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Optimum Position of Outrigger with Belt Wall

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ABSTRACT: Tall buildings need a lateral load resisting system to resist the lateral loads induced by wind or earthquake forces. One of the most efficient systems is outrigger. Outriggers are structural systems that support building against lateral loads. The various parameters like lateral displacement, storey drift, core moment and optimum position related to outrigger and belt wall are reviewed. The reviewed approach for the design and development of tall building using outrigger and belt wall is useful to provide a potential solution. Recently, outrigger and belt wall system is widely used to reduce lateral drift. To achieve required stiffness of tall building increase of bracings sizes as well as introduction of additional lateral load resisting system such as belt truss and outriggers is required. The placement of outrigger trusses increases the effective depth of the structure and significantly improves the lateral stiffness under lateral load. Three dimensional modelling for G+45 storey building of concrete is done and the analysis results are taken for the same. For the seismic analysis zone factor for zone II and medium soil type is considered according to IS: 1893 (part1)-2002. Therefore the analysis of wind load can taken from IS: 875 (part 3)-1987. Finally, a relative study of time period according to stiffness was done using software “ETABS v. 16”.

KEYWORDS: Tall buildings, lateral load, lateral stiffness, outrigger and belt wall system, ETABS.

I. INTRODUCTION

Outriggers are rigid horizontal structure i.e. truss or beam which connect core wall and outer column of building to improve building strength and overturning stiffness. Outriggers have been used in tall building for nearly half century, but innovative design principle has been improving its efficiency. Outrigger system is one type of structural system which is formed from a cantilever shaped horizontal member connected to structures inner core and outer columns. Through the connection, the moment arm of the core will be increased which lead to higher lateral stiffness of the system. Central core in a building act as cantilever, outriggers are provided to reduce overturning moment in core and to transfer moment from core to outer column by connecting the core and column. The outrigger systems can be produced in any combination of steel, concrete and composite construction. Outrigger may be extended to both side of central core or core may be located at one side of building with outrigger extending to other side column. Belt wall connects outer perimeter column of a building and offer a wider perimeter to resist lateral deflection of building. Behaviour of outrigger with belt wall proven to be more effective when compare to the outrigger without belt wall. The exterior columns and belt wall system resist the rotation of central shear core and decrease the lateral deformation as well as bending moment at base of the structure. The belt truss tied the peripheral column of building while the outriggers engage them with main or central shear wall. Therefore; exterior columns restrained the core wall from free rotation through outrigger arms. Effectiveness of outrigger and belt wall can be affected by the various factors like position of outrigger and belt wall, number of outrigger, geometry of building, types of core i.e. concrete or steel and floor to floor height.

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II. LITERATURE SURVEY

P.M.B. Raj KiranNanduriet. al. (2016)^[12] investigated, as the height of the building increases the stiffness of the building decreases. To increase the stiffness of the building some lateral system should incorporate in the building which can resist the lateral load such wind load. The study concluded that the maximum reduction in lateral displacement occurred when the outrigger and belt truss placed at top and mid height of the building and earthquake load acting on building.

Abdul Karim Mulla and Shrinivas B.N (2015)^[7] carried out research in regular as well as vertically irregular structure to increase axial stiffness with exterior columns to resist the overturning moment by introducing outrigger structural system with steel bracing. It was observed through this research that there is considerable reduction in Time period when outrigger was introduced in regular and irregular building structure which will improve the overall stiffness of the structure.

Rafael Shehu et al. (2015)^[10] studied ductile characteristic of the structures and investigated three reinforced concrete buildings with different heights and four types of structural models through nonlinear analysis using finite elements method. From study it is concluded that Performance of Outrigger structure is higher than without Outrigger structures, but their ductility is reduced.

Krunal Z. Mistry et al. (2015)^[8] analyzed 40–storey three dimensional models of outrigger and belt truss system subjected to wind and earthquake load to find the lateral displacement reduction related to the outrigger and belt truss system location. Wind load in this study is established in accordance with IS 875(part 3) and Earthquake load is accordance with IS 1893(part 1)-2002. There is maximum reduction in displacement and shear force when 1st outrigger is placed at 20th floor, 2nd outrigger is placed at 10th floor and 3rd outrigger is placed at 30th floor i.e. location of three outriggers are at mid height, 1/4th height, and 3/4th height.

