Seismic Strengthening of High Rise Buildings Using Outriggers – A State of The Art

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Abstract - *In an era of vertical dwellings to combat exponentially raising population worldwide, resistance to lateral loads has become more significant in the design of stable tall structures. A special lateral load resisting system – outriggers with belt truss, is used in tall structures to improve the lateral stiffness and reduce over turning moments. The seismic performance of the structures is enhanced with the provision of such systems and a knowledge on the same is mandatory to understand the challenges and solutions encountered in the design of tall buildings. This study presents review of works performed on tall structures with and without outriggers. The introduction of outriggers had proven to be an economical and reliable alternative to other lateral load resisting systems opted for high rise buildings.*

Key Words: Belt truss, Lateral load resisting systems, Outrigger, Overturning moments, Tall structures

1. INTRODUCTION

Construction of vertical buildings (tall buildings) is preferable to meet the demand of population and space concern. So that it must be designed for gravitational and lateral forces. Lateral forces in the tall structure produce structural and non-structural damages. In tall structures lateral forces are induced and moments are created, which is tremendous when compared to gravity load. And these moment leads to overturning. These can be reduced with help of outrigger system. Generally, the outrigger is a horizontal projection attached to any member and helps in increasing its stability. Where overturning moment can be reduced in the tall structure, with the help of horizontal member (outriggers). Outrigger is a rigid structure helps to slash the overturning moment and helps in increasing its stability, this outrigger helps in connecting the core wall of the building to external columns along the height of the structure.

2 OUTRIGGER SYSTEMS

Outrigger are members that act like spreaders and it is connected to columns in the periphery or the core. Outrigger is a rigid horizontal structure provided to enhance the building's overturning stiffness and lateral strength by connecting the building core to its columns in the center or periphery (distant columns). Outrigger systems function by tying together two structurally systems- a core system and a perimeter system. The total height of a building, the number of levels of outrigger provided, their plan locations, and the presence of belt truss to engage adjacent perimeter columns versus standalone mega columns, all play a vital role in the performance of the structure.

2.1. Merits

- Reduction in lateral Deformation of the structure
- Enhancement of Lateral Stiffness
- Improves over all response of the structure
- Improves Structural Integrity

3. REVIEW OF LITERATURES

Abhishek Arora, Ravi Kumar (2016) has studied the behavior of a thirty storey structure present in earthquake zone 5 for different depth of outriggers. They computed the drift capacity of stories and compared the conventional system with the outrigger system at the top most storey. The study revealed that with reduction in depth of the outriggers will increase the drift of the storey.

Viren P. Ganatra et al. (2017) et al. discussed the vulnerability of a 50 storey structure to seismic and wind loads with help of the outriggers by varying its depth. Depth of outrigger is reduced about to half, one-third and two-third of the total height of the building. Also, a comparison of the same structure with shear walls is also done. The story displacement and story drift were appreciably reduced for full story height with the presence of outriggers.

Anilakumar Mashyal and Chitra D M (2017) compared forty storeyed RCC structure with an RCC and Steel outrigger system (X and V type). The natural time period decreased as the outriggers came into picture and was much reduced for RCC belt system. The storey displacement and drift reduced for concrete outrigger than steel ones.

Kiran Kamath and Divya, Asha U Rao (2012) investigated the RCC structure with and without outrigger by varying its position along height of the structure and relative flexural rigidity. Outrigger is positioned at the top storey where 30% reduction in peak acceleration and 50% reduction in drift was witnessed.

Shivacharan, Chandrakala and Karthik (2015) The lateral bracing system consisting of core with outriggers is one of the most efficient systems compared to the one with peripheral system. Outrigger beams connected to the core and external columns are relatively more complicated and it is understood that the performance of such coupled wall systems depends primarily on adequate stiffness and strength of the outrigger beams. A clear increase in stiffness with the inclusion of such systems decreased the drift and displacement between stories.

Sandesh Kumar Shirole et al. (2016) analyzed a thirty storey RC model situated in seismic zone III for an Elcentro time history excitation. The performance of the structure was studied for different load combinations. Finally, the position of outriggers was optimized to 0.66 times the storey height of the structure modelled. Increase in storey stiffness of 2.5 times with the inclusion of outriggers was observed during the study.

Darshan and Shruthi (2016) studied a forty meters tall structure with mass irregularity in varied floors and analyzed the response of the building. The behavior of a regular structure with a structure with mass irregularity was evaluated from Response Spectrum and Time History analysis to compute the base shear, mode shapes, story drift, story displacement and torsion. It was concluded that a structure with equal distribution of mass performed better compared to that of an irregular one.

Raj Kiran Nanduri (2013) et al. discussed the optimum positioning of outriggers and belt truss in a thirty storeyed tall building. A detailed comparison varying the position of outrigger with and without belt truss along with a center and offset core was analyzed and their behavior for same seismic excitation was studied. A desirable increase in stiffness in buildings with outrigger systems was witnessed thereby decreasing the displacement. An optimum position for second outrigger system was suggested at the mid height of the building.

Herath et al. (2009) studied the optimum position of outrigger beam in a fifty storeyed building. Different strategies had been adopted to find out the optimum location of the outrigger beam on lateral load condition. The structure was subjected to three different peak ground accelerations to peak ground velocity ratio. Response spectrum analysis was conducted and behavior of the building was determined considering the response parameter like lateral displacement and inter storey drift. This study assessed the global behavior of outrigger braced building under earthquake.

Shruthi Badami and M.R. Suresh (2014) investigated some of the common structural systems including outrigger in reinforced concrete tall buildings. The key idea is limiting the wind drift in a tall building by changing the structural form of the building into something more rigid and stable to confine the deformation and ultimately increase the stability. The study suggests different lateral load systems for increasing storey heights and concludes outrigger systems can be used for structures of twenty story height and above.

Willford et al. (2008) compared two 60 storey towers in Manila through a performance-based procedure for lateral load action. Arup Damped Outrigger Systems, a patented damping system is provided in the buildings. A robust supplementary damping system is added instead of stiffening the building, which leads to reduction of wind response and seismic forces intern reduction in the construction cost.

Spoorthi D.C and Sridhar R (2016) presents a comparative study on regular and irregular structure subjected to both static and dynamic behavior of the RCC structure. In irregular building, displacement and drift recorded is more for a reduced stiffness. Though the shear walls offer strength, the shear walls with outrigger systems were found to improve both strength and stiffness.

4. CONCLUSION

The lateral strength and stiffness of tall buildings can be increased by making better use of the structural components like outriggers as they carry an appreciable amount of the overturning moment induced on the core of the building. Outriggers and belt truss employed to a skyscraper are found to reduce the deflection at the top story and also the amount of moment resisted by the core. Thus, the outriggers are one of the most effective lateral load resisting systems commonly used for tall structures. The height and depth of outriggers play a vital role in its performance so care has to be taken while designing and installation to make the system applicable.

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