types of model | Conventional structure with central core and Conventional structure with central core and outriggers. |
| Location of outriggers | One fixed at the top and location of second one is varied at 0.25H, 0.5H and 0.75H |
| Number of storeys | 30 storey |
| 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 *600 |
| Size of beams | 250*600 |
| Slab Thickness | 150 |

| Parameter | 20 Storey | 40 Storey | 60 Storey |
|---|---|---|---|
| Bay Width | 3m | 4m | 5m |
| No. of Bays | 5 | 5 | 5 |

| | | | |
|---|---|---|---|
| Plan Dimensions | 15m x 15m | 20m x 20m | 25m x 25m |
| Storey Height | 3m | 3m | 3m |
| Height of structure | 60m | 120m | 180m |
| Slenderness Ratio | 4 | 6 | 7.2 |

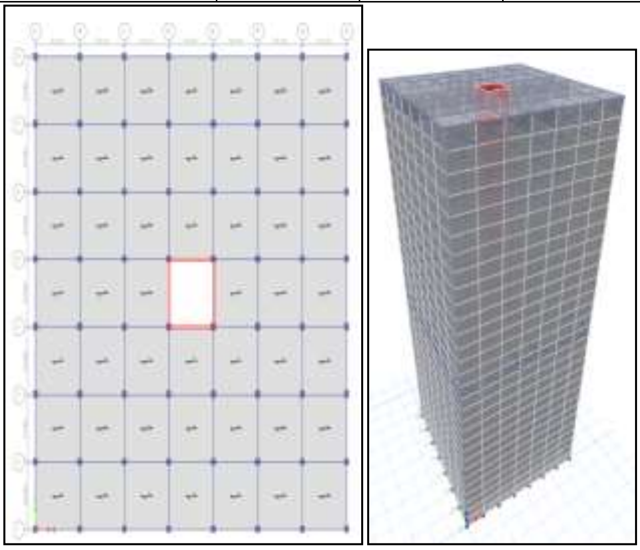

Fig. 2: Deck slab with Bottom chord and stringers beam

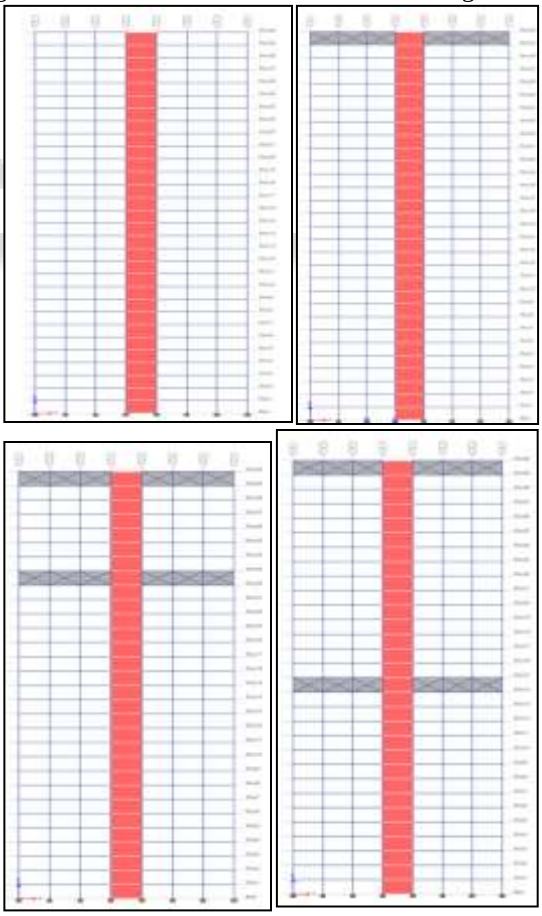

Fig. 3: isometric view of truss bridge in SAP200 software

## IV. RESULTS

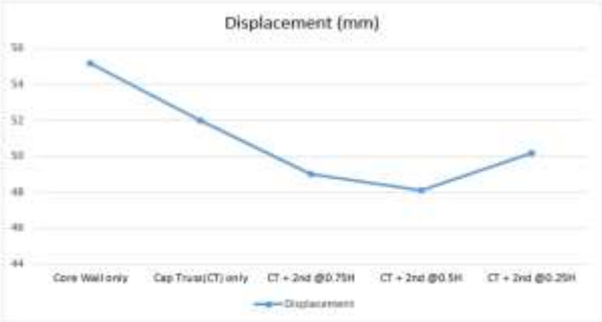


Figure 4 Results obtained in problem validation.

