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A Review on Dynamic Analysis of Outrigger Systems in High Rise Building against Lateral Loading

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Abstract: In this research dynamic analysis of outrigger system was carried out for a 60-storey building having an overall height of 180 m. First of all, comparison of performance between single and multi-outrigger was drawn, then analysis was carried out on different outriggers such as X, V, Inverted V and shear wall. Outriggers were placed according to Taranto theory i.e. (1/n+1), (2/n+1), (3/n+1), (4/n+1) … (n/n+1) of height [30]. Frame with only shear wall core and other outrigger models were analysed in ETABS software and different parameters as Maximum Story Displacement, Maximum Story Drift and Story Shears was compared. By analysing all the models by dynamic analysis for Earthquake Load (Response Spectrum) and static analysis for Wind Load it was concluded that structure becomes more resistive to lateral load with increase in no. of outriggers. Between X, V and inverted V type steel outrigger, inverted V is most effective but when shear wall was used as an outrigger, it gave better results than steel outriggers. Also belt trusses or shear bands increases the effect of outriggers even more.
Keywords: Outrigger System, ETABS, Dynamic Analysis, Static Analysis, Lateral Load

I. INTRODUCTION

From the early days of the human civilization migration has been a common part of day-to-day life. Early people travelled thousands of miles in search of food, water and safety. In the modern era people still migrate from one place to other for better job opportunities and lifestyle. As we know big cities and metropolis provides a great deal of life to human these days hence a lot of people are attracted toward the big cities. Due to which the population of these cities are raising ten folds. Supporting a large amount of population in a limited area of land has been a challenge to the society. Different types of land utilization techniques were evolved in the past years, one of these techniques is high rise buildings. High rise building is best land utilization technique in present time it can save a lot of land as the plan of high-rise buildings are very less as compare to the elevation.

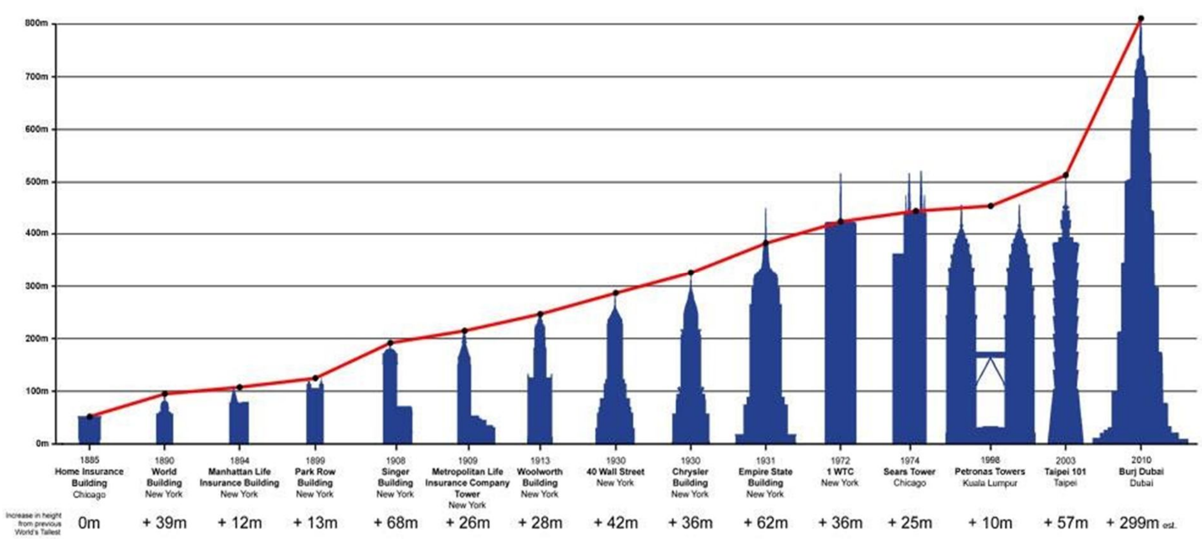

Figure:1 History of High-Rise Buildings
Source: www.ctbuh.org

With less plan area and more elevation, it has no limitations in vertical direction till sky. A high-rise building is a building having height more than 35 meters. High rise buildings that are taller than 150m are termed as “skyscrapers”, buildings taller than 300m are termed as “Supertall” and buildings taller than 600m are termed as “Megamall”.

