Study On Outrigger Structural System

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***Abstract*—The rapid developments of materials, construction technologies and structural systems have given rise to a significant increase of skyscrapers over the past decades. The reduction of the top drifts and base core overturning moments under lateral loads, such as earthquakes and wind loads, has drawn increasing attention in the structural design of super-tall buildings. The principle of using an outrigger system to enhance the structural lateral stiffness and overall stability is that the core-tube and the external columns are connected by rigid horizontal cantilevers. Optimum locations for Installations of outrigger systems can be founded. Overall displacements and lateral drift can be reduced. Outrigger systems enhance the stiffness of high-rise buildings by the introduction of stiff outriggers at different locations. The loads considered are as per IS codes. An ETABS model of 45-storey building is considered for this study.**

Keywords— Outrigger, ETABS, Displacement, Drift, Time period, Belt Truss System

I. INTRODUCTION

1.1 General

The fascination of constructing tall buildings were started by the mankind from the early stage of Civilization. Human race had always fascinated for height and throughout our history, we have constantly sought to reach for the stars, from the ancient pyramids to today's modern skyscraper. Initially they were constructed for defence purposes, however now a days it is been largely used for commercial, residential and mixed purposes also.

Consequent development of urban population, constrained availability of space, cost of plots, urge to preserve agricultural lands, significance of pride, advanced technologies has contributed to construct tall buildings.

Once the height of the structure increases, its stiffness and strength decreases. Therefore an engineer will be having a tedious job of taking due concern about the various parameters such as strength, stability, displacements, storey drifts etc. The major loads acting will be vertical like gravity load (Dead Load and Live Load), lateral like Earthquake Load and Wind Load. The main function of the structural elements is to withstand all these forces.

Tall structures can basically be simplified into a cantilever which is restrained at the base and free at the top. Even though gravity loads are the prominent loads on the structure, lateral loads like earthquake and wind loads are dominant as they are unpredictable and has the tendency to tilt and overturn the whole structure.

1.2 Structural Behaviour of Outrigger System

The outrigger and belt truss system acts very important role to resist the lateral loads in the structure. In this structure the external columns are tied to the central core wall with stiffened outriggers and belt truss at one or different levels. The outrigger and belt truss system effectively control the excessive drift due to lateral load and minimize the risk of structural and non-structural damage. Outriggers are stiff elements connected to a structure core to outer columns. Whenever a lateral load is acting on an outrigger structure, column-restrained outrigger offers resistance to the core from rotation. It induces tensile force and compressive force in windward and leeward mega-columns resulting in an increased effective depth of the whole structure.

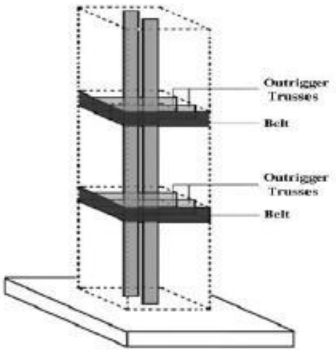


Fig- 1.1: Structure with Outriggers and Outrigger with Belt Truss

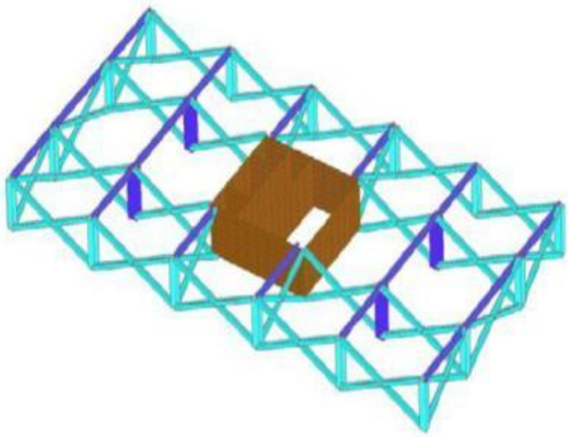


Fig- 1.2: 3D view of Outrigger and belt truss belt truss

II. LITERATURE REVIEWS

2.1 *General*

The literature review is the most important which has the similar studies give on focus from recent parts of outrigger system of reinforced concrete frames to determine the research work using high seismic zone wind analyzed. The concept of modeling and analysis used for purpose of improvement technique and economically.

