International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056
Volume: 04 Issue: 05 | May -2017 www.irjet.net p-ISSN: 2395-0072

COMPARATIVE STUDY OF OUTRIGGER AND BELT TRUSS STRUCTURAL SYSTEM FOR STEEL AND CONCRETE MATERIAL

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Abstract –*Rapid growth of infrastructure to accommodate modern civilization is demanding tall structures in cities. As the buildings are becoming taller the problem of their lateral stability and sway has to be tackled by engineering judgment. Structural system development has evolved continuously to overcome the problems related to lateral stability and sway, one such structural system is outrigger and belt truss structural system.*
The outrigger and belt truss structural system has proved to be most promising structural system in resisting problem related to lateral stability and sway. The present study is conducted for 70 storied high rise building with core shear wall. High rise building with floor plan of 30 m x 30 m in addition with core shear wall of 10 m x 10 m is considered with building aspect ratio of 7.Wind analysis is carried out to study parameter's maximum storey displacement, inter storey drift and base shear to compare building with application of concrete and steel outrigger at various position varying with the height of building and the software used for this analysis is ETABS of 2016 version.

Key Words: outrigger, belt truss, shear wall, lateral stability, sway, storey drift, storey displacement, base shear, wind.

1.INTRODUCTION

In today's modern era it has become need to undertake development in tall structure to accommodate the present population as the cities are growing fast and land availability is becoming lesser for human beings, so there is need for development of tall structures, but with development of tall structures there is need to tackle the problems related to it .Outrigger and belt truss structural system has proved to be efficient and economical solution for the problems related to tall structure development.

1.1. Outrigger and belt truss structural System

The outrigger and belt truss system comprises of a main concrete core connected to exterior columns by relatively stiff horizontal members such as bracings termed as outriggers. The bracing can be of different shape. The core may be centrally located or it may be located on one side of the building with outriggers extending to the building columns on one side. The basic structural response of the system is based on very simple concept. When structure is subjected to lateral loads, the columns on which the outriggers rest combining the column restrained by outrigger resist the rotation of the core, causing the mitigation in magnitude of lateral deflections and moments in the core in comparison to the freestanding core alone resisted the loading. The external moment is now resisted by combined action of the bending of the core and the axial tension and compression of the exterior columns connected to the outriggers. As a result of this effect the strength of the structure for resisting bending is increased when the core acts as a vertical cantilever, by the development of tension in the windward columns and compression in the leeward columns. The column located at periphery also help in distributing the moments and reducing the rotation of outriggers, which can happen by combining the exterior columns with bracings commonly referred to as a "belt truss," around the building. The belt truss is the bracing around the building at the same floor which are located between adjacent columns. The belt truss and the outrigger together combined stiffens the building and mitigate the rotation of the core, storey displacement and storey drift. This method is aimed to reduce obstructed space compared to the conventional method. The outrigger and belt truss system has solved the problems of other structural system so the use of outrigger in recent tall structures has increased tremendously. Outrigger and belt truss is economical in comparison to other structural system and is simple in terms of its arrangement and technical background.

1.2 Concept of Outrigger

Outriggers have been effectively used in the sailing ship industry for long time which were used to resist wind. The slender mast was connected with horizontal outrigger, the above mentioned arrangement can be imagined as the core treated like the mast, the outriggers like the spreaders and the exterior columns like the shrouds or stays. Engineers had observed this behavior of sail boats in resisting wind and so it was implemented in buildings which further was studied and used as outrigger and belt truss system in building especially in high rise buildings. The basic concept of outrigger and belt truss system was found out from the arrangement of mast, spreaders and shrouds in sail boats.

