Optimum position of outrigger with belt truss in tall building under horizontal load

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Abstract— While the world is full of interesting structures, large and small, old and modern, the most eye-catching and the ones that instill the greatest sense of wonder in the onlooker are the modern skyscrapers. Undoubtedly, the factor that governs the design of a tall and slender structure most of the times is not the fully stressed state, but the drift of the building for wind loading. The acceptable drift limit (top deflection in tall building) for wind load analysis (according to the IS-875-part3 (1987) is 1/500 of the building height. This paper studies the use of outrigger and belt truss system for high-rise concrete building subjected to wind load. Thus, 60-story reinforced concrete buildings is studied in order to determine the optimum location to construct the outriggers to minimize the drift due to wind load. Buildings with different location of outriggers are analyzed by a structural analysis software ETABS. Results from the analysis shows that the optimum location to construct the outriggers is one third of the height of the building. It has been shown from this study that the structure is optimized when the outrigger is placed at 20th level. Therefore it can be concluded that the optimum location of the structure is between 0.25-0.33 times its height (taken from the bottom of the building).

Index Terms— Drift, Outrigger, Skyscrapers, Wind load.

I. INTRODUCTION

The achievement of structural system for tall buildings is not an easy task. Where, as building height increases the importance of lateral loads action rises in an accelerating rate. The major factor that affects the design of tall structures is its sensitivity to the lateral load. There are two types of lateral loads, wind and seismic loads. Wind load presents the most critical lateral loading for modern tall buildings, which have lightweight skeletons that cause uncomfortable horizontal movements for occupants. The use of core-wall system has been a very effective and efficient structural system used in reducing the drift due to lateral load. However, as and when the height of the building increases, the core does not have the adequate stiffness to keep the wind drift down to acceptable limits. For such tall structures a structural system known as outriggers may be introduced. Outriggers are deep, stiff beam which connects the central core to the exterior most columns which helps in keeping the columns in their position in turn reducing the sway. This system helps in reducing the movement of the core when compared to the system with freely standing core without outriggers. The restrain caused by the outrigger reduces the lateral drift at top. The use of outriggers in high-rise buildings started about 5 decades ago.

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. When the lateral load acts on the building, the bending of the core rotates the stiff outrigger arms, which is connected to the core and induces tension and compression in the columns. The belt truss tied the peripheral column of building while the outriggers engage them with main or central shear wall. The aim of this method is to reduce obstructed space compared to the conventional method. The floor space is usually free of columns and is between the core and the external columns, thus increasing the functional efficiency of the building. Exterior columns restrained the core wall from free rotation through outrigger arms. Outrigger and belt trusses, connect planar vertical trusses and exterior frame columns. Outrigger system can lead to very efficient use of structural materials by mobilizing the axial strength and stiffness of exterior columns.

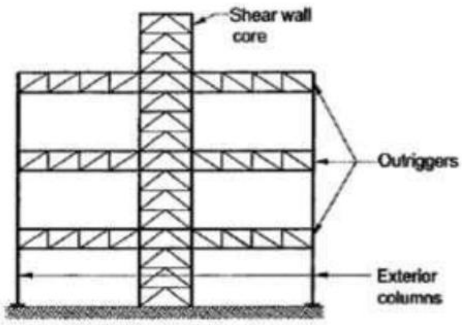

FIG.1 OUTRIGGER SYSTEM WITH A CENTRAL CORE

II. OBJECTIVES AND DETAILS OF THE PRESENT STUDY

The objective of the present work is to study the use of outrigger and belt truss placed at different location subjected to wind. The design of wind load was calculated based on IS 875 (Part 3). The location of outrigger and belt truss for reducing lateral displacement, building drift. The ETABS software program is selected to perform analysis. The present study is limited to reinforced concrete (RC) multi-storied building. The building model analyzed in the study have 60 storey with constant storey height of 3.5 meters. Number of base and the bay-width along two horizontal directions are kept constant for the model for convince.

In the present context of study an R.C.C. structure is taken into consideration and the analysis is done as per the Indian standards. This building does not represent a particular real structure that has been built or proposed. However, the dimensions, general layout and other characteristics have been selected to be representative of a building for which the use of outriggers would be a plausible solution. Till now all the studies have been performed on the steel structures and there was an absence of a research on slender concrete structure.

The model considered for this study is a 210 m high rise reinforced concrete building frame. The building represents a 60 storied building. The Plan area of the Structure is 30m x 42m with columns spaced at 6m from center to center. The height of each storey is 3.5m and all the floors are considered as Typical Floors. The location of the building is assumed to be at Pune. An elevation and plan view of a typical structure are shown in fig.2 and fig.3

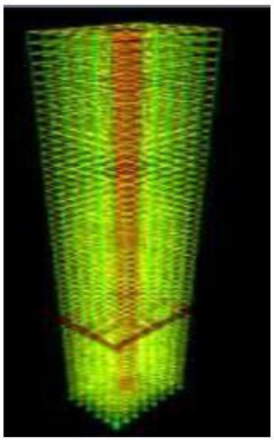

Fig.2 Building Elevation with central core portion and outrigger position.

