DYNAMIC ANALYSIS OF HIGH RISE STRUCTURE WITH RC SHEAR WALL AND OUTRIGGER

Vinay B. Dandagalkar¹, Usha K N²
¹P G Student Department of Civil Engineering, EWIT, Karnataka, India
²Assistant Professor, Department of Civil Engineering, EWIT, Karnataka, India

Abstract— Tall building development has been rapidly increasing worldwide introducing new challenges. In tall structures high lateral forces develops due to wind load and earthquake load are crucial. Thus the effect of lateral loads need consideration for strength and stability of the structures. The Outrigger in structures provides lateral stiffness that provides significant drift control for tall buildings. The study includes Rigid Frame, Shear Wall/Central Core, Wall Frame Interaction and Outrigger effect on tall structures. The objective of this study is to know the performance of outrigger structural system in high-rise building subjected to wind load and seismic load as per Indian standards. In this comparative study mainly the bare frame will be compared with Steel outrigger with core for the structural efficiency. In this comparative study, the static and dynamic behaviour of the composite structure for different models such as steel bare frame, steel frame with outrigger, steel frame with shear wall, steel frame with shear wall and outrigger, steel frame with shear wall openings, and Steel frame with shear wall openings and outrigger will be compared for the structural response of a 40 storey composite building frame situated in earthquake zone-II and zone-V using ETABS software.

Keywords—Shear Wall, Outrigger.

I. INTRODUCTION

Tall Building has always been a vision of dreams and technical advancement leading to the progress of the world. Presently, with the rapidly increasing urbanization, tall building has become a more convenient option for office and residential housing. Tall buildings are usually designed for Residential, office or commercial use. They are primarily a reaction to the rapid growth of the urban population and the demand by business activities to be as close to each other as possible. A large portion of India is susceptible to damaging levels of seismic hazards. Hence, it is necessary to consider the seismic load for the design of high-rise structure. The different lateral load resisting systems are used in high-rise building as the lateral loads due to earthquake are a matter of concern. These lateral forces can produce critical stresses in the structure, inducing undesirable stresses in the structure, and undesirable vibrations or cause excessive lateral sway of the structure.

In the past years, structural members were assumed to carry primarily the gravity loads. Today, however, by the advances in structural design/systems and high strength materials, building weight has reduced, in turn increasing the slenderness, which necessitates taking into account majorly the lateral loads such as wind and earthquake. Specifically for the tall buildings, as the slenderness, and flexibility increases, buildings are severely affected from the lateral loads resulting from wind and earthquake. Hence, it becomes more necessary to identify the proper structural system for resisting the lateral loads depending upon the height of the building. There are many structural systems that can be used for the lateral resistance of tall buildings.

II. RELATED WORK

Po Seng Kiran and Frits Torang Siahaan (2001) [1]: have worked on the idea to increase the stiffness and make the structure proficient under wind as well as seismic load by introducing outrigger and belt truss system connecting core to exterior column. In this research work authors have studied the application of diagonal outrigger and belt truss with different configurations. They have carried out the analysis on a 40 storied 2-dimensional models subjected to wind load by introducing outrigger and belt truss systems with eight different configurations by varying the locations of outrigger as per the
Researchers have carried out research to examine the reduction in lateral displacement. Researchers have also focused on to determine the optimum location of outrigger. Investigation of this research paper have found that 65% maximum reduction in displacement is attained in the 40 storied 2-dimensional models subjected to wind load by providing two outriggers. The first outrigger is assigned at the top and second at the mid height of the structure. Further, about 18% maximum reduction in displacement is attained in 60 storied 3-dimensional model subjected to earthquake load by providing optimum location of outrigger truss at the top and 33rd level.

N. Herath et al. (2009) [2]: carried out the research based on the understanding that earthquake ground motion can occur anywhere in the world and the risk associated with tall buildings, especially under severe earthquakes, should be given special attention, since tall buildings often accommodate thousands of occupants. When the height of building increases, the consideration of stiffness is very important in tall building. In such case outrigger beam is proposed to be provided in between the shear wall and external columns to improve satisfactory lateral stiffness to the structure. The main intention of this research was to optimize the location of Outrigger for safety against Earthquakes and Economy in design. For this purpose, researchers have consider 9 previous earthquake records and based on acceleration to velocity ratios (A/V Ratio) namely, Park field (28 June 1966), Friuli (6 May 1976), Patras (29 Jan 1974), Gazli (17 May 1976), El Centro (18 May 1940), Spitak (7 Dec 1988), Mexico City (19 Sep 1985), Tabas (13 Sep 1978), San Fernando (9 Feb 1971). The performance of high rise building has been examined by studying different configurations of outrigger structural system. A model of 50 stories was analyzed for three different ratios of peak ground acceleration to peak ground velocity. In each category of earthquake records were incorporated in this research study to provide a consistent level of approach. Response spectrum analysis was conducted to determine behaviour of the building considering parameters such as lateral displacement and inter storey drift. It was proved from this study that the structure is optimized when the outrigger is placed between 22nd to 24th levels. Therefore it can be concluded that the optimum location of the structure is between 0.44-0.48 times its height (taken from the bottom of the building).

