Effective position of Shear walls and Braces as an Outrigger systems in tall building

[1]Mohd. Imran Mohd. Azghar, [2]Hemant B. Dahake

[1]PG Student, [2]Assistant Professor
Department of Civil Engineering,
G. H. Raisoni College of Engineering & Management, Amravati, Maharashtra, India

***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 this paper, 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.

***Index Terms*: 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.

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 load resisting structural systems to understand the realistic performance of the building during earthquake and under the excessive wind pressure as well as to select structural system of tall building to stay in good condition with effect of gravity, live load and external lateral 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 shear wall location, Tube structure and outrigger structure. Results of the analysis reveal that the values of displacement were less in tube structure and outrigger structural system. Also stability of structure will boost 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 story which 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 of tall buildings, because as the height of the building increases the core alone is not adequate to keep the drift within permissible limit. Therefore some other structural element is to be added in that building to take care of drift. Outriggers are the structural system, 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 has been drawn. When there was provision of only one outrigger, the system was not effective as concerning of drift. There was a remarkable change observed in the drift profile when two outriggers were provided. One important conclusion figured out from this research is no story was found as soft story for all 9 trials made in model with two outriggers with changes in cross sectional dimensions of columns and thickness of shear wall.

Shivshankar K et al. (2015), presented research involving investigation of the action of outrigger structural system in Tall vertical irregularity structure. Vertical geometric irregularity shall be considered to exist where the horizontal dimension of the lateral force resisting system in any storey is more than 150 percent of that in its adjacent storey. In this study, 30 storey models having vertical irregularity were taken. The building plan changes at 11th and 21st storey. These models were analyzed with only bare frame and bare frame with one outrigger and belt truss for 6 configuration of outrigger beam by changing their position. Similarly bare frame with two outrigger and belt truss for 5 different configurations and the response of the structure was evaluated under the different parameters i.e. Lateral displacement, building drift, maximum storey shear and axial load of different columns. To examine the behaviour of vertical irregularity of outrigger structural system, linear static analysis has been carried out as per the Indian standard. It was recognized through this research that around 28.58% and 27% lateral deflection and building drift was restrain by providing outrigger structural system in high rise vertical irregularity structure when it is provided at 0.67 times its height compare to bare frame as well as 37.7% and 36.11% of the Deflection and drift is controlled by providing outrigger with belt truss at 0.67 times and 0.5 times its height when compared with bare frame. This study concluded that the optimum location of outrigger was between 0.5 times its heights in tall vertical irregularity structure.

From the available literatures, it is observed that, the tall buildings are 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.

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 masonryare taken as 25 kN/m3 and 20 kN/m3 respectively. Live load intensity is taken as 3 kN/m2 for all floor level. Weight of floor finish is considered as 1.5 kN/m2. 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 300mm x 300mm.

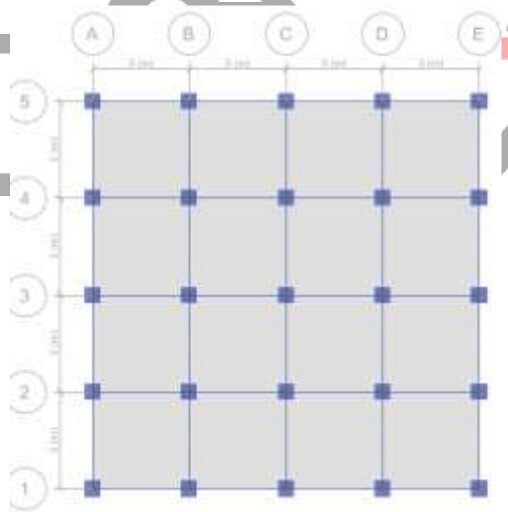

Fig 1: Plan of building

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 23rd & 24th Storey as shown in figure 3.
Model III: Building with shear walls at 23rd & 24th Storey as shown in figure 4.
Model IV: Building with X Brace at Core area as shown in figure 5.
Model V: Building with Shear Wall at Core area as shown in figure 6.

