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Review on Behaviour of Outrigger System on High Rise Structure by Varying Outrigger Depth

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Abstract: Tall building development has been rapidly increasing worldwide introducing new challenges that need to be met through engineering judgment. In modern tall buildings, lateral loads induced by wind or earthquake are often resisted by a system of coupled shear walls. But when the building increases in height, the stiffness of the structure becomes more important and introduction of outrigger beams between the shear walls and external columns is often used to provide sufficient lateral stiffness to the structure. The outrigger and is commonly used as one of the structural system to effectively control the excessive drift due to lateral load, so that, during small or medium lateral load due to either wind or earthquake load, the risk of structural and non-structural damage can be minimized. For high-rise buildings, particularly in seismic active zone or wind load dominant, this system can be chosen as an appropriate structure. The objective is to study the behavior of outrigger and, optimization of outrigger depth.
***Keywords*: Outrigger, Outrigger Depth, High-rise Buildings**

I. INTRODUCTION

Humans had always fascinated for height and throughout our history, we have constantly sought to metaphorically make to the stars. Today, the symbol of economic power and leadership is the skyscraper. There has been a demonstrated competitiveness that exists in humans to proclaim to have the tallest building in the world. The recent development of structural analysis and design software coupled with advances in the finite element method has allowed the creation of many structural and architecturally advanced forms. Yet, increased reliance on computer analysis is not the solution to the challenges that lie ahead in the profession. The basic understanding of structural behaviour with power of computing tools are the elements that will change the way structures are designed and built. The design of skyscrapers is usually governed by the lateral loads imposed on the structure. As buildings have become taller and narrower, the structural engineer has been increasingly challenged to meet the imposed drift requirements while minimizing the architectural impact of the structure. In response to this challenge, the profession has proposed a multitude of lateral schemes that are now expressed in tall buildings across the globe.

The design of tall and slender structures is controlled by three governing factors, strength (material capacity), stiffness (drift) and serviceability (motion perception and accelerations), produced by the action of lateral loading, such as wind. The overall geometry of a building often dictates which factor governs the overall design. As a building becomes taller and slenderer, drift considerations become more significant. Proportioning member efficiency based on maximum lateral displacement supersedes design based on allowable stress criteria. Having constraints for the building immediately defines and solves part of the unknown variables but it is the geometry of the structural system inside these basic parameters that identifies an efficient design. The factor that governs the design for a tall and slender structure most of the times is not the fully stressed state but the drift of the building.

There are numerous structural lateral systems used in high-rise building design such as: shear frames, shear trusses, frames with shear core, framed tubes, trussed tubes, super frames etc. However, the outriggers and belt trusses system is the one providing significant drift control for the building. Innovative structural schemes are continuously being sought in the field. Structural Design of high rise structures with the intention of limiting the drift due to lateral loads to acceptable limits without paying a high premium in steel tonnage. The savings in steel tonnage and cost can be dramatic if certain techniques are employed to utilize the full capacities of the structural elements. Various wind bracing techniques have been developed in this regard; one such is an Outrigger System, in which the axial stiffness of the peripheral columns is invoked for increasing the resistance to overturning moments.

The outrigger and belt truss system is one of the lateral loads resisting system in which the external columns are tied to the central

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core wall with very stiff outriggers and belt truss at one or more levels. The belt truss tied the peripheral column of building while the outriggers engage them with main or central shear wall. Outrigger systems are widely used to provide efficient lateral load resistance in tall slender buildings. Outriggers are rigid horizontal structures connecting a building core or spine to distant columns. They improve stiffness against overturning by developing a tension- compression couple in perimeter columns when a central core tries to tilt. Generating a restoring moment acting on the core at the outrigger level. Outrigger system behaviour is simple in principle, but analysis, design, detailing and construction of a complete core-and-outrigger system is complex in practice: being indeterminate, distribution of forces between the core and the outrigger system depends on the relative stiffness of the elements, differential strains between elements and other factors.

II. LITERATURE REVIEW

Abhishek Arora and Ravi Kumar presented in their research paper 'A Strengthening of High Rise Building with Outrigger System' that Drift decreased with provision of outrigger and increased with reducing outrigger depth.

S. Fawzia et al presented that provision of outriggers and belt truss was more efficient in deflection minimization then the required value achieved from fundamental frequency of vibration. Composite buildings usually had structural steel bracings truss which did not have appreciable locally stiffness rather it could be very useful in providing a tie down effects between shear walls and columns.

Hi sun choi et al presented research in 'Outrigger System Design Considerations' and concluded that Building core-and-outrigger systems have been used for half a century, but have kept evolving and reflected changes in preferred materials, building proportions, analysis methods and design approaches. They concluded that outrigger design was not amenable to a standardize procedure due to variety of challenge posed, solutions used and new concepts being developed.

