INTERNATIONAL JOURNAL OF ADVANCE RESEARCH, IDEAS AND INNOVATIONS IN TECHNOLOGY

IJARIIT

ISSN: 2454-132X
Impact factor: 4.295
(Volume 5, Issue 3)
Available online at: www.ijariit.com

A review on "Study the performance of outrigger system under seismic loads"

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ABSTRACT

High-rise structures in high seismic zones are subjected to earthquake forces, where the building performance is weakest in storey displacement and storey drift. Many types of research have adopted various techniques to improve the performance of high rise building. These techniques include the provision of core shear wall, bracing systems, dampers, etc. these techniques are able to reduce storey displacement to some extent, but the storey drift is the constraint was the performance of building weakens. This constraint makes the research work to adopt the technique of outrigger as an ancient technique used to reduce the vibration of the structure under the seismic shake. Hence, in this paper, a review of literature is studied to check the performance of the outriggers structural system in high rise building under seismic regions. The outrigger location and depth play an important role in the performance of the building. It is also observed that the outrigger structural system along with the core system reduces storey displacement up to some extent, but helps to reduce storey drift within the limit.

Keywords— *High rise building, Outriggers, Depth, Seismic performance, Storey displacement, Storey drift*

1. INTRODUCTION

Outriggers are used in tall and narrow structures, from half a century, but the design principle of outriggers has been used over 100 years. The outriggers in oldest form were connecting the horizontal beams with the canoe-shaped ocean shaped hulls of ocean-going boats for stabilizing floats of the boat, shown n figure 1. This concept illustrates the system of outriggers in building structures. As the boat may overturn due to the unexpected waves, but due to the weight of outriggers leverages creates upward resistance which in turn avoids the overturning of the boat. Similarly, the building outriggers connected to the outer periphery of the building has the capacity to resist upward and downward forces and this improves the building's resistance to overturning. Instead of beam and canoe-shaped hull arrangement, the boat may still experience discomfort for a long period. Outriggers help to reduce the overturning behavior and shortens the period of movement after the occurrence of upward and downward forces.

Fig. 1: Polynesian oceangoing boats with outriggers

Similarly, building outriggers can also reduce the lateral displacement, story drift and period of vibration. Boats may have outriggers on both sides and one sides. In the same way, the building may be incurred with outriggers from the central core of building and extending to both sides, or sometimes building core is located on one side with outriggers and extended on one side of a building.

During the appearance of external forces, the building with outrigger system acts in such a way that, the outriggers holds stiffly the outer periphery columns when the central core of building tends to tilt. This rotation at the outrigger creates tension and compression couple in the outer column, which acts in the opposite direction of movement. This results in the formation of restoring moments on the core at the level.

The analysis and design of the overall core and outrigger system are not that simple. One cannot arbitrarily assign the overturning forces to the core of the building. Certainly, the perimeter structural elements along with the core being one lateral load resisting system will help to reduce core overturning moments, the core horizontal storey shear forces will not be reduced, but will be at outrigger stories, because of outrigger horizontal force couples acting on the core.

Belts, such as walls or trusses encircling the building, have the capacity to improve lateral system efficiency. For towers incurred with outriggers, where individual mega columns engage, belts induce more gravity load to the mega columns. This, in turn, minimizes net uplift, column splices or the amount of reinforcement required for resistance to tension and reduce concrete associated stiffness in net tension.

Frequently, the concept of the core-and-outrigger system is selected for the lateral load-resisting system of high rise structure and slender buildings, where overturning moments are larger as compared to shear, and where building's overall flexural deformations contribute mainly to lateral deflections such as story drift. In these cases, outriggers reduce core wind moments and building drift. Outriggers provide increased stiffness and hence, are very efficient and cost effective. It also reduces building acceleration and improves the comfort of the occupants during heavy winds

2. PROBLEM STATEMENT

In tall buildings structures, lateral loads induced by wind or earthquake often resisted by a system of coupled shear walls. But when the building height increases, the stiffness of structure becomes more important. For buildings taller than a certain height, moment resisting frame structures, shear wall structures, braced frame structures, tubular structures etc. may not provide adequate stiffness to resist lateral wind and earthquake loads. The outrigger beams are introduced often between the sheer walls and external columns to provide sufficient lateral stiffness to the structure. To control the effect of a lateral load either due to earthquake or wind, in terms of excessive drift and to minimize the overall structural damage, outriggers are commonly used in high rise structure, particularly in wind load dominant or seismic active zone, this system can be chosen as an appropriate structure.