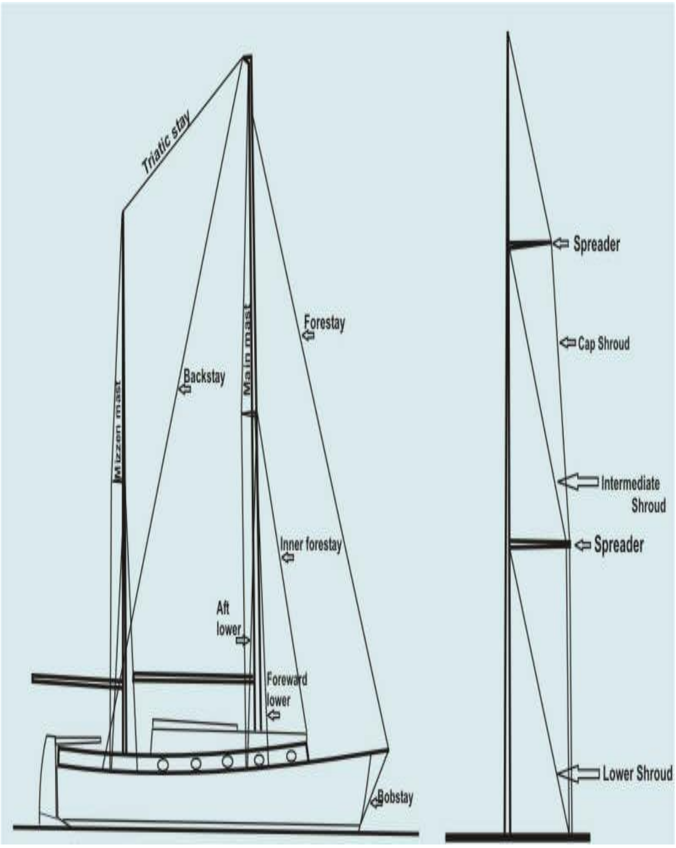

Fig.1.2.1 Sail boat with mast, spreader and shroud.

1.3 Classification of Outrigger structural system

On the basis of connection to the core there are two types of outrigger truss;

1.Conventional Outrigger system
2.Virtual Outrigger system

Conventional Outrigger System

In the conventional outrigger system, the outrigger bracings are connected directly to shear walls at the core and with columns at the periphery of the building. The intermediate columns between the external columns and the shear walls are connected with outrigger bracings. The outrigger can be applied simultaneously at multiple floors simultaneously. The outrigger bracings connected to the core and external columns converts the moment in core to vertical couple in columns. Problem of axial shortening and elongation of the columns and deformation of the trusses causes rotation of the core at the outrigger in minor level, maximum times it is found that there is reverse curvature due to small rotation in core.

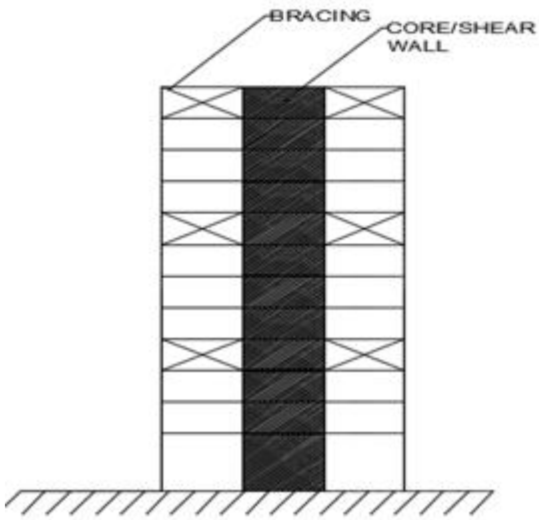

Fig. 1.3.1. Tall building with conventional outriggers.

Belt Trusses as Virtual Outriggers

The floor diaphragm action restrict the rotation of the core is resisted by the floor diaphragms at the top and bottom of the belt trusses which results in conversion of moment in core into a horizontal couple in the floor, which in turn is transferred to the inclined bracings which then shift their forces to the vertical columns supporting it. Three dimensional elastic analysis is used to determine forces and moments created in all components. The lateral load resisting system consists of shear wall core, external columns, belt truss bracings and floor diaphragm action. The belt truss is connected to the external columns; belt truss is bracing that are connected to the external column which tie down the periphery of the building.

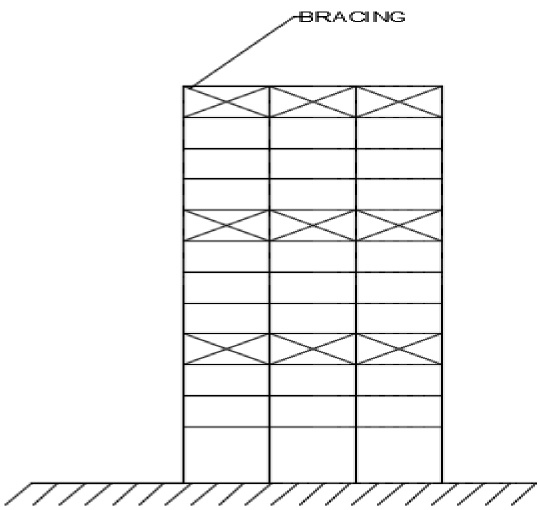

Fig.1.3.2. Tall building with belt trusses as "virtual" outriggers

2. MODELLING AND ANALYSIS

High rise building of 70 storey having 30x30m plan dimension with each storey height of 3 m with core shear

wall of 10 m x 10 m is taken into consideration. The dynamic analysis is performed using time history method. The nonlinear time history analysis is carried out by using El-Centro time history data. Wind load in this study is established in accordance with IS 875(part 3-Wind loads). The location selected is Mumbai. The Basic wind speed as per the code is Vb=44 m/s. The coefficients K1 and K3 are taken as 1.0. The terrain category is taken as, Category 3 with structure class C.
Comparison between structures is carried out the parameter such as base shear, maximum storey displacement, storey drift, and acceleration are taken into consideration for comparison using ETABSv16.

