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Analysis and Comparative Study of Reinforced Concrete Frame with Different Outrigger System

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Abstract

The urbanization requirements of the modern world & the futuristic requirements of the smart Buildings seeking innovative & creative ideas in the ages of Reinforced concrete (RC) frame structures, which has been addressed through outrigger system. The outrigger system is one through which the tall RC Structures are benefited by high stiffness, structural framework, controlled excessive drift due to lateral load, Minimizes the risk of structural & Non structural damages, and increases the stiffness of buildings. In this article Analysis and Comparative Study of Reinforced Concrete Frame with Different Outrigger System was done by analysing the various RC Structures.

Introduction

The high-rise construction boom in the current trends and futuristic requirements of the Smart buildings seeking the attention of innovative, creative ideas where the demands of tall structures simultaneously put the new challenges for the lateral stiffness of the tall buildings and to fulfil such needs structural designers come up with an idea to address the above issue and outrigger is one such solution which just not only address the lateral stiffness it also address the high stiffness, structural framework, controlled excessive drift due to lateral load, Minimizes the risk of structural & Non structural damages, and increases the stiffness of buildings.

Basically outrigger is the systems for enhancing structural stiffness and stabilizing the structure by adding extra stiffness & strength to the buildings which can be easily achieved through by placing in to the different levels of the structure and which will connect to the core part of the building as shown in the bellow diagram.

Generally speaking, outriggers are horizontal structures with additional rafters that split lateral force into push forces. Compared to steel, concrete outrigger systems are less expensive and have higher rigidity. The outrigger system must consist of a concrete wall or a firm concrete deep beam under wind stress scenarios, which can be easily achieved through Outriggers system.

There are two different kinds of outrigger systems: One is virtual outrigger concept and the second one is conventional outrigger concept. And where in conventional method shear walls are directly attached to the outrigger trusses and in virtual outrigger overturning moments of the structure are being transferred from the core to elements outside of the core.

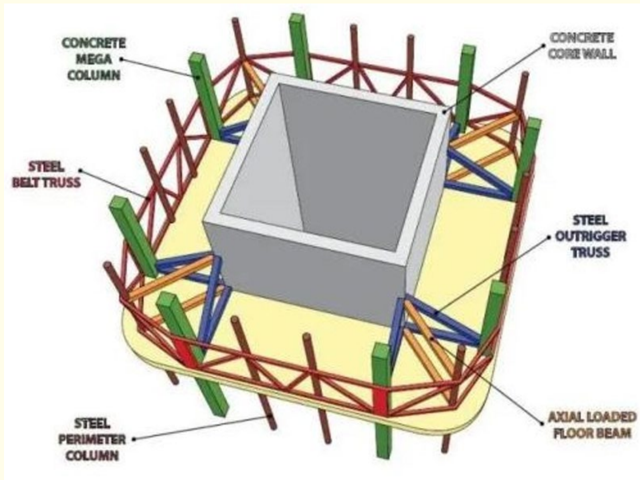

Figure 1: Outrigger Truss tie up with the core concrete.

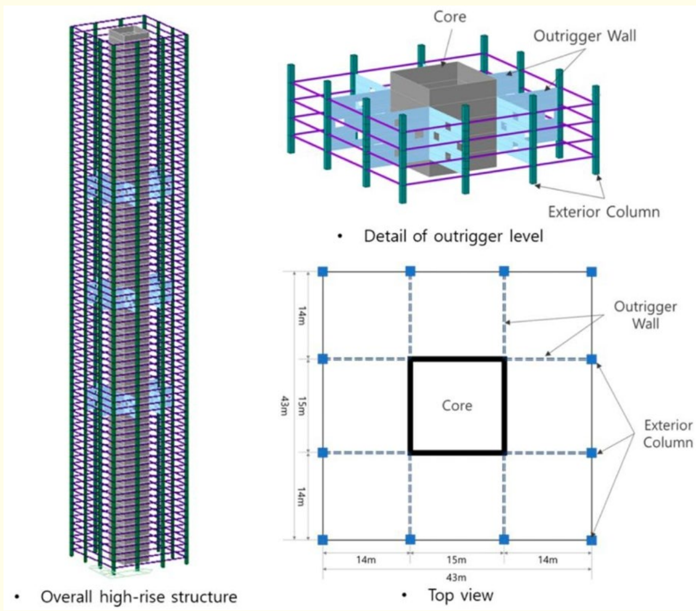

Figure 2: Outrigger Structure and levels.

Analysis Design Constraints for outriggers

Need of Outrigger Condition to the tall structure: Concern to the tall structures corner columns tend to offer most of the overturning resistance as the number of floors get increases an indirect or outrigger belt truss design corner columns may not attract the majority of the gravity load unless special consideration is given to the relative tensile strength of all system components.

With an aspect ratio of at least 10 or less than this, structural premium for drift control and overturning resistance is high enough to warrant the consideration of outriggers. Considering the core's stiffness in relation to its beam, the placement of the damped strut, and any damping factor present is taken in to the consideration for tall structures.