2.2 *Reviews:*

K.Kamath et al (2012) carried out a study on static and dynamic behaviour of Outrigger structural system for tall buildings. A three-dimensional 40 storey building with 7m x 8m central shear wall was considered. The typical floor height is 3.5m and a total height of 140m.The building was modelled using ETABS software for reinforced structure with central core wall with outrigger and without outrigger. Column and beam sizes considered in the analysis were 0.75m x 0.75m and 0.23m x 0.45m respectively. An analytical study was conducted by varying the flexural rigidity and varying the position of outrigger along the height of the building in ETABS software.

Han-So Kim et al (2019) conducted studies on dual purpose outrigger in tall buildings to reduce lateral displacement (LAT) and differential axial shortening (DAS). Finite element method was used to evaluate lateral displacement and differential axial shortening. Outrigger systems have proven to be efficient for reducing lateral displacements in tall buildings subjected to wind and earthquake. The vertical locations of outrigger affect the restraining performance of the buildings. The locations of outriggers affect their effectiveness in terms of reducing lateral displacements and axial shortening. So there is a need for investigation of optimal locations of outriggers for minimising LAT and DAT. To analyse the effect of outrigger in tall building a structure with 80 floors was chosen. Total height of the structure was 280 m and the typical storey height is of 3.5 m.

Indrajeet Jain et al.,(2017) investigated the use of outrigger and belt truss system for high rise RCC building. The model analysed was a 60 storey building with constant storey height of 3.5 m and total height of the building is 210 m high rise R.C frame. The plan of the structure is L shaped with columns spaced at 6 m from centre to centre. All the floors are considered as typical floors. Analysis is done using E tabs software. For the model with only one outrigger, location of the outrigger beam was changed from the first floor to the top floor in the building model and wind load analysis was carried out for each location. Profiles for maximum lateral displacement for each outrigger location were then plotted for each case and their relationships were investigated. Maximum drift at the top of structure when only core is employed is around 493 mm and this is reduced by suitably selecting the lateral system. The placing of outrigger at 20th storey reduces the maximum drift to 385 mm. The optimum outrigger location of a high rise building under the action of wind load is between 0.25-0.33 times the height of the building (from the bottom of the building), which is consistent with the optimal location associated with wind loading.

S. Fawzia and T. Fatima, this has studies **the deflection control in composite building by using Belt truss and outrigger system** .This stated the design and analysis of high-rise structures is more frequently to determine the serviceability than strength. These are investigation of deflection control by efficient use of belt truss and outrigger system of 60 storey building subjected to lateral load. According to this three-dimensional analysis is performed with one, two, three outrigger level which give the reduction as compared to without outrigger are 34%, 42%, and 51%.

III. METHODS OF ANALYSIS

Most of the building structures were not designed to resist major and moderate types of seismic by using manually, in fact it usually by gravity loading and lateral load which make susceptible to attack the building during the event of earthquake. So its uses to consider the seismic loads by using the ETABS software, it is to improve hazard life and capability of essential facilities after an earthquake. The ETABS software is also to create three dimensional models and to carry out the design and analysis.

A 45-storey regular building and building was modelled with bay frame with and without the outrigger structural system at various locations to evaluate the seismic performance of the structure. Plan dimension was 35m × 35m. Storey height is taken as 3.1m. It has 7 bays in longitudinal direction and transverse direction with an equal spacing of 5 m. Fig 3.1 depicts the 3D of the base model of the 45-storey building. All beams are of the size 300mm x 600mm and M50 grade is used. Column size is mm 700 mm x 700mm for stories 24 to 45. Column size of 900 mm x 1000 mm is used for storey 1 to 23. All columns are of M 60 grade concrete and HYSD 500 steel is used. Slab thickness is considered as 150mm. The size of shear wall is taken as 400 mm. A live load of 4 kN/m² is applied as per IS: 875 (Part II) 1987 and the dead load is software assigned. Floor finish of 1 kN/m² is provided. Lateral loads are applied as seismic load in X and Y direction as per IS 1893 (Part 1 2002). The design earthquake load is computed based on the zone factor of 0.36, hard soil, importance factor of 1 and the response reduction factor of 5 (IS: 1893 (Part-I), 2002).The support conditions are assumed as fixed. The columns were checked for load combinations of 1.5 (D.L+L.L) and was found safe. The property moment of inertia was modified for columns as 0.3.