3. LITERATURE REVIEW

Z. Bayati1, M. Mahdikhani and A. Rahaei (Oct 2008) [1] this paper have carried out a study on analysis of optimized use of the multi-outrigger system to stiffen tall buildings. In this paper, the author represents the results of an analysis on drift reduction in uniform belted structures with rigid outriggers, through the analysis of a sample structure built in Tehran's Vanak Park. From the results, it is concluded that using an optimized multi-outriggers system reduces the seismic response of the building. Also, the results show that a multi-outriggers system is able to decrease elements and foundation dimensions.

Gerasimidis S., Efthymiou E. & Baniotopoulos C. C. (July 2009) [2] in this paper author have carried out an analysis of high rise steel building for wind loads for finding out optimum outrigger locations. The structure is analyzed for indicative wind loading with all possible outrigger locations monitoring important factors, like a drift of the building and moments on the core. It is concluded that the governing factors for the design of tall and slender structures area strength (material capacity), stiffness (drift) and serviceability (motion perception and accelerations), produced by the action of lateral loadings, such as wind. Although depending on the design criteria, the empirical thumb rule is to place the outriggers in the mid-height of a building, the optimum location of the outriggers differs significantly.

S. Fawzia, A. Nasir and T. Fatima (2011) [3] in this paper author have carried out an analysis on the behaviour of outrigger structural system in high-rise buildings for the cyclonic region. The study is conducted keeping in view the challenging nature of high-rise construction with no generic rules for deflection minimizations and frequency control. On 28- storey, 42-storey and 57-storey, the effects of cyclonic wind and provision of outriggers are examined in this paper. Vital impacts on structural heights are observed with the change in plan dimensions. Keeping the plan dimensions the same and increasing the height of the building leads to the reduction in the lateral rigidity. The writer concluded that rigidity/stiffness of composite high-rise building is inversely proportional to its height i.e. the lateral stiffness reduces with a height increase of the structure while keeping the other. Therefore the introduction of the additional bracing system is required to keep up with the serviceability limits.

P. M. B. Raj Kiran Nanduri, B.Suresh, MD. Ihtesham Hussain (2013) [4] in this study, the author has carried out an analysis of the optimum position of the outrigger system for high-rise reinforced concrete buildings under wind and earthquake loadings. The main objective of this paper is to study outrigger and outrigger location optimization and the efficiency of each outrigger when three outriggers are used in the structure. In Nine 30–storey three dimensional models of outrigger and belt truss system are subjected to wind and earthquake load analyzed and compared to find the lateral displacement reduction related to the outrigger and belt truss system location. For the 30–storey model, 23% maximum displacement reduction can be achieved by providing the first outrigger at the top and second outrigger in the structure height. The above investigation comes to the conclusion that the use of outrigger and belt truss system in high-rise buildings increases the stiffness and makes the structural form efficient under lateral load. The placing of outrigger at the top storey as a cap truss does not give many reductions in drift with belt truss. It can be concluded that the optimum location of the outrigger is between half the height of the building.

Sabrina Fawzia, and Tabassum Fatima (July 2015) [5] in this paper, the author have considered high rise steel composite building subjected to wind loads to find the optimum position of steel outrigger system. The analysis is done to determine the optimum location of steel belt and outrigger systems by using a different arrangement of single and double level outrigger for various size, shape and height of the composite building. A finite element analysis is carried out for different layouts, rectangular, Octagonal and

L shaped building with 28, 42 and 57 storey. The summary of conclusions are, 28-storey provided the best result with the addition of bracings at the top level of the model in three layouts of the plan. The provision of a double level of outrigger at mid-height in 42-storey provides maximum reduction of lateral deflection. It is concluded that, in the case of 57 storey model with double belt-truss and outriggers levels, the provision of secondary outrigger at 2/3rd height (measured from ground level) is the most suitable alternative.

Srinivas Suresh Kogilgeri, Beryl Shanthapriya (July 2015) [6] in this author have carried out an analysis of high rise steel structure to study the behavior of the outrigger system by varying outrigger depth. The static and dynamic analysis is conducted for reduced depth of outriggers. Also, the analysis of the central core and outriggers structural system of the varied depth of outriggers are compared. The outrigger depth is reduced to 2/3rd and 1/3rd of the story height along with the full story height. The depth of the belt-truss is equal to the height of the typical story is maintained the same in all the structures. It is concluded that stiffness of the structure is increased with the use of outrigger structural system by connecting the building core to the distant column. Considering variable depth, when the depth of outrigger is decreased to 2/3rd of the story height reduces the percentage reduction of lateral displacement and story drift is decreased up to 4% to 5% in comparison with outrigger depth of full story height. Comparative study of the performance of outrigger with a depth of full storey height & decreased depth shows the minor difference.