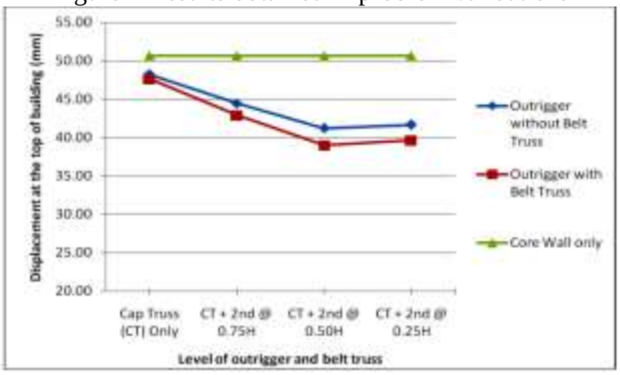


Fig. 5: Results obtained by P.M.B. Raj Kiran Nanduri et al.

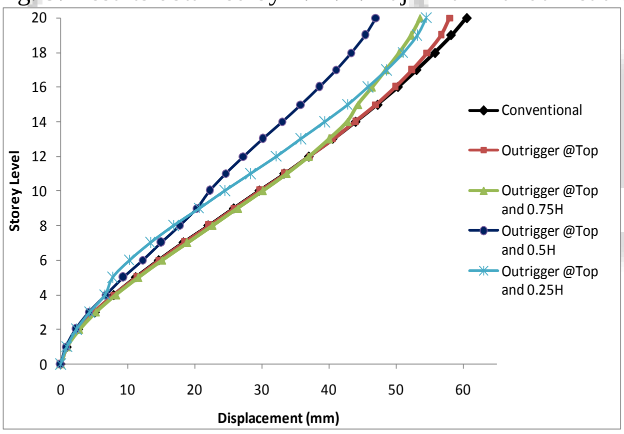


Fig. 6: Storey displacements of 20 storey models

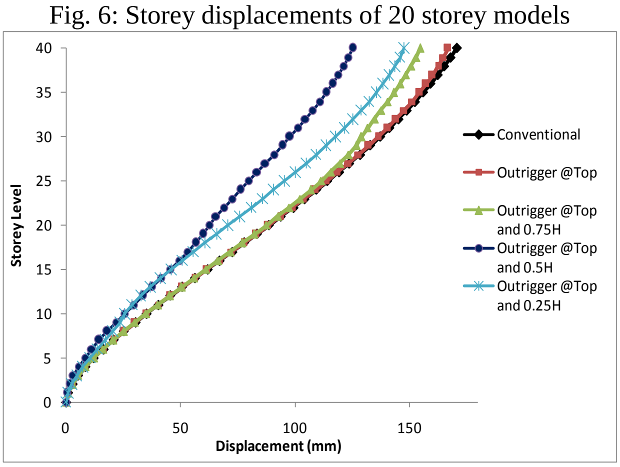


Fig. 7: Stringer beam flange area Vs Slab Displacement

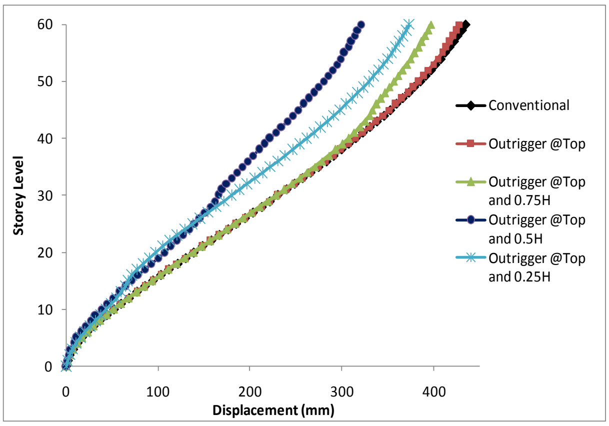


Fig. 8: Stringer beam flange area Vs Base Shear

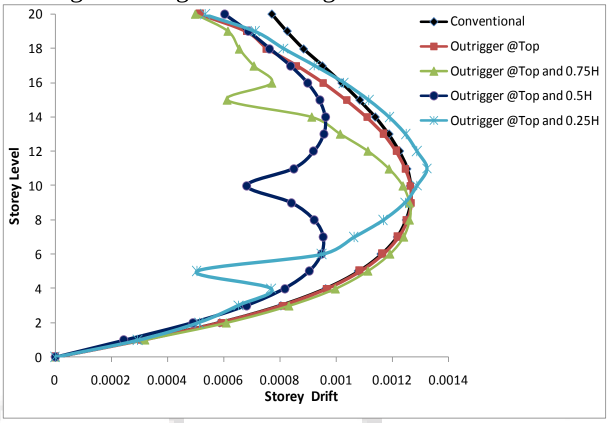


Fig. 9: Storey drift of 20 storey models

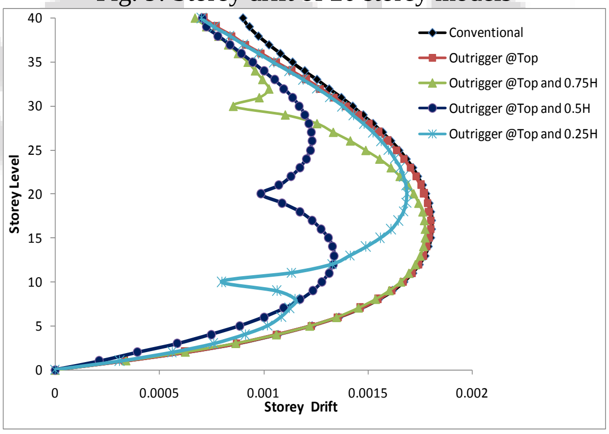


Fig. 10: Storey drift of 40 storey models

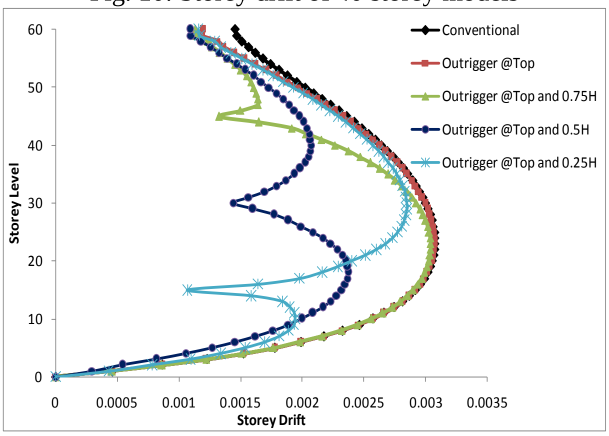


Fig. 11: Storey drift of 60 storey models

## V. CONCLUSION

- From the present comparative study of conventional model and various configurations of the outrigger bracing models by Equivalent Static Method, Response Spectrum Method and Time History Analysis, it can be summarized that the outrigger bracing systems are effective in controlling the excessive lateral displacement and storey drift. The optimized location of outrigger is found to be at top and 0.5H considering various factors such as the lateral displacement, maximum storey drift, roof acceleration, roof velocity, base shear and time period.
- It is found that the lateral displacement and storey drift is minimum if outriggers are constructed at top and mid height of structure. Also, time period is found to be the least in this case which means that the stiffness of the structure is increased.
- There is marginal decrease in case of base shear in the outrigger models. The roof acceleration and roof velocity are found to be minimum in the model with outriggers at the top and 0.5H in the time history analysis.
- The moment at the base of the central core decreases and the axial force in the peripheral column connected directly to the central core through the outrigger truss increases when outriggers are provided at the top and middle (0.5H) of the structure. This helps in resisting the lateral loads more efficiently since the peripheral gravity columns are converted to the lateral load resisting columns by forming a tension compression couple in the outer peripheral columns.
- It is also found that increasing the number of outriggers does not decrease the lateral displacement with the same rate. Single outrigger at top and mid height is very economical and efficient in controlling excessive drift and displacement but adding on a greater number of outriggers increases the stiffness of the structure but the magnitude of further decrease in displacement is not that much and leads to uneconomical solutions. Hence outriggers become uneconomical beyond a certain limit.