A. MATERIAL PROPERTIES

1. concrete - M40
2. reinforcement- Fe415
3. steel- Fe345

B. SECTIONAL PROPERTIES

1.Columns -1200 mm*1200mm
2.Beam1 -600 mm*400mm
3.concrete outrigger -1000 mm*400mm
4.steeel outrigger (Box Section)-1000mm*400mm
4.Slabs -125mm thick
5.Shear wall -175 mm thick

C.LOADINGS

1. Super dead load - 1 KN/m2
2.Live load - 4KN/m2
3. Zone factor - 0.24
4. Soil Type - II
5. Importance factor - 1
6. Response reduction factor-5

3.RESULTS AND DISCUSSION

3.1 MAXIMUM STOREY DISPLACEMENT(WIND ANALYSIS)

The storey displacement below is maximum storey displacement which are compared for concrete and steel outrigger.

Table 3.1.1: Displacement for with and without concrete outrigger and belt truss.

MODELS	TOP STOREY DISPLACEMENT(mm)	PERCENTAGE REDUCTION
WITHOUT OUTRIGGER	323.31	
CONCRETE OUTRIGGER AT 0.25H &0.5H &0.75H &H	252.52	21.89%
CONCRETE OUTRIGGER AT 0.2H &0.4H &0.6H &0.8H	239.25	25.99%

*Note:- H is total height of building in meters.

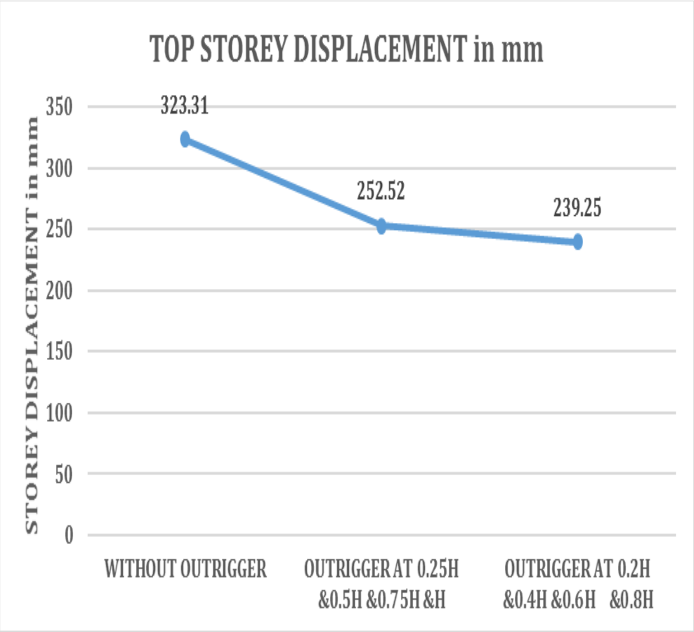

Chart 3.1.1: Comparison for with and without concrete outrigger and belt truss
The chart 3.1.1 is plotted based on the table 3.1.1 values for Symmetrical structure of maximum storey displacement.

Table 3.1.2: Displacement for with and without steel outrigger and belt truss.

MODELS	TOP STOREY DISPLACEMENT (mm)	PERCENAGE REDUCTION
WITHOUT OUTRIGGER	323.31	-
STEEL OUTRIGGER AT 0.25H&0.5H &0.75H&H	241.92	25.17%
STEEL OUTRIGGER AT 0.2H&0.4H &0.6H&0.8H	227.23	29.71%