M. R. Jahanshahi et al. (2013)^[4] presented a methodology for determining the optimum location of an outrigger-belt truss system, based on maximizing the outrigger-belt truss system's strain energy. Optimum location for outrigger-belt truss system is calculated for three types of lateral loadings, i.e. uniformly and triangularly distributed loads along structure's height, and concentrated load at top of the structure. Optimum location of outrigger-belt truss system for concentrated load at top of the structure, uniformly and triangularly distributed loadings along height of the structure were calculated respectively as 0.667, 0.441 and 0.490 of structure's height as measured from the base.

III. METHEDODOLOGY AND MODELLING

ETABS is commonly used to analyse: Skyscrapers, parking garages, steel & concrete structures, low and high rise buildings, and portal frame structures. This paper mainly emphasizes on structural behaviour of multi-storey building for different plan configurations like outrigger and belt wall. Modelling of G+45storeys R.C.C. framed building is done on the ETABS software for analysis. Post analysis of the structure, maximum shear forces, bending moments, and maximum storey displacement are computed and then compared for all the analyzed cases. Loads considered are taken in accordance with the IS-875(Part 3), IS 1893(2002) code. Post analysis of the structure, maximum shear forces, bending moments, and maximum storey displacement are computed and then compared for all the analysed cases. Steps included in ETABS analysis and the design procedures are as follows,

1. Define Plan Grids and Story Data
2. Define Material Properties
3. Define Frame and Slab Sections
4. Define Load Cases
5. Draw Beam and Column Objects (Frame Members)
6. Assign Slab Sections
7. Assign Restraints
8. Assign Slab Loads
9. Run the Analysis and View Analysis Results Graphically

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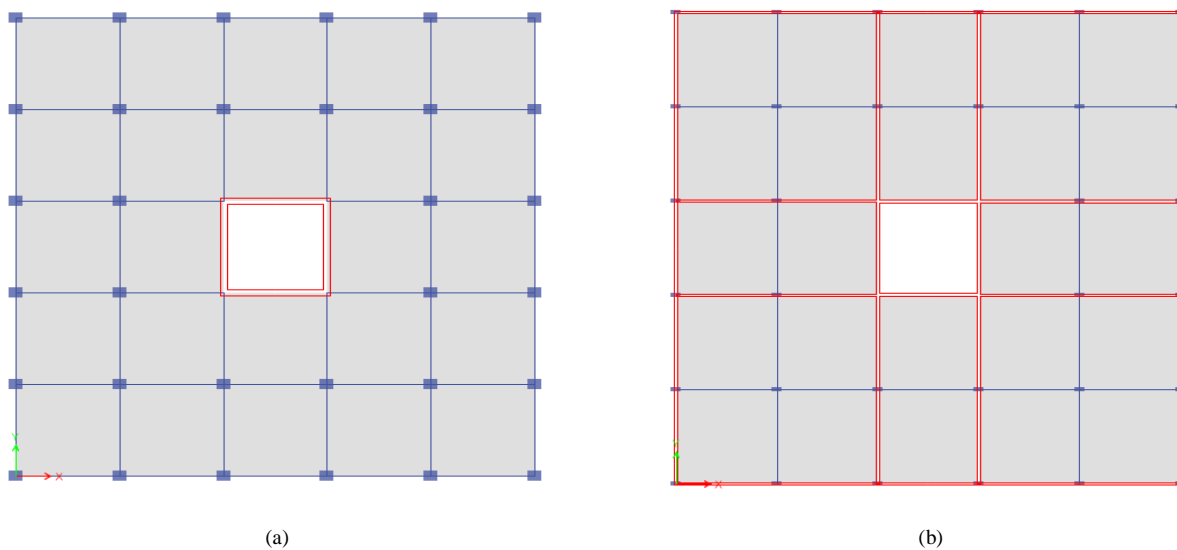
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10. Design Concrete Frame Element

Table 1-Building description

Number of stories	G+45
Total height of the building	149.55m
Height of each storey	3.45m
Height of service floor	2.1m
Size of the beam (mm)	230X300,400X350,500X450,600X500
Size of column (mm)	600X300,600X500,700X400,800X700
Thickness of slab (mm)	150,175,200,250
Shear wall sizes (mm)	175,200,250,300
Grade of concrete	M50
Grade of rebar	HYSD500
Support at base	FIXED
Seismic zone	II
Response Reduction Factor	3
Importance Factor	1
Aspect ratio	5.00

This structure data provides model geometry information, including items such as storey levels, height of each storey etc. Plan of the building for all the cases is shown in the following figure. Figs. (a) shows plan without outrigger and belt wall. (b) shows plan with outrigger and belt wall.