Distribution of loads: Mainly tall structures are suffered with horizontal load affecting due to seismic events as well as wind speed this uniform distribution prevents concentrated stresses and possible structural damage.

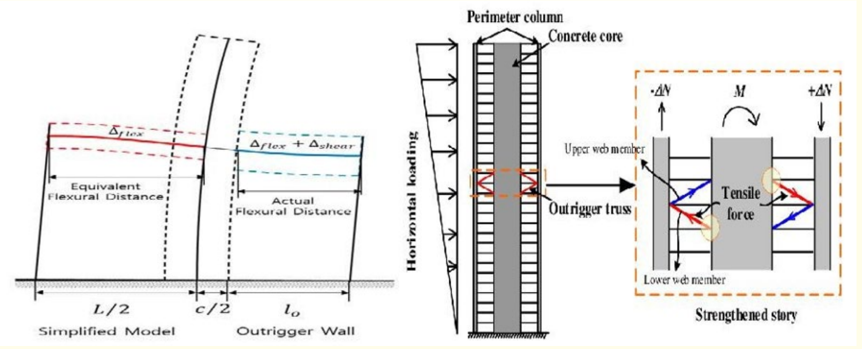

Figure 3: Load Distribution in Outrigger Structure.

The use of free span with outrigger truss belt reduce the bending stiffness of the adjacent wall is in contract with share deformation of the tall structure and strengthen the structure as shown in the above diagram.

Outrigger structural system & Locations

Majority of the tall buildings have have escape floors, and some buildings have mechanical intermediate floor levels to enhance the stiffness of the building and the usage of the outrigger system instead of the intermediate floor levels acts like the supporting legs at the base level of the building with Moment Diagraph between various stages by generating restraining movement as shown bellow. Mbase = oMbase + M1 + M2

And the location of the outrigger differed from buildings to buildings normally outriggers are introduced at the half of the building length in majority of the tall buildings intruding the outriggers at one third & two third is considered to be best optimal solution to strengthen the building.

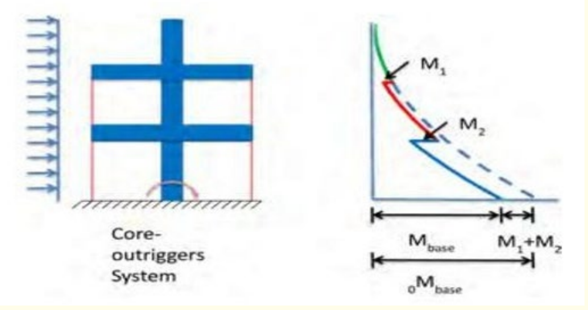

Figure 4: Core Outrigger Structure with Moment Diagraph.

Multiple Outriggers

The multiple outrigger concepts is to strengthen the building and usage of the outriggers at corners which is subjected to high tensile stresses where the loads affecting from the different corners of the building is considered to the introduction of the outriggers which further introduction of such outriggers helps for transformation of the loads from the core to elements outside of the core.

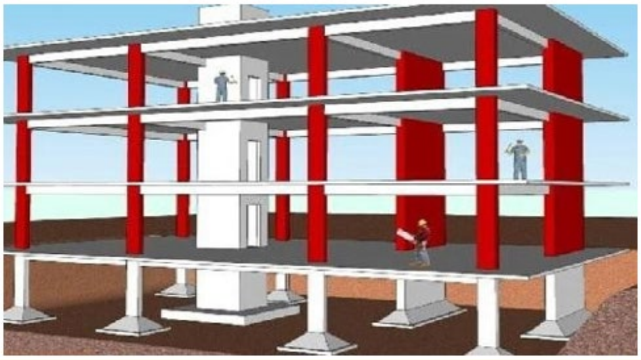

Figure 5: Multiple Outriggers Structure.

Building Stiffness

Horizontal trussing is an effective method for enhancing the tall building stiffness which can be ensured by decreasing side deflection of the tall structures and also ensuring rigidity across the structure which helps for transforming lateral forces in to tension in the perimeter of the tall structure.

The model analysed and Properties are mentioned bellow

Properties	***Detailed Description***
Stories Number	100
Dimension of the building	50*50mm^2
Story Height	5m
Outrigger Location	Each 20-stories, there is an outrigger floor, except the top story
Outriggers levels	5levels
Shape of Outrigger Truss	K Shape
Outrigger Truss height	5 Floor Height
Belt-Trusses Levels	Every 5th Level
Belt-Trusses Floors	20th floor
Shape of Belt-Truss	XX Shape
Height of Belt-Truss	2 flor Height

Table 1: Above table describes Properties for the building to be considered.

Load	*Detailed Description*
Live Loads	10 KN/ m^2
Dead load	5 KN/ m^2
Cladding Loads	2.5 KN/ m^2
Response Modification Coefficient	3
Seismic Exponent	2
Seismic Spectral Acceleration	2.5g

Table 2: Above table describes loads on building to be considered.