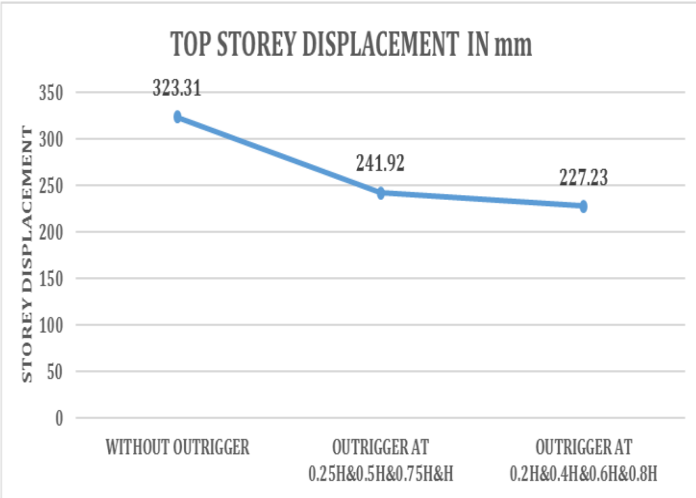

Chart 3.1.2: Comparison for with and without concrete outrigger and belt truss

The chart 3.1.2 is plotted based on the table 3.1.2 values for Symmetrical structure of maximum storey displacement.

3.2MAXIMUM STOREY DISPLACEMENT (TIME HISTORY ANALYSIS)

The storey displacement below is maximum storey displacement which are compared for concrete and steel outrigger.

Table 3.2.1: Displacement for with and without concrete outrigger and belt truss.

MODELS	TOP STOREY DISPLACEMENT (mm)	PERCENTAGE REDUCTION
WITHOUT OUTRIGGER	252.04	-
CONCRETE OUTRIGGER AT 0.25H&0.5H &0.75H&H	222.38	11.77 %
CONCRETE OUTRIGGER AT 0.2H&0.4H &0.6H&0.8H	213.85	15.15 %

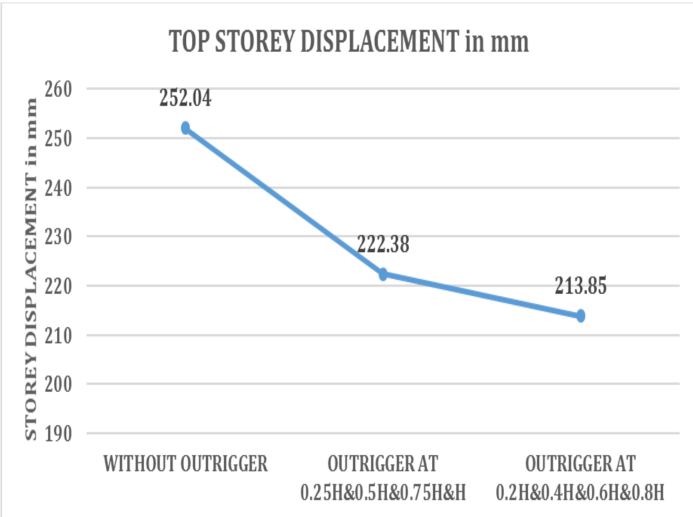

Chart 3.2.1: Comparison of displacement for with and without concrete outrigger and belt truss

The chart 3.2.1 is plotted based on the table 3.2.1 values for Symmetrical structure of maximum storey displacement.

Table 3.2.2: Displacement for with and without steel outrigger and belt truss

MODELS	TOP STOREY DISPLACEMENT (mm)	PERCENTAGE REDUCTION
WITHOUT OUTRIGGER	252.04	-
STEEL OUTRIGGER AT 0.25H&0.5H &0.75H&H	217.7	13.62 %
STEEL OUTRIGGER AT 0.2H&0.4H &0.6H&0.8H	207.89	17.51 %

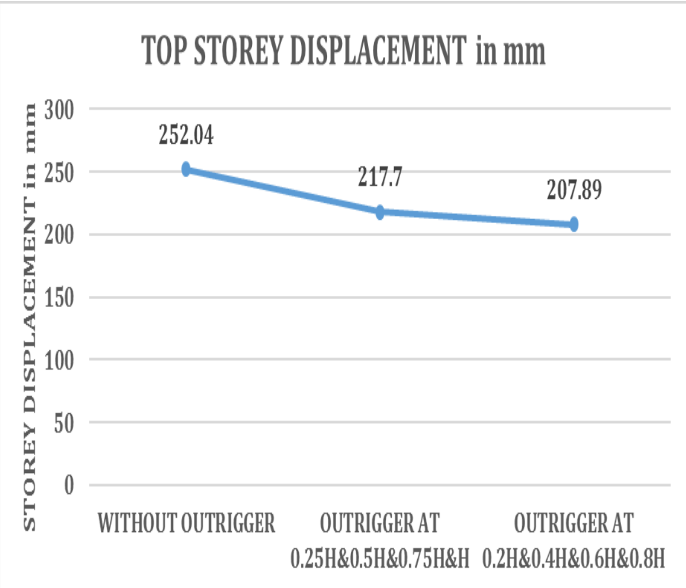

Chart 3.2.2: Comparison for with and without concrete outrigger and belt truss

The chart 3.2.2 is plotted based on the table 3.2.2 values for Symmetrical structure of maximum storey displacement.