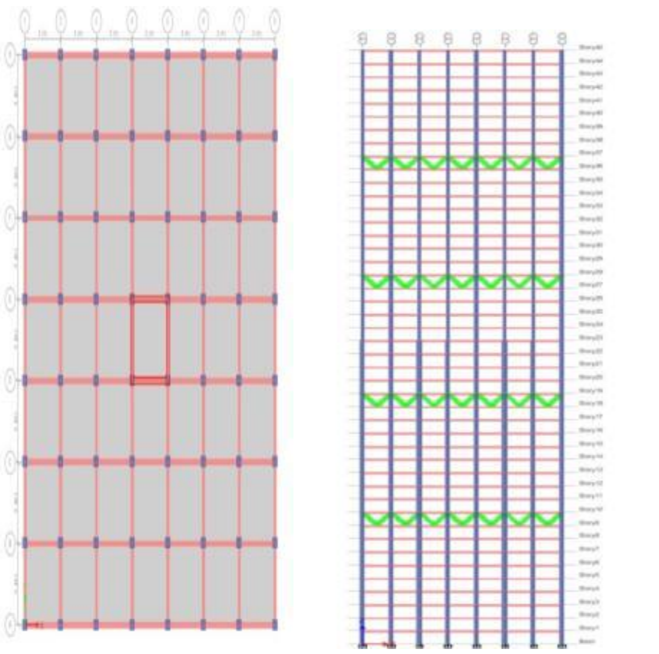


Fig. 3.1. Plan & Elevation of the Building

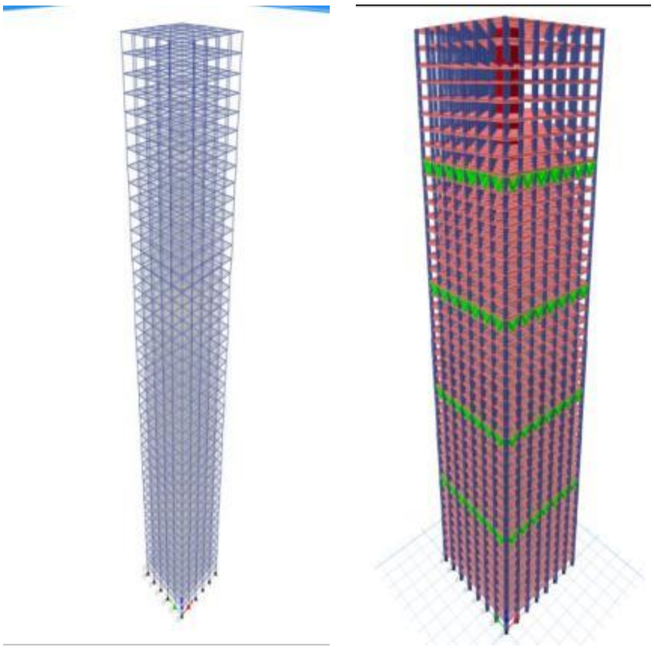


Fig. 3.2. Three-Dimensional view of a Regular Building

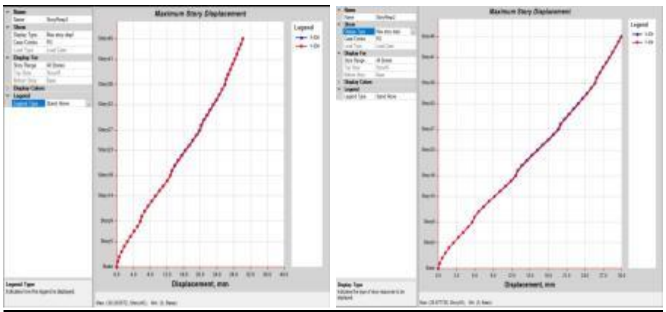
Modelling was done using the ETABS 2016 designed according to IS codes. Time history analysis using El-Centro Earthquake data is carried out for all the models to determine the seismic performance. Parameters like Maximum storey displacement and Maximum storey drift values were considered to compare the results. Comparison of seismic performance of the G+44 building with outrigger at various locations (0.2H, 0.4H, 0.6H and 0.8H) and without outrigger structural system was done. Outrigger location at 0.2H indicates that the outrigger is placed between the 8th and 10th floor Outriggers are placed in 9th, 18th, 27th and 36th storey of the 45-storey building (H is the number of storeys of the building). Investigations are also done to evaluate the performance of outrigger configurations among various shapes like X, V shaped bracings with and without belt truss by comparing the various seismic parameters.

IV. RESULT AND DISCUSSIONS

4.1 ***Comparison of Lateral Displacement, Shear and Time Period***

The results of base shear, lateral displacements, storey drifts, and natural period of vibration and overall performance for the building models are presented and compared.