The moment of inertia at each interval the cross-section area of the core superelement is:

$$A_{core(i)} = t_{core(i)} \sum_j l_i^j \tag{1}$$

$$I_{core(i)} = t_{core(i)} \sum_j \left[l_i^j (y_i^j)^2 + \frac{(l_i^j)^3 cos^2\theta_i^j}{12} \right] \tag{2}$$

The moments of inertia are defined from the following equations

$$A_i^{Col\,j} = A_{core(i)} \times \frac{F_i^{Col\,j}}{F_i^{Core}} \tag{3}$$

$$I_i^{Col\,j} = \frac{(A_i^{Col\,j})^2}{12} \tag{4}$$

And for the Mega Column the movement of the inertia was given such that

$$F_i^{Col\,j} = F_{i-1}^{Col\,j} + \gamma^c h_{i-1} A_{i-1}^{Col\,j} + n_i A_{Tr}^{Col\,j}(DL+LL) + h_i P_{Tr}^{Col\,j} CL + \gamma^s V_i^{Tr-Colj} \tag{5}$$

$$F_i^{Core} = F_{i-1}^{Core} + \gamma^c h_{i-1} A_{i-1}^{Core} + n_i A_{Tr}^{Core}(DL+LL) + \gamma^s V_i^{Tr-core} \tag{6}$$

And element stiffness is calculated with the given equation

$$K_i^{Core} = \left(0.25 \times I_{core(i)} + I_i^{Col\,A} + I_i^{Col\,B} + 0.5 \times I_i^{Col\,C} + I_i^{Col\,D} + 0.5 \times I_i^{ColE}\right) E^c \tag{7}$$

And stiffness matrix of the core superelement in each interval is given by:

$$\begin{array}{c c} & \begin{array}{cccc} \Delta_i & \theta_i & \Delta_{i+1} & \theta_{i+1} \end{array} \\ \begin{array}{c} \Delta_i \\ \theta_i \\ \Delta_{i+1} \\ \theta_{i+1} \end{array} & \begin{bmatrix} 12K_i^{Core}/h_i^3 & -6K_i^{Core}/h_i^2 & -12K_i^{Core}/h_i^3 & -6K_i^{Core}/h_i^2 \\ -6K_i^{Core}/h_i^2 & 4K_i^{Core}/h_i & 6K_i^{Core}/h_i^2 & 2K_i^{Core}/h_i \\ -12K_i^{Core}/h_i^3 & 6K_i^{Core}/h_i^2 & 12K_i^{Core}/h_i^3 & 6K_i^{Core}/h_i^2 \\ -6K_i^{Core}/h_i^2 & 2K_i^{Core}/h_i & 6K_i^{Core}/h_i^2 & 4K_i^{Core}/h_i \end{bmatrix} \end{array} \tag{8}$$

Stiffness column super elements A, B, C &D is given by

$$K_i^{Col\ A} = \frac{E^c A_i^{Col\ A}}{h_i} \tag{9}$$

$$K_i^{Col\ B} = \frac{E^c A_i^{Col\ B}}{h_i} \tag{10}$$

$$K_i^{Col\ C} = \frac{E^c A_i^{Col\ C}}{2h_i} \tag{11}$$

$$, K_i^{Col\ D} = \frac{E^c A_i^{Col\ D}}{h_i} \tag{12}$$

And stiffness matrix of the column j superelement is Given By

$$\begin{array}{ccc} & \delta_i^{col\ \ j} & \delta_{i+1}^{col\ \ j} \\ \delta_i^{col\ \ j} & K_i^{Col\ \ j} & -K_i^{Col\ \ j} \\ \delta_{i+1}^{col\ \ j} & -K_i^{Col\ \ j} & K_i^{Col\ \ j} \end{array} \tag{13}$$

And two-element truss can be derived

$$K_i^{out} = 2 \times \frac{E^s \times A_i^{out}}{L_i^{out}} \times \sin^2\theta = \frac{E^s \times V_i^{out}}{n_i^{out}} \times \left(\frac{\sin\theta}{L_i^{out}}\right)^2 \tag{14}$$

And to calculate force vector seismic loads is taken and given by the formula

$$F_k = \frac{W_K^{dead} \times (H_K)^{\beta}}{\sum_k [W_K^{dead} \times (H_K)^{\beta}]} \times \frac{S_a}{R} \times \sum_k W_K^{dead}$$

Analysis of Outrigger System's

The major challenges & issues in outrigger formulation is completely designed Based upon the various reviews of the Analysis work carried out across the majority of the case studies further in order to investigate the various challenges and different analytical parameters an computational model is to be considered and which will be the crucial for performing linear statistical as well as dynamic analysis. Further Finite Element based software, such as ETABS software, which is specifically made for the design and analysis of three-dimensional building frames, must be used to produce three-dimensional models.

Conclusion

The outrigger system is one through which the tall RC Structures are benefited by high stiffness, structural framework, controlled excessive drift due to lateral load, Minimizes the risk of structural & Non structural damages, and increases the stiffness of buildings. In this article Analysis and Comparative Study of Reinforced Concrete Frame with Different Outrigger System was done by analysing the various RC Structures. And the model descriptions with formulas are being used to convey the work done during the analysis phase.

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