3.3 STOREY DRIFT

The storey drift below is compared for concrete and steel outrigger.

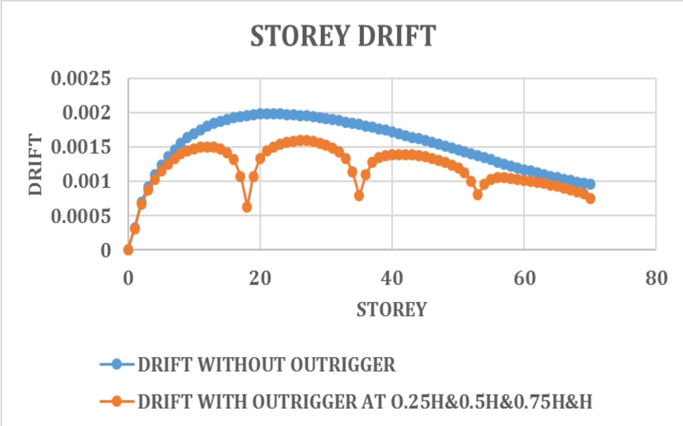

Chart 3.3.1: Comparison of drift for with and without concrete outrigger and belt truss

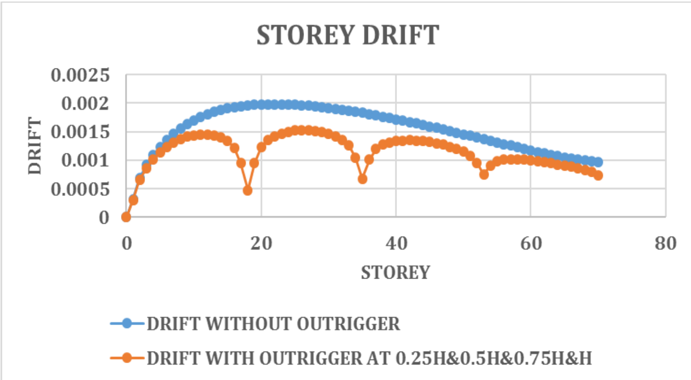

Chart 3.3.2: Displacement for with and without steel outrigger and belt truss.

3.4 BASE SHEAR

Table 3.4.1: Base shear comparison

MODELS	BASE SHEAR(kN)	PERCENTAGE REDUCTION
WITHOUT OUTRIGGER	20638	-
CONCRETE OUTRIGGER AND BELT TRUSS	21146	2.46 %
STEEL OUTRIGGER AND BELT TRUSS	20958	1.55 %

4. CONCLUSIONS

After performing analysis and studying the results we can come to the below conclusion's:
1. Outrigger system is found to be efficient in controlling the lateral loads and has proved to be economical.
2. The top storey deflection by wind analysis of the concrete outrigger for outrigger at 0.25H&0.5H&0.75H&H has resulted in 21.89% reduction in displacement.
3. The top storey deflection by wind analysis of the concrete outrigger for outrigger at 0.2H&0.4H&0.6H&0.8H has resulted in 25.99% reduction in displacement, which is found to be best for the combination of four outriggers.
4. The top storey deflection by wind analysis of the steel outrigger for outrigger at 0.25H&0.5H&0.75H&H has resulted in 25.17% reduction in displacement.
5. The top storey deflection by wind analysis of the concrete outrigger for outrigger at 0.2H&0.4H&0.6H&0.8H has resulted in 29.71% reduction in displacement, which is found to be best for the combination of four outriggers.
6. The top storey deflection by time history analysis of the steel outrigger for outrigger at 0.25H&0.5H&0.75H&H has resulted in 11.77% reduction in displacement.
7. The top storey deflection by time history analysis of the concrete outrigger for outrigger at 0.2H&0.4H&0.6H&0.8H has resulted in 15.15% reduction in displacement, which is found to be best for the combination of four outriggers.
6. Steel outrigger has found to be efficient in reduction of displacement as compared to concrete outrigger.
7. Storey drift of steel outrigger is found to be less in comparison to concrete outrigger.
8. Base shear of steel outrigger is found to be less in comparison to concrete outrigger.
9. Overall, steel outrigger and belt truss system is found to be efficient in comparison to concrete outrigger and belt truss system.

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