4.1.1 Lateral displacement



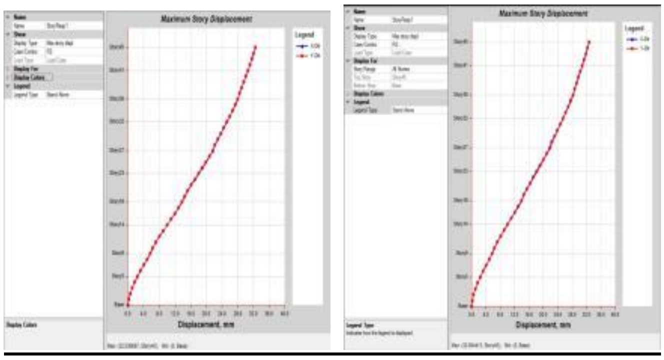


Fig. 4.1.1. Storey displacement for regular building with various outrigger locations.

MODEL	MODEL DESCRIPTION	DISPLACEMENT
1	CONCRETE- X outrigger with V bracings	27.47
2	CONCRETE - V outrigger with X bracings	27.67
3	STEEL - X outrigger with V bracings	29.99
4	STEEL - V outrigger with X bracings	30.14

Table 4.1.1 Models for comparing steel and concrete outrigger by displacement

4.1.2 Base shear

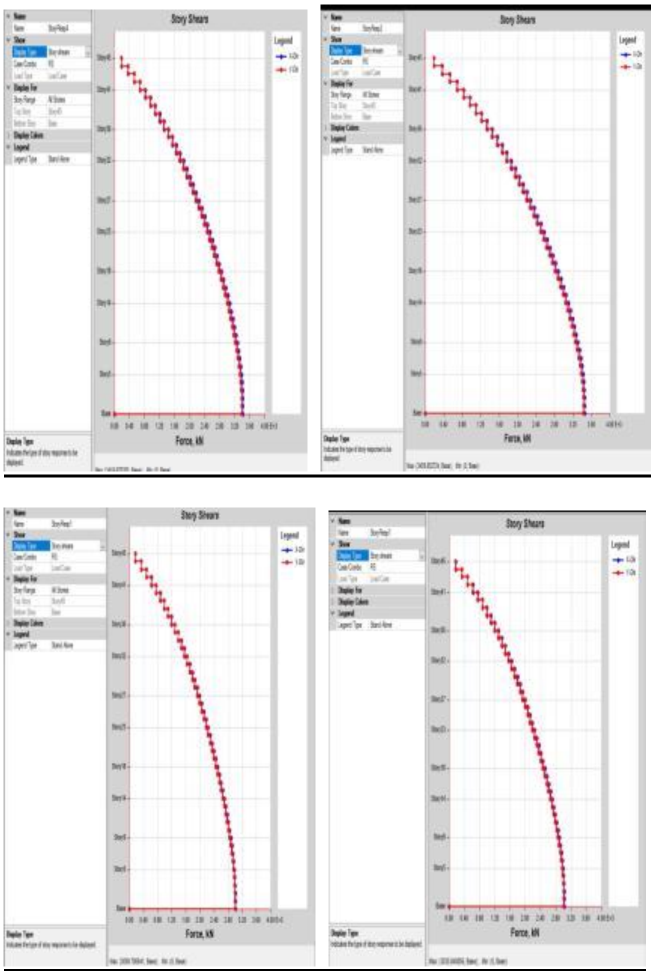


Fig. 4.1.2. Storey shear for regular building with various outrigger locations

MODEL	MODEL DESCRIPTION	SHEAR
1	CONCRETE- X outrigger with V belt	3703.49
2	CONCRETE - V outrigger with X belt	3670.45
3	STEEL - X outrigger with V belt	3338.78
4	STEEL - V outrigger with X belt	3320.64