## REFERENCES

[1] B.S. Taranath (1975). “Optimum belt truss locations for high rise structures.” The Structural Engineeing. 53: 345-348.
[2] J.W. McNabb (1975). “Drift reduction factors for belted high rise structures.” Engineering Journal, AISC 14:44-47.
[3] H. C. Chan and J. S. Kuang (1988). “Stiffened Coupled Shear Walls.” Journal of Engineering Mechanics, 115(4), 689–703.
[4] Xiaoxuan Qi and Shuang Chen (1996). “Design Issues Associated with Outriggers in Concrete High-Rise Buildings.” Tall Building Structure-A World View.
[5] Po Seng Kian And Frits Torang Siahaan (2001), “The Use Of Outrigger And Belt Truss System For High-Rise Concrete Buildings”. Dimensi Teknik Sipil, Vol 3, No. 1, Maret 2001.
[6] J.C.D Hoenderkamp and M.C.M. Baker (2003). “Analysis of high-rise building braced frames with outrigger belts.” Structural Design of Tall and Special Buildings.
[7] Navab Assadi Zeidabadi, Kamal Mirtalae and Barzin Mobasher (2004). “Optimized use of the outrigger system to stiffen the coupled shear walls in tall buildings”. Struct. Design Tall Spec. Build. 13, 9–27 (2004)
[8] K K Sangle, K M Bajoria And V Mhalungkar(2012). “Seismic Analysis of High Rise Steel Frame With And Without Bracing”. 15th World Conference of Earthquake Engineering 2012.
[9] Junais Ahmed AK and Yamini Sreevalli (2014). “Application of Outrigger in Slender High-Rise Buildings to Reduce Fundamental Time Period”. International Journal of Mechanical and Production Engineering, ISSN: 2320-2092, Volume- 2, Issue- 7, July-2014
[10] Shruti Badami and M. R. Suresh (2014). “A Study on Behavior of Structural Systems for Tall Buildings Subjected to Lateral Loads”. International Journal of Engineering Research & Technology (IJERT), Vol. 3 Issue 7, July – 2014
[11] Abdul Karim Mulla and Shrinivas B.N (2015). “A Study On Outrigger System In A Tall R.C. Structure With Steel Bracing”. International Journal Of Engineering Research & Technology,Vol. 4, Issue 7, July 2015.
[12] H.S. Sukesh, H.S. Suresh Chandra and P.S. Lakshmi (2017). “ Influence of Outrigger system in RC Structures for Different Seismic Zones”. International Research Journal of Engineering and Technology (IRJET), Volume: 04 Issue: 06 June -2017
[13] Prajyot A. Kakde and Ravindra Desai (2017). “Comparative Study of Outrigger and Belt Truss Structural System for Steel and Concrete Material”. International Research Journal of Engineering and Technology (IRJET), Volume: 04 Issue: 05 ,May -2017
[14] Sajjad Baygi and Amin Khazaee (2019). “The Optimal Number of Outriggers in a Structure Under Different Lateral Loadings”. J. Inst. Eng. India Ser. A
[15] Nair R. S. (1998). “Belt trusses and basements as virtual outriggers for tall buildings”. Engineering Journal AISC, Fourth Quarter, 140-146, 1998
[16] J R Wu and Q S Li (2003). “Structural Performance of Multi Outrigger-Braced Tall Buildings”. The Structural Design of Tall and Special Buildings. Published online by Wiley INterScience, page 155-176, 2003.
[17] Z Bayati, M Mahdikhani And A Rahaei (2008). “Optimized Use of Multi-Outriggers System to Stiffen Tall Buildings”. 14th World Conference of Earthquake Engineering 2008.
[18] S. Fawzia, A Nasir and T. Fatima (2011) “Study of Effectiveness of Outrigger System for High-Rise Buildings under Earthquake Loads”. International Journal of Civil Environmental, Structural, Construction and Architectural. Volume: 05, Number: 12, Page 789-797, 2011.
[19] Joseph, L. and Choi, H. (2012). “Outrigger System Design Considerations”. International Journal of High-Rise Buildings. Council on Tall Buildings and Urban Habitat: Chicago, Volume 1 Number 3
[20] Andrew J. Horton. “Virtual Outriggers in Tall Buildings”

 

[21] Ajinkya P. Gadkari and N.G. Gore (2018). "Performance of Multy Outrigger Structural System in Geometrically Irregular Shaped Highrise Building". International Research Journal of Engineering and Technology (IRJET), Volume: 05 Issue: 07 , July 2018
[22] IS 456: 2000. "Plain and Reinforced concrete- Code of Practice", Bureau of Indian Standard, New Delhi.
[23] IS 1893 (Part 1): 2016. "Criteria for Earthquake Resistant Design of Structures". Bureau of Indian Standard, New Delhi.
[24] IS 16700 – 2017. "Criteria for Structural Safety of Tall Concrete Buildings". Bureau of Indian Standard, New Delhi.

 