International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2016): 79.57 | Impact Factor (2017): 7.296

Study of Outrigger System for High Rise Structures

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Abstract: ***With increased demand of high-rise structure in recent scenario of increasing population .It has been a mandatory need to study about the proficient methods for safe and adroitly serviceable structure. On of such method is Outrigger method, which is eventually a stiffening method with a central core connecting to outer columns with the help of trusses laid horizontally, possibly with belt truss on periphery. This kind of structure can be very corroborative by preventing the overturning of structure hence reducing the storey drift making the core of stout nature. Another important determinant in choosing the outrigger format of structure is that since the system is quite rigid in comparison to conventional vertical cantilever system hence the foundation part is required to be designed much burly.***

Keywords: Outrigger, High Rise Building, Belt truss, Storey Drift.

1. Introduction

High rise structures have always been a reason for inducement, but it has always been a conceptual demur. Since the beginning of organised structural engineering construction and analysis of Tall buildings have always been a fascinating topic and with advancement of technology in terms of materials, concept, construction technologies etc. Various lateral load resisting systems like tube in tube, bundled tube, shear wall, outrigger system etc. have been developed. Outrigger system has been a theme that is very propitious method for tall building technology. Tall buildings are prone to huge lateral motions, obviously because of their slenderness the cardinal lateral force earthquake and wind pressure. Need of lateral stiffening system like outrigger is entail. This system basically involves a central core connected with outward laid out columns via a system of trusses, fitfully strengthened by belt trusses strapped at the outer perimeter of the structure. Many landmark structures have been constructed with this system like Taipei 101 (509m), Hong Kong IFC2 (380m), CTF Tower (520m) etc. A big issue for engineers dealing with tall buildings is the drift between storeys increasing as the height increases, providing a system as such hinders the amelioration of drift creating a stiff system.

2. Literature Review

In [1] the author has discussed briefly about the concept of Outrigger and its design. The author has made the study over the outrigger system with CTBUH, and also states that it is the first ever development of the outrigger system. In this study the author has made review about the design guidelines stated by the CTBUH. The author has stated the benefits of outrigger, challenges in design of outrigger and also non-favorable conditions for the implementation outrigger system. Further the author has explained the design consideration for outrigger system and also explained the core with some present examples. The author states that there is no any single standard method for the designing of the outrigger system and they should be designed and implemented with respective favorable conditions.

In [8], A.J.Horton has made very deep study of literature very outrigger system. The author has classified and discussed the types of outrigger system. He has made study over present structures utilizing the conventional type outriggers. The author has also investigated on the usage of offsets, alternative offsets and virtual outrigger in place of conventional outriggers. Further the author has discussed about conventional outrigger, virtual outrigger, offset outrigger and alternative offset outrigger with some examples. This discussion is based on the previous literature mainly. The author has also performed FEM analysis over a 75 storey building. The model is based on the previous literature author model, the only change by present author was he implemented column in place of champers. The author concludes that the use of virtual outrigger is more efficient than the conventional one. The author also observed that when the virtual outrigger system is utilized the levels at which outrigger to be placed could be much optimized. Further the author also observed that when the virtual outrigger is used to its full depth and when continuous perimeter bet trusses is implemented there is reduction in shear lag type effects. At last the author also concludes that when virtual outrigger is used it is more efficient against torsion and shows reduced differential shortening effects that are shown by conventional outrigger system.

In [7] author has designed an outrigger system by using software. In this the author has analyzed forty storey steel building by the use of ETABS software. The author has formulated the results for displacement, drift and base shear reduction for steel building frame. The analysis is made through time history analysis. The author found that location of outrigger is great influencing factor for efficiency of the outrigger system. The author concludes that the optimum position for outrigger is at 0.75 times the building height along with cap truss. The author found that there is reduction in factors like base shear, displacement and storey drift of the structure. This makes the building more efficient against earthquake and it becomes a need to design the building only for structural and wind load. The author also states that the outriggers were analyzed at various locations and they found that strorey drift, displacement and base shear were in safety limits as per IS 1893-2002 when placed at three fourth height.

In [5], the author has mainly concentrated on the drift reduction of the structure. For this the author has made a case study on Vanak Park, Tehran. The author has also discussed about the empherical formulas for deflection and moment at base from the previous research work. In present study the author have analyzed the building taken for case study which is 80 storey. The author has used Iranian Building Code for load calculations and has used ETABS software for building design and analysis. The author states that the use of belt truss as virtual outrigger with same column size and location is less effective as compared to the conventional type outrigger and this is due to reduced stiffness of the indirect force transfer mechanism. The author observed that by use of virtual outrigger there is no need to locate large exterior column at exterior for transfer mechanism. The author also observed that with implementation of this there is reduction in differential shortening effect in outriggers. The author also suggest that when one implements this system it is necessary to model the floor diaphragms accurately and cannot be modeled as rigid as the in-plane stiffness of the floors transfers horizontal forces from the core to outrigger.