Table 4.1.2 Models for comparing steel and concrete outrigger by shear

4.1.3 Time Period

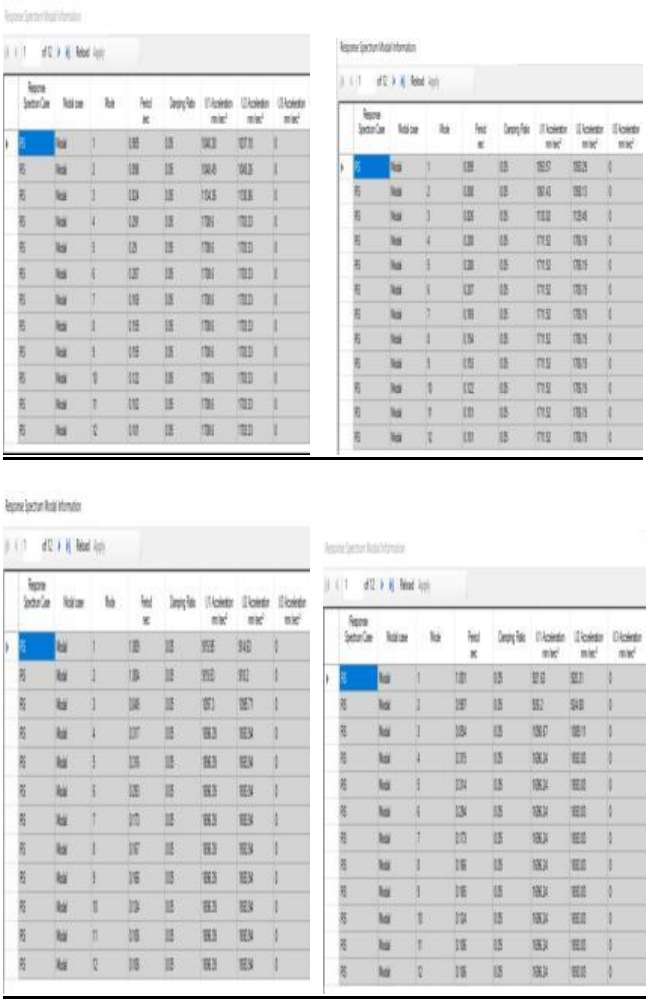


Fig. 4.1.3. Time period for regular building with various outrigger locations.

MODEL	MODEL DESCRIPTION	TIME PERIOD
1	CONCRETE- X outrigger with V belt	0.826
2	CONCRETE - V outrigger with X belt	0.833
3	STEEL - X outrigger with V belt	0.913
4	STEEL - V outrigger with X belt	0.918

Table 4.1.3 Models for comparing steel and concrete outrigger by time period

4.2 Optimum location

4.2.1 Regular building

In this study RB indicates regular building without outrigger configuration;

MODEL ID	REMARKS
RB	No Outrigger
RB02	Outrigger at 0.2 H
RB04	Outrigger at 0.4 H
RB06	Outrigger at 0.6 H
RB08	Outrigger at 0.8 H

Table 4.2.1 Models for optimal location study of RB

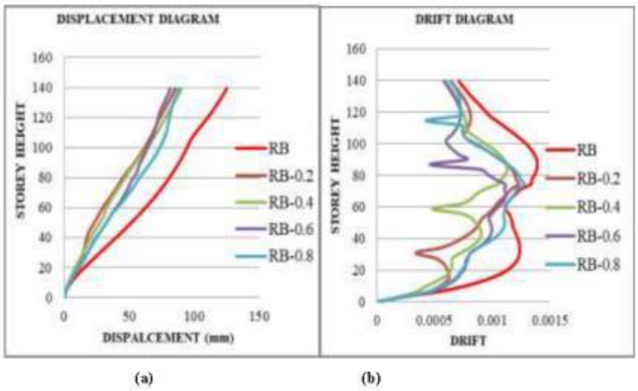


Fig.4.2.1(a) & (b) Storey displacement and drift for regular building with various outrigger locations.

The variation of lateral displacement and drift is shown in Fig 4.2. From Fig 4.2.1(a), It was observed that when the outrigger was provided at 0.6H location i.e., 27th floor, maximum top storey displacement control was by 34.75% and from Fig 4.2.1(b), it was observed that maximum top storey drift control was by 15.38%.This was in accordance with the journal values. Thus by providing outrigger at 0.6H drift and displacement of the regular building has maximum control.

V. CONCLUSION

In this paper, the technique of using Multi-Outrigger and Belt truss and its locations has been proposed based on its behaviour due to the applied lateral loads. Analysis has been carried out using ETABS structural software for various models discussed earlier.

Based on the outcomes obtained following are the conclusions made:

- Base shear in steel structure is less than the RC structures because of less seismic weight which gives better response during earthquake.
- Maximum point displacement and time period of Steel outrigger structure is more than RC outrigger structures.
- The behaviour of outrigger with belt truss system is studied in multi-storied building. It is studied that the outrigger with belt truss system is effective in controlling drift, displacement, of the building and makes the structural form efficient under seismic loading.

- Hence outrigger with belt truss improves the performance of the building by resisting the seismic forces.
- In regular symmetrical building, by providing outrigger at 0.6H location, top storey drift was controlled by 15.38% and displacement by 34.75 % in x and y direction. Hence optimum location for outrigger in regular symmetric building was found as 0.6H.
- Location and type of outrigger plays a very important role in the design of tall buildings.

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