Kishan P. Solanki1, Prof. Pradeep Pandey (April 2017) [7] the objective of this paper is to study the behavior of outrigger and, optimization of outrigger depth. In 50 storey structure, story displacement reduces from 425mm to 342mm before and after providing L type outrigger. After decreasing the height of outrigger, storey displacement slightly increases. Decrease in the depth of the outrigger to 2/3rd., 1/3rd. and 1/2 of the story height helps to reduce the percentage of lateral displacement and story drift up-to 3% – 4% and 5% - 6% respectively in comparison with outrigger depth of full story height. Hence, the reduction of depth of outrigger increases. There is not much difference observed in storey displacement for different outrigger depth. Up to some height of the building (up to 16 stories) then it increases slightly.

Sarfaraz I. Bhati, Prof. P. A. Dode, Prof. P. R. Barbude (May 2016) [8] in this paper, the author have carried out an analysis on high rise building with concrete outrigger structural system. Using ETABS software, Static and dynamic analysis of a 42 storey RCC model was examined for earthquake and wind loadings. It was concluded from the analysis, that provision of outrigger effectively reduces the displacements and drifts significantly, while the base shear of the building did not show much change with the introduction of outriggers. The above investigation concluded that the most critical lateral displacement due to wind load in y-direction was reduced by 38.35% and brought under the limit to satisfy the criteria of Displacement < H/500.

Ajinkya Prashant Gadkari, N. G. Gore (2016) [9] This paper deals with the study of the performance of the outrigger structural system in high-rise RC Building subjected to seismic load and Wind Load. A literature review is studied in this paper on various aspects of outrigger structural system as; Behaviour of outrigger structural system in High-Rise RC building, it was concluded that outrigger structural system is proficient in controlling top displacement as well as plays an important role in reducing inter-story drift. It has been suggested that the outrigger system works efficiently up to 60 storey high-rise building. In high rise building with plan irregularities to resist seismic loading, provision of the shear wall as closed box type is extremely effective as compared to a provision of shear wall in interior bays. Outrigger performs an essential role in reducing base shear and improves the structural flexural stiffness when the structure is subjected to earthquake static and dynamic loads.

Sreelekshmi. S, Shilpa Sara Kurian (August 2016) [10] the behavior of the outrigger system on high rise building is studied in this paper. This paper shows the results of an analysis on building with rigid outrigger based on displacement, drift and base shear through time history analysis using ETABS 2015 software. With the outrigger implementation, factors such as base shear, storey drift and displacement of the structure during an earthquake are reduced and hence the design of the building is to be done for wind and gravity loads. A 40 storied building was under consideration where the numerical study was conducted on steel structure providing outriggers at the top, one fourth, middle and three fourth height of the building, and outrigger at three fourth along with cap truss was found most efficient among the three in terms of story drift, displacement and base shear since

Alok Rathore, Dr. Savita Maru (Nov 2017) [11] In this paper, behaviour of outrigger structural system in high-rise RC building behaviour of different lateral load resisting structural system, behaviour of outrigger structural system steel and composite high rise building, behaviour of outrigger structural system with vertical plan irregularities and mass irregularities in the structures is studied. This study comes to the conclusion that use of outriggers did not show any significant change in base shear, Outrigger improves the structural flexural stiffness by reducing base shear when the structure is subjected to seismic static and dynamic loads. Outrigger structural system is proficient in controlling top displacement and also reducing inter-storey drifts. While the wind drifts in high rise building need to be reduced by adopting a more rigid and stable option to confine deformation and increase stability.

Karan Dipak Sitapara, Prof. N. G. Gore (May 2016) [12] In this paper, analysis of high rise building is carried out to check the feasibility of high rise outrigger structural system when the building is subjected to earthquake forces in seismically active zones. This paper discusses the brief introduction to various structural systems and elaboration on Outrigger System. It is concluded that the optimum outrigger position under seismic loads in a grid frame is between 0.4-0.48 times the structure height i.e., from the bottom of the building. Outriggers are placed at mid height to reduce the storey drift to the lowest amount. In multi-outrigger system, the maximum reduction in displacement is achieved when the ratios of heights of the two outriggers are 1.5 and relative axial rigidity of 0.75. Displacements and Depth of the outriggers are indirectly proportional.

4. CONCLUSIONS

Damped outrigger approach is not considered in previous researches. The study of the outrigger system by providing various damping system can be studied. Many researchers have studied the performance of outrigger structural system for a regular shaped building. However, the practical situation for geometrically irregular structure with unsymmetrical shapes has to be considered for analysis.

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