Model I: Building without any Outrigger systems:

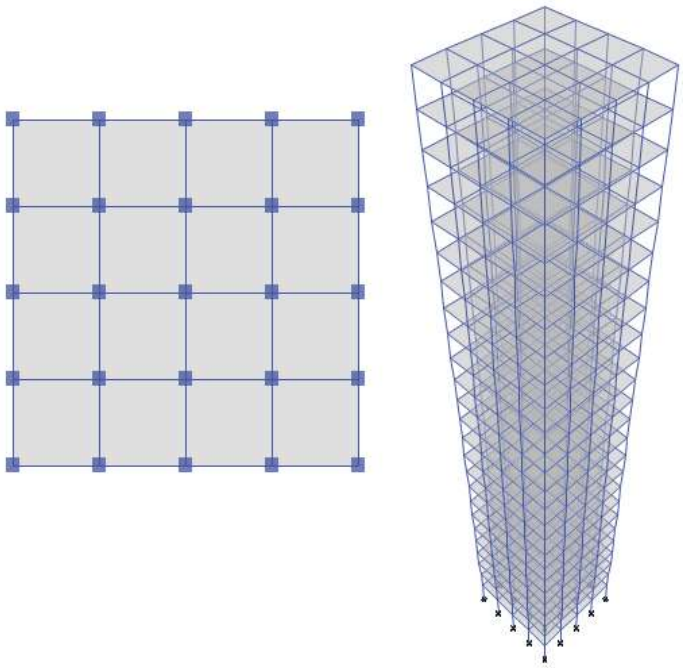

Figure 2: Building without any Outrigger systems (Model I)

Model II: Building with External X Brace at 23rd & 24th Storey:

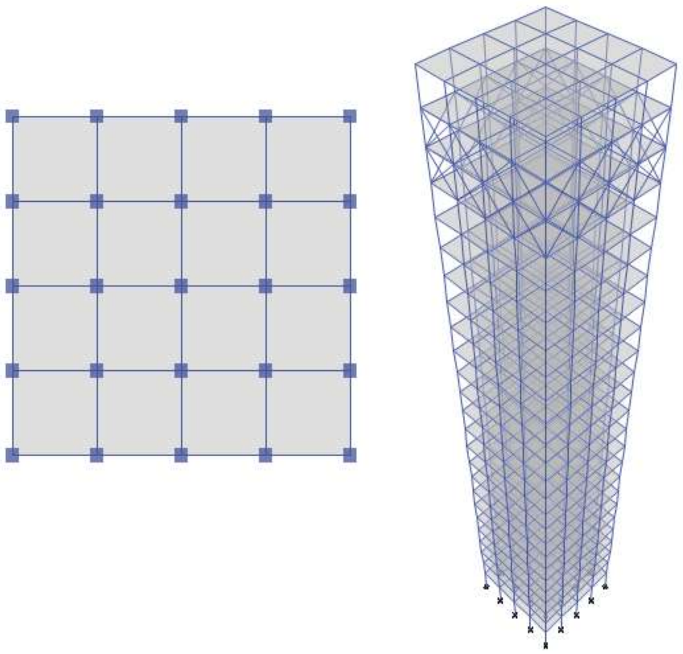

Figure 3: Building with External X Brace at 23rd & 24th Storey (Model II)

Model III: Building with shear walls at 23rd & 24th Storey:

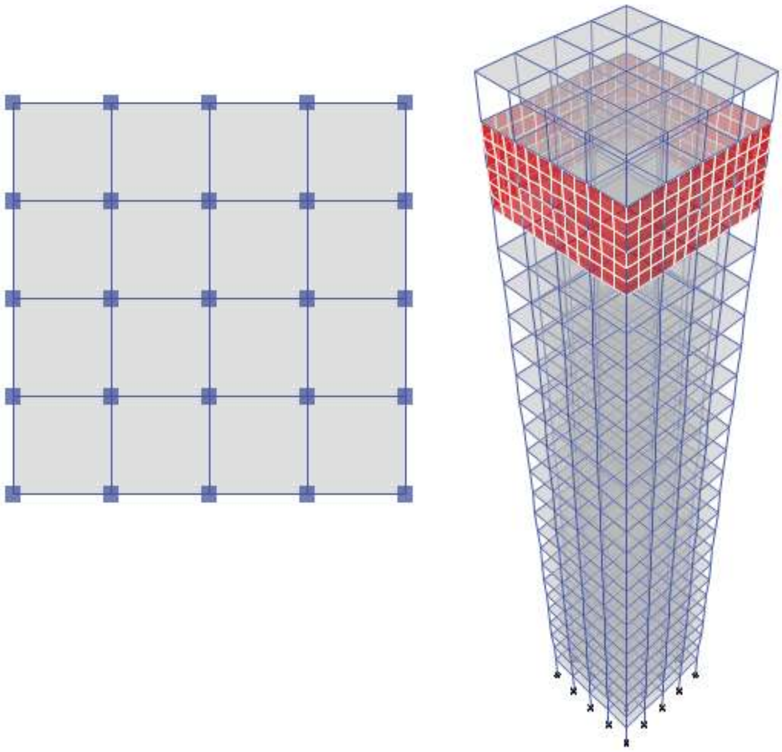

Figure 4: Building with External shear walls at 23rd & 24th Storey (Model III)

Model IV: Building with X Brace at Core area:

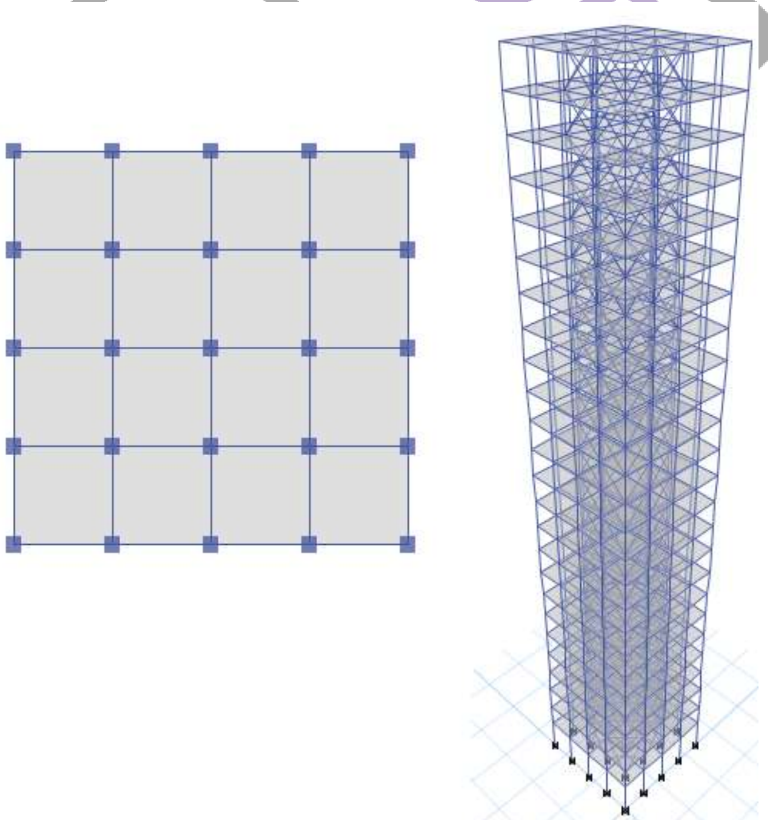

Figure 5: Building with X Brace at Core area (Model IV)

Model V: Building with Shear Wall at Core area:

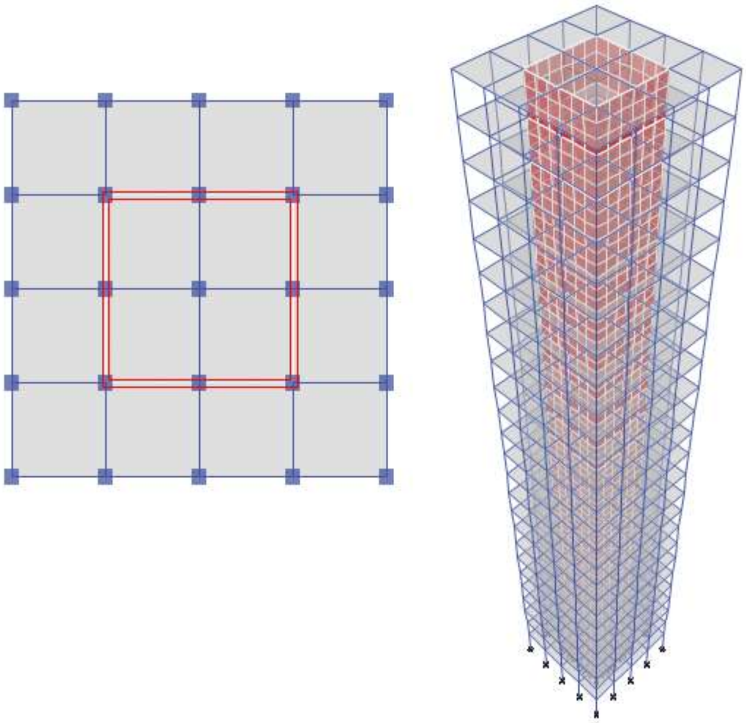

Figure 6: Building with shear walls at Core area (Model V)

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 23rd & 24th Storey (Model II), use of peripheral shear walls at 23rd & 24th Storey (Model III) reduces the displacement up to very negligible value i.e. 1.4%. Use of X bracing at core area (Model IV) reduces the displacement up to 96%. The building with use of shear walls at core area (Model V) reduces the displacement up to 180%.

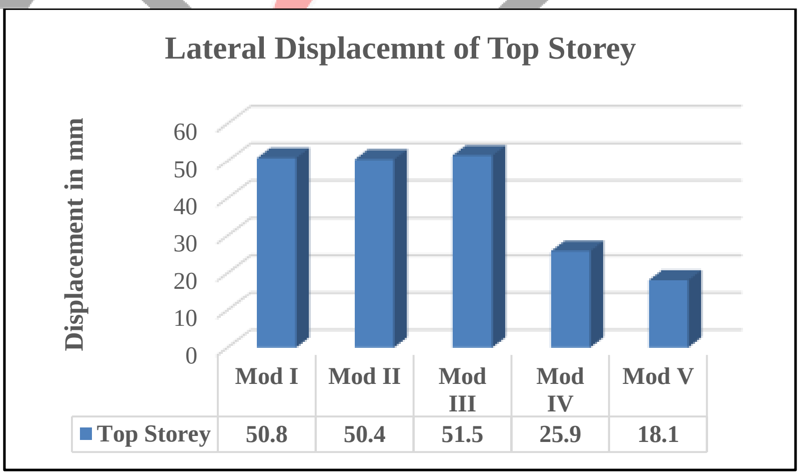

Fig 11: Comparison of lateral displacement

Base shear

There is no considerable change in Base shear of model II (Building with External X Brace at 23rd & 24th Storey), model III (Building with shear walls at 23rd & 24th Storey), model IV (Building with X Brace at Core area). For model V (Building with Shear Wall), base shear is reduce to 21% of model I (Building without any Outrigger system).