In [6] the author has reviewed various techniques and methods that are used for outriggers and belt truss system in tall buildings. The parameters related to outriggers like lateral displacement, storey drift, core moment and optimum positioning are being discussed by the author in this study. They have also made a deep literature review based on the outrigger and belt truss system. Later on discussion is made based on the literature. The author make statement that many researches have tried to investigate on the optimum positioning of the outrigger and now it is need to discuss on controlling core moment, column reaction and building deflection. The author observed that although by research study it is clear that the optimum positioning of outrigger is at mid height of the building but it is mostly dependent on the system to be implanted and should be decided based on the design criteria. They observed that manual and software based results are nearly same for finding the optimum position of the outrigger.

In [4], the author has mainly concentrated on optimum positioning of the outrigger system when the tall structure is under lateral loading. For this study the author has considered a 30 storey building which is modeled and analyzed using ETABS. The load calculations and the earthquake force calculations are done by Indian Codes. Results have been formulated with respective of storey drift, column axial forces and moments in columns and at base. The authors have analyzed the structure for different positioning of the outriggers and have tabulated the results respectively. The author observed that the outriggers increase the stiffness of the building and in turn increases its stability under lateral loading. The author observed that there is 23% reduction in maximum displacement when the first outrigger is provided at the top and the second in the middle of structure height. The author concludes that by provision of second outrigger there is much reduction in lateral displacement.

In [2], the author has utilized two types of outrigger system i.e. concrete and steel. They have carried out their study by considering a 70 storied building and is being analyzed and modeled by ETABS software. For this the author has placed the outrigger at different locations to get optimum position. The author has also carried out wind analysis and the results are compared which are based on maximum storey displacement, inter storey drift and base shear. The author has made the placement of the outrigger at heights with interval of 0.2 times height and second with 0.25 times the height. The author has found that in both material cases i.e. concrete and steel the interval of 0.2 times height is best for four outrigger system. The author observed that steel outriggers are more efficient to reduce the lateral displacement as compared to concrete outrigger. Similarly, the author states there is reduction in values of storey drift and base shear in case of steel outriggers as compared to concrete outriggers. Overall the author concludes that steel outrigger system is more efficient then concrete outrigger system.

3. Concept

Outrigger system basically is a stiffening mechanism which helps the structure to prevent itself from swaying laterally in situation of lateral push or pull which may be applied due to net external forces acting along the structure. In this system unlike conventional framed structure which has differentiated connection and thus when the lateral component of forces acts on the frame it tends to create an uprooting moment at the bottom of the structure, which in turn sets a motion at the bottom of the structure. That motion of structure also encounters the peripheral soil with adequate strength at a discrete locus tends to experience an opposing stress. Contrariwise in outrigger system a central core is connected to the peripheral beams with inner outrigger beams, and apart from that outer peripheral is banded with belt truss, thus in this system the connection of core-outrigger-peripheral beam with belt tends to eccentricate the structure by producing a restoring moment and thus deteriorating the tendency of structure to move laterally. An interconnected system thus helps to confiscate the system on a broad aspect.

Reversals of load are also a very challenging concept, as far as a arduous system like that of an tall building is to be considered. The spatial properties should stay symmetrical in order to have controlled behavior under various load cases. Also, the storey drift of Structure may be controlled by stiffening through this outrigger system. Location of outrigger is a very important, as discussed earlier two concerning issues in tall buildings being moment generated at the bottom and lateral sway at upper portion. Anyways Core plays a very unalterable part since mid-rise and high-rise structures needs to have a lift-pit for escalating the vertical distance therefore an outrigger can be well amalgamated with such a system with much hassle. So, location of outrigger can be productively being placed at both upper and lower of the central part of the tower, it may also depend upon the symmetry of structure but still it is matter of further work with the help of software, experiments and further study.

4. Advantages and Disadvantages

Advantages:-

- A building which consist central core braced frame, an outrigger system holds perimeter columns to conveniently reduce building deformations from overturning moments and the resulting lateral movement at upper floors.
- If we compare free cantilever with outrigger system it is found that a tall building structure which embody an outrigger system can experience a reduction in core overturning moment up to 40 percent
- A building which consist central core braced frame, an outrigger system holds perimeter columns to conveniently reduce building deformations from overturning moments and the resulting lateral movement at upper floors.
- If we compare free cantilever with outrigger system it is found that a tall building structure which embody an outrigger system can experience a reduction in core overturning moment up to 40 percent
- And also a notable reduction in drift depending on the relative rigidities of the core and the outrigger system.
- Up to 60 percent reduction can be done in core overturning when in supertall towers mega column are used as perimeter for drift control.
- The column sized for gravity load may be efficient of resisting outrigger forces with minimal changes in size, are used as perimeter columns and belt truss holds all perimeter columns.
- Force reduction at core foundation.
- Overturning loads are completely distributed on foundation by help of outrigger systems.
- The shear and flexural need will be reduced by reducing core overturning in the tower foundation mat.

Disadvantages:-

- Outrigger systems intrude with the engage and rentable space
- The costly and thorough work should be there for connection at the interface between core and foundation
- To resist overturning moments costly foundations are required.
- Outrigger system has elements that are in vertical plane, which affects the floor area or say obstruction free area.

5. Conclusion

Outrigger system of High-rise building construction is an efficient method for reducing the risk of overturning of structure. Apart from overturning it also reduce the c chances of catastrophic failure of structural system and enhancing the low peril of high-rise building. One very important factor related to the system is the requirement of robust foundation, as healthy chunk of moments are produced at the bottom. But overall adaptability of this system should turnout on the positive edge of the curve.

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