Kiran Kamath et al researched 3D models using ETABS software for reinforced concrete structure with central core wall with outrigger and without outrigger by varying the relative flexural rigidity from 0.25 to 2.0 with step of 0.25. They concluded that when the criterion considered was lateral displacement then the optimum position of the outriggers was at mid height for both static and dynamic behaviour for the structure considered. When the criterion for design was peak acceleration the optimum position of outrigger was at top where it was reduced up to 30%.

M.R Suresh et al researched in their paper by providing the outrigger system at different levels along the height of the building by varying the relative stiffness and represented that the percentage reduction of lateral displacement and inter- story drift with respect to bare frame varied for different model configuration. however, the variation was not significant when compared between different seismic zones. Maximum inter-story drift was observed at building height in the range of 5 to 15m.

N. Herath, et al. presented in 'Behaviour of Outrigger Beams in High Rise Buildings under Earthquake Loads' that the behaviour of a structure under earthquake load was different from earthquake to earthquake. The location of the outrigger beam had a critical influence on the lateral behaviour of the structure under earthquake load and the optimum outrigger locations of the building had to be carefully selected in the building design. The optimum outrigger location of a high rise building under the action of earthquake load was between 0.44-0.48 times the height of the building (from the bottom of the building), which was consistent with the optimal location associated with wind loading.

P.M.B. Raj Kiran Nanduri, et.al researched, in their research paper Optimum Position of Outrigger System for High-Rise Reinforced Concrete Buildings under Wind and Earthquake Loadings that the maximum drift at the top of structure when only core was employed was around 50.63 mm and this was reduced by suitably selecting the lateral system. The placing of outrigger at top story as a cap truss was 48.20 mm and 47.63 mm with and without belt truss respectively. Hence there were not much reductions in drift with belt truss. Using second outrigger with cap truss gave the reduction of 18.55% and 23.01% with and without belt truss. The optimum location of second outrigger was middle height of the building.Shruti B. Sukhdeve et al analysed tall building and found that the optimum position of outrigger system using lateral loads and concluded that the maximum deflection at the top of structure when only flat slab with core was employed was around 625.7mm and that was reduced up to 411.18mm by when first outrigger provided at mid height of structure i.e. 29.45% deflection reduction occured for first position of outrigger. The maximum deflection at top of structure reduced up to 335.15mm when provided with second outrigger at 3/4th height of structure.

Srinivas Suresh Kogilgeri et al presented in their paper a study on behaviour of outrigger system on high rise steel structure by varying outrigger depth that the decrease in the depth of the outrigger to 2/3rd of the story height reduced the percentage reduction of lateral displacement and story drift up-to 4% – 5% when compared with outrigger depth of full story height. Further decrease in the depth of the outrigger to 1/3rd of the story height reduced the percentage reduction of lateral displacement and story drift up-to 6% – 7% in comparison with outrigger depth of full story height.

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Akash Kala et al Presented in their research paper that the maximum drift at the top of structure when only core was employed was around 440 mm and that was reduced by suitably selecting the lateral system. The placing of outrigger at 20^{th} storey reduced the maximum drift to 406 mm. The optimum outrigger location of a high rise building under the action of wind load was between 0.25 - 0.33 times the height of the building (from the bottom of the building), which was consistent with the optimal location associated with wind loading.

Y. Chen, et al introduced the concept of dampers to control the time period and the fundamental frequencies and the vibrations induced due to lateral loads. He developed a simple beam-damper system model for a building with such dampers to gain insight into the conceptual design of such damped outrigger system in a tall structure. He found that there exists an optimal damper size, which results in system modal damping approaching its maximum value, for an assigned damper location and this maximum system modal damping varies with damper location and modal order.

III. CONCLUSIONS OBTAINED FROM LITERATURES

For 40 story steel building when the depth of the outrigger reduced to 2/3rd and 1/3rd of the story height the percentage of lateral displacement and story drift reduced up-to 4% – 5% and 6% - 7% respectively when compared with outrigger depth of full story height. Hence, Drift increased when depth of outrigger decreased.

The optimum outrigger location of a high rise building under the action of earthquake load was found to be between 0.44 - 0.48 times the height of the building (from the bottom of the building).

For peak acceleration criteria, the optimum position of outrigger was at top where it was reduced up to 30%.

The optimum location of first outrigger was at top of the building. The optimum location of second outrigger was at middle height of the building.

In comparison of outrigger at top story as a cap truss with and without belt truss, there were not much reductions in drift with belt truss. Using second outrigger with cap truss gave the reduction in drift with and without belt truss. The optimum location of second outrigger was middle height of the building.

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