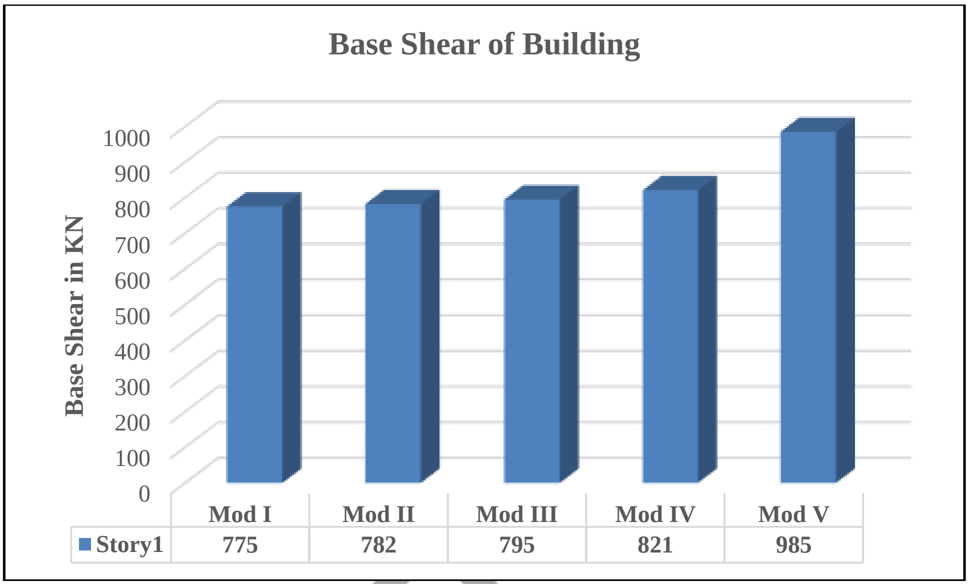

Fig 15: Comparison of Base shear

Time period and frequency

It is observed that the time period of vibration is more for Model I (Building without any Outrigger 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 shear walls at core area)

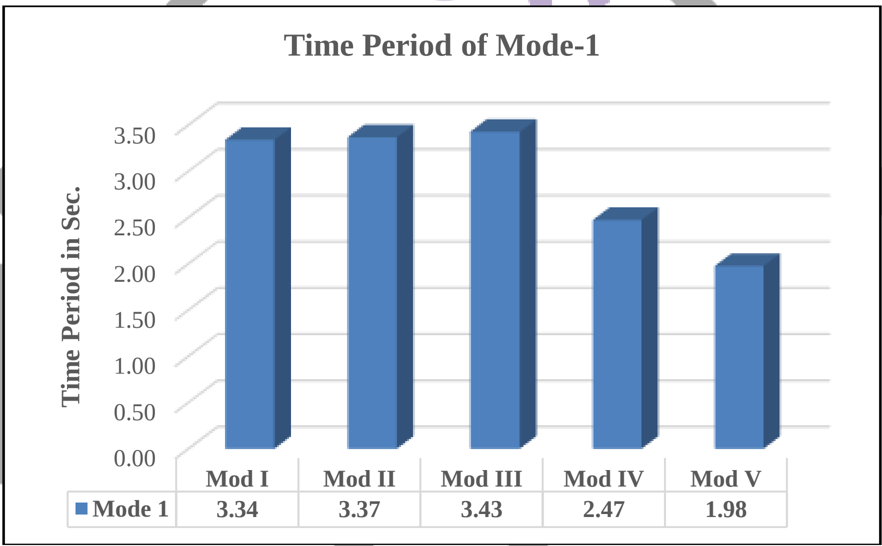

Fig 16: Comparison of time period for first modes

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.
- For outrigger system as an X bracing and shear walls at peripheral of building on 23rd & 24th Storey, there is negligible change in time period of building and base shear of building.
- Outrigger system as an X bracing at core area of building reduces displacement by 96%. There is reduction in time period of building by 35% and base shear of building by 5.6%.
- Outrigger system as a shear walls at core area of building reduces displacement by 180%. There is reduction in time period of building by 69% and base shear of building by 21%.
- The effective type of outrigger is Model V i.e. Building with shear walls at core area.

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