But with great advantages there are some great challenges which are faced by engineer daily to make these buildings into reality. One of these challenges is lateral forces i.e., earthquake and wind forces. High rise building consists of a large elevation area than plan which makes them easy target for lateral forces. Hence, they are very venerable to earthquake and wind loads on regular basis. Hence to make high rise buildings safe against lateral loads different types of structural systems are used.

A. Description of the Model

In this research a 60-storey building was considered having 3 m of storey height. Plan dimension was of 38 × 38 m with five bays of 8 × 6 × 10 × 6 × 8 m in both directions. Total height of the building was 180 m. M30 grade of concrete and Fe345 steel was used in different members of structures. Size of the column was taken as 0.8 × 0.8 m and beam of size 0.5 × 0.8 m and for the outrigger beams ISMB250 was used. Slab thickness was kept 0.2 m. Vertical and horizontal loads were calculated as per recommendations of IS 456 [10], IS1893 (Part1) [9] and IS-875 (Part 3) [14]. First of all, comparison of performance between single and multi-outrigger was drawn, then analysis was carried out on different outriggers such as X, V, Inverted V and shear wall. ETABS software was used for modelling and analysis purpose, two type of analysis was done i.e., Response Spectrum and Static Wind Analysis.

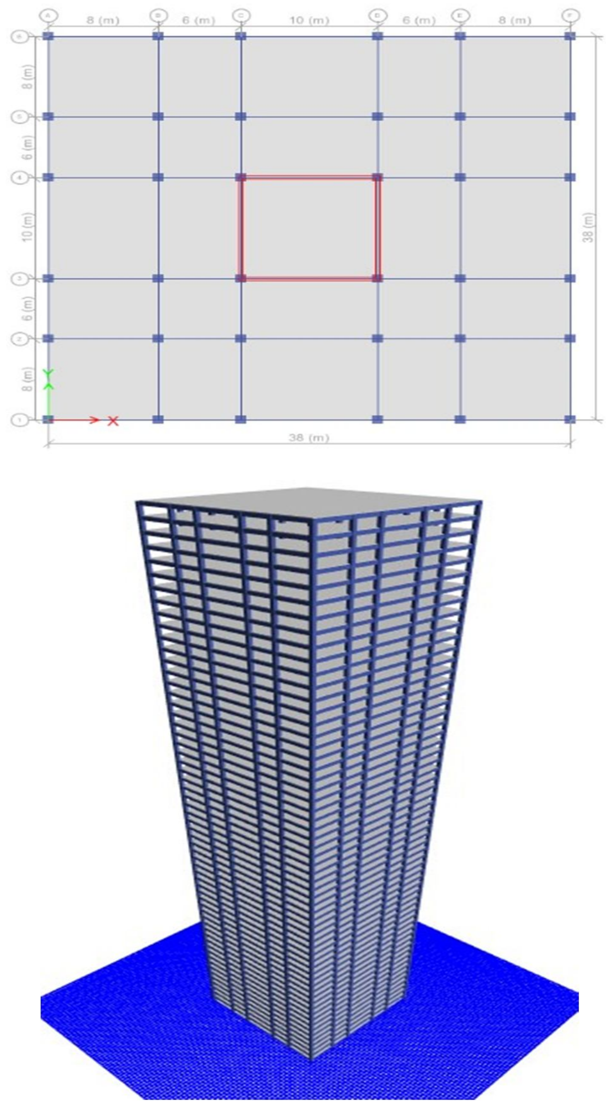

Figure: 2 Plan and Elevation of the Model

Table: 1 Model Data

Sr. No.	Title	Details
1.	Type of Structure	RC frame with Steel Outrigger Bracing
2.	Grid Data	Plan regular - Rectangle geometric shape
	Grid Spacing	X and Y direction - 8 x 6 x 10 x 6 x 8 m
	Total Dimension	38m x 38m Base dimension
	Storey Height	Uniform – 3 m
	No. of Stories	60
3.	Material Properties	Standard Values input in N-mm
	Grade of Structural Steel	FE 345
	Grade of Concrete Deck	M30
4.	Frame Section Properties	
	Column	RC 0.8 x 0.8 m
	Beams	RC 0.5 x 0.8 m
	Outrigger	ISMB250
	Slab	0.2 m
5.	Static Loads	kN/m^2
	Self-weight	Considered
	Dead load (DL)	1
	Live load (LL)	3
	Masonry load (kN/m)	Considered
6.	Seismic Data	Values as per IS 1893
	Response Reduction Factor (R)	5
	Importance Factor (I)	1.5
	Zone(z)	0.36 (V)
	Soil type	II
7.	Type of Analysis	
	Dynamic Analysis	Response spectrum
	Static analysis	Wind analysis

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II. LITERATURE REVIEW

Outrigger is a very old concept but still a lot of things in it are not very clear, this chapter consists of some past researches on outriggers by different authors.