An RCC framed structure is basically an assembly of slabs, beams, columns and foundation inter-connected to each other as a unit. The load transfer mechanism in these structures is from slabs to beams, from beams to columns, and then ultimately from columns to the foundation, which in turn passes the load to the soil. In recent decades, outrigger-

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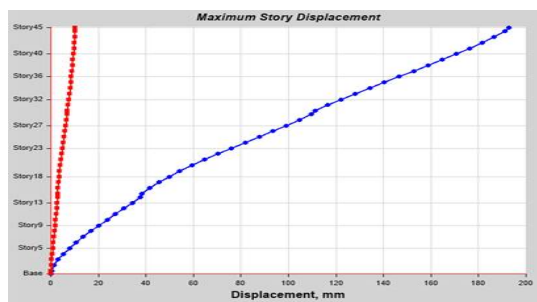
belt truss systems have been widely utilized in tall buildings for decreasing structure's deformation and increasing its resistance to lateral loads. Many researchers have studied the optimum location of an outrigger-belt truss system in a tall structure subjected to lateral loading based on the decrease in lateral displacement at the top of the structure.

IV. RESULT AND DISCUSSION

Table II-prototype model result

	With outrigger and belt wall (RCC)	Without outrigger and belt wall
MAX.STORY DISPLACEMENT (mm)	EX : 195 EY : 211 WX : 118 WY : 128	EX : 329 EY : 386 WX : 339 WY : 339
TIME PERIOD (sec)	4.5	5.6
DISPLACEMENT (mm)	58	81
STOREY DRIFT	SPECX:0.001463 SPECY:0.001574	SPECX:0.002273 SPECY:0.002716

The time period is 4.5, actual time period 4.6 and also maximum story displacement, lateral displacement and story drift is less than the model (without outrigger and belt wall). The structure is analysed and the conditions are checked on the displacement, which is safe enough. Fig. 2 (a) Maximum story displacement of the building for earthquake load (b) Maximum story displacement of the building for wind load(c) Maximum story drift.



(a)



(b)



(c)

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From the above Fig.2 (a), the maximum lateral displacement for the building without outrigger and with outrigger beam is gradually reduced for $h_2/h_1=1.3$ that is first outrigger at 15th and second outrigger at 30th storey. When compared to building without outrigger, the maximum lateral displacement is found to be 195 mm for the building subjected to earthquake load at the outrigger position of $h_1=h/2$. From the Fig.2 (b), it is observed that the maximum lateral displacement due to wind load is found to be 118 mm. The maximum lateral displacement is effectively reduced at outrigger position of $H_2/H_1=1.3$ that is one outrigger at 15th and other outrigger at 30th storey. From the Fig.2 (c), the maximum storey drift is effectively reduced at outrigger position of $H_2/H_1=1.3$ that is one outrigger at 15th and other outrigger at 30th storey. When compared to the building without outrigger, the maximum storey drift for with outrigger was observed to be 0.001463.

V. CONCLUSION

The various methods and techniques used to investigate uses of belt wall and outrigger in tall buildings structural system were discussed in this paper. It is found that many researchers focused on to obtain position of belt wall and outrigger to control deflection of building, controlling core moment and column reaction are the secondary need of research. Outrigger and belt wall is active and cost effective structural system which is one of the most developing structural systems. The present study in turn is useful for various research persons involved in design the tall buildings by using outrigger and belt wall system.

1. The use of outrigger and belt wall system in high-rise buildings increases the stiffness and makes the structural form efficient under lateral load.
2. Using second outrigger with cap truss gives the reduction of time period with belt wall. The optimum location of second outrigger is calculated by $h/2$ of the building.
3. Due to presence of the wall outrigger and belt wall in, it is stiffer structure when compared to structure with beam outrigger and belt wall. This is reflected in reduction of story displacement and story drift values.
4. In this concept outrigger beam or wall should connect lateral load resisting core to the columns at the exterior of the building. The core consists of shear walls. The use of beam or wall outrigger system in high-rise buildings increases the stiffness and makes the structural form efficient under lateral load.

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