All walls are identical with a uniform wall thickness of 150mm over the entire height. All the beams are 450mm wide and 750mm deep, Grade 40 (Mix – M40) concrete is considered (Compressive strength 40 N/mm²) throughout the height of the building. And number of stories considered for all the cases are 60 stories, and roof height is considered as 210 M. And storey to storey height is 3.5 M. And the outer and inner columns sizes are considered as 625 x 625 mm and shear wall thickness is considered as 450 mm.

III. ANALYSIS

The method of analysis of the above mentioned system is based up on the assumptions that the outriggers are rigidly attached to the core; The core is rigidly attached to the foundation; The sectional properties of the core, beams and columns are uniform throughout the height; Tensional effects are not considered; Material behavior is in linear elastic range; The Outrigger Beams are flexurally rigid and induce only axial forces in the columns; The lateral resistance is provided only by the bending resistance of the core and the tie down action of the exterior columns connected to the outrigger; The rotation of the core due to the shear deformation is negligible.

Since the building is assumed to be a office building live load is considered as 4 kN/m². A floor load of 1 kN/m² is applied on all the slab panels on all the floors for the floor finishes and the other things. A member load as u.d.l. of 9.075 kN/m is considered on all beams for the wall load.

Wind load in this study is established in accordance with IS 875(part 3-Wind loads). The location selected is Pune. The Basic wind speed as per the code is V_b=39m/s. The coefficients K_1 and K_2 are taken as 1.0. The terrain category is taken as ,Category 3 with structure class C. Taking internal pressure coefficient as ± 0.2 the net pressure coefficient Cp (windward) works out as + 0.84 and Cp (leeward) as 0.56 based on h/w and L/w ratio of table 4 of IS 875 (part3). Using the above data the ETABS automatically interpolates the coefficient K_3 and eventually calculates lateral wind load at each storey. Same load is applied along positive and negative X & Y axis one direction at a time to determine the worst loading condition.

IV. RESULTS AND DISCUSSIONS

Maximum lateral displacement:

For the model with only one outrigger, the location of the outrigger beam was changed from the first floor to the top floor in the building model and wind load analysis was carried out for each location . Profiles for maximum lateral displacement for each outrigger location were plotted for each case and their relationships were investigated. The combined graphs plotted for these results are presented in fig4.

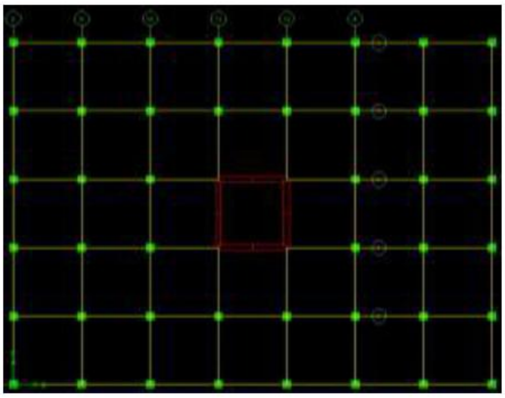

Fig.3 Building plan.

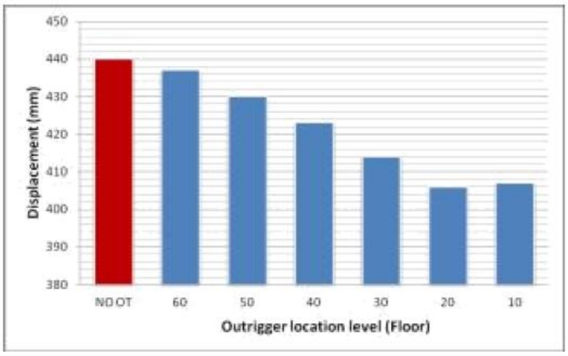

Fig.4 Lateral Displacement of the top storey

V. CONCLUSION

This study assessed the global behavior of outrigger braced building under wind loads from which the following conclusions can be drawn based on the above results:

- The location of the outrigger has a critical influence on the lateral behavior of the structure under wind load and the optimum outrigger locations of the building have to be carefully selected in the building design.
- The maximum drift at the top of structure when only core is employed is around 440 mm and this is reduced by suitably selecting the lateral system. The placing of outrigger at 20th storey reduces the maximum drift to 406 mm.
- The optimum outrigger location of a high rise building under the action of wind load is between 0.25-0.33 times the height of the building (from the bottom of the building), which is consistent with the optimal location associated with wind loading.

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