1) *Akbar A. et al. (2016):* In this paper 40 storey cored shear wall irregular building was analysed with the help of ETABS software. ISMB150 was used for outriggers and belt truss, size of which was 0.2 x 0.6 m for beam and 0.75 x 0.75 m for column. Storey height was kept constant at 3 m. Outriggers were placed at top, bottom and ¾ height of the building [1]. It was found that the lateral displacement and storey drift values was lowered with the use of outriggers in the structure. Also, the value of overturning and storey storey shear was reduced which increases the stiffness and stability of the building.
2) *Bayati Z. et al. (2008):* In this study an 80-storey steel framed building was investigated for the performance of belt trusses as virtual outriggers comparison was drawn between conventional and virtual outriggers systems in ETABS software. Building consists of a storey height of 4m and has three, four storied deep outriggers at floors 77 to 73, 46 to 50, and 21 to 25 storeys. The plan of the building was 45 x 45 m with a central core of 15 x 15 m. 3 bays of each 15 m were there in both directions. It was found that structure without outriggers have a displacement of 2.75 m, by using belt trusses as virtual outrigger displacement was reduced to 0.95 m and displacement in structure with conventional outrigger was 0.7 m. then structure with belt truss as virtual outrigger was again analysed with increasing the stiffness 10 times with this displacement was reduced to 0.8 m and when in addiction the belt truss size was increased by 10 times the displacement further reduced to 0.65 m with these conclusion effectiveness of virtual outrigger was found.
3) *Chen Y. et al. (2018):* In this study multi objective genetic algorithm (MGA) was used on a mathematical model of outrigger braced structure and practical model to get an optimum solution. MATLAB software was used to determine optimum number and optimum location of outriggers against wind load. It was found that MGA provide great advantages to the designer as it become easy to get the optimum location as well as optimum numbers of outriggers in the structure.
4) *Taholah A. et al. (2012):* In this study two steel framed models having 20 and 25 storeys with outriggers and belt truss were analysed. The storey height was kept constant at 3.2m throughout the building. Frame space was 5 m in x direction and 5.5 m in y direction also Xshaped bracing was used. SAP2000 was used for two types of analysis i.e., response spectrum and time history analysis. It was found that the optimum location of outrigger according to response spectrum was 10 and 14 storeys for 20 and 25 storey models respectively and in case of time history it was 14 and 16 storeys for 20 and 25 storey models respectively.
5) *Hasan R. (2016):* In this study a 30-storey building was analysed in ETABS with beam and wall outriggers. Three types of models were analysed, first one without outrigger, second with beam outrigger and belt truss and last one with wall outrigger and belt wall. Position of outrigger was obtained by Taranto theory i.e. (1/n+1), (2/n+1), (3/n+1), (4/n+1) … (n/n+1) of height. With this conclusion was drawn that the wall outrigger behaves better than beam outrigger to lower the value of displacement and drift of the building.
6) *Herath N. et al. (2009):* In this study a 50-storey building was analysed to find the optimum location of outriggers. Storey height of building was kept 3.75 m. Size of the outer column was 2 x 1.2 m, beam of 0.45 x 1 m, shear wall thickness of 0.45 m and outrigger beam of 0.25 x 3.75 m. STRAND7 and SpaceGass frame analysis package was used for modelling and analysis purpose. Firstly, one outrigger was used than for 2nd outrigger location 1st outrigger was fixed at top and 2nd outrigger was varied under earthquake action. Response spectrum analysis was conducted and it was found that optimum location for outrigger is 0.44 to 0.48 of height of the structure form bottom.

III. CONCLUSION

This study compares the behaviour of multi outriggers, effect of belt truss (shear band) on outriggers and effect of different bracings as outriggers. The results of parameters such as maximum story displacement, maximum story drift and story shears are drawn. Hence the conclusions are made as follows

With the increase in the no. of outriggers performance of the building also increases and use of belt trusses and shear band with outriggers is more effective than only outriggers. Between X, V and Inverted V type steel outrigger bracing beams, inverted V combined with 4 outriggers is most effective but shear walls are far better than steel bracings.

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