Kiran Kamath et al. (2012) [3]: fulfilled the study of efficient Outrigger Structural System in high rise reinforced concrete building. The basic thought behind this research study was to increase the stiffness and make the structural form efficient under the lateral load acting on the structure due to wind load as well as earthquake loads. Their research examined the behaviour of reinforced concrete structure with central core wall with various configurations of outrigger system by varying relative flexural rigidity. In this paper authors had also focused on optimum location of outrigger system in tall buildings by considering the relative height of outrigger beam i.e. (ratio of height of outrigger to total height of building).

In this research article researchers have considered 40 storey three dimensional models of 6 different configurations of outrigger of varying Hs/H ratio and varying relative flexural rigidity between 0.25 to 2 for modelling of structure. For static behaviour purpose equivalent static analysis was performed as well as for dynamic behaviour purpose. Time history analysis by considering the previous earthquake data of peak ground acceleration of California region as per Indian standard codes was carried out. A comparative study for the investigation of various parameters, such as lateral deflection, peak acceleration and inter story drift has been performed. From the whole investigation it is

International Journal of Recent Trends in Engineering & Research (IJRTER)
Volume 04, Issue 11; November - 2018 [ISSN: 2455-1457]

@IJRTER-2017, All Rights Reserved
observed that by considering the criteria for reduction in top displacement, optimum position of outrigger is at mid height of the building with relative flexural rigidity of 0.25 by static and dynamic analysis. Further, according to the authors, in time history analysis the response of structure does not show any particular trend with peak acceleration, though for all earthquake histories of California region the top lateral displacement was least for outrigger structure with relative height of 0.5.

**Thejaswini R. M. and Rashmi A. R. (2015) [4]:** have carried out a comparative study and analysis of different lateral load resisting structural systems to understand the realistic performance of the building during earthquake and under the excessive wind pressure as well as to select structural system of tall building to stay in good condition with effect of gravity, live load and external lateral load, moment, shear force and torque with acceptable strength and stiffness.

For this research work they have modelled a geometrically irregular 14 storey RCC high rise building with different forms of structural system, such as Rigid frame structure, Core wall structure, and Shear wall structure with different configurations of shear wall location, Tube structure and outrigger structure. Results of the analysis reveal that the values of displacement were less in tube structure and outrigger structural system. The authors have also stated that in geometrically irregular structure; stability of structure will boost and the columns sway can be reduced by implementing L-shaped shear wall along the corners of the structure. One important conclusion that the researchers have drawn from this study is that when outrigger structural system is provided at a story which has maximum drift, it can perform as a maximum drift controller.

**Alpana L. Gawate and J. P. Bhusari (2015) [5]:** have published their paper which focused on enhancement the lateral stiffness of tall buildings, because as the height of the building increases the core alone is not adequate to keep the drift within permissible limit. Therefore some other structural element is to be added in that building to take care of drift.

Outriggers are the structural system, which help in reducing the lateral drift increasing the stiffness of the structure by huge amount.

In this paper, the optimum location of the outrigger is found by considering few constraint conditions. The parameters on which the conclusions made are the lateral drift and formation of soft storey. A soft storey is one in which the lateral stiffness is less than 70 percent of that in the storey above or less than 80 percent of the average lateral stiffness of the three storeys above. It also takes into account the change in results due to changes in sizes of cross sections of columns and shear walls. For the analysis of this problem researchers have chosen a 30 storied three dimensional model with various configurations of outrigger such as system with single and double outrigger by changing cross sectional dimensions of columns and thickness of shear wall. The said model was analyzed by response spectrum analysis as per Indian standard codes and following conclusion has been drawn. When there was provision of only one outrigger, the system was not effective as concerning of drift. There was a remarkable change observed in the drift profile when two outriggers were provided. One important conclusion figured out from this research is no story was found as soft story for all 9 trials made in model with two outriggers with changes in cross sectional dimensions of columns and thickness of shear wall.

**Abdul Karim Mulla and Shrinivas B.N (2015) [6]:** had carried out research in regular as well as vertically irregular structure to increase axial stiffness with exterior columns to resist the overturning moment by introducing Outrigger structural system with steel bracing. Irregular structure has discontinuity in mass, stiffness and geometry of the structure. According to author the major reason of earthquake was vertical irregularities though it can
be avoided by providing outrigger to increase lateral stiffness. In this article researchers have performed the comparative analysis of 3 dimensional regular and vertically irregular shaped symmetrical plan 20 storey structures with and without providing outrigger beam subjected to earthquake load. The analysis of structure was done by equivalent static method and response spectrum method as per the Indian standard code practice. To measure the efficiency of the structure authors have considered parameters such as lateral displacement, story drift, base shear and fundamental natural period. On the same line authors have also examined the response of the structure with varying seismic zones as well as the behaviour of outrigger by equivalent static and response spectrum method by incorporating concrete and steel outrigger. Further they have also focused on the determination of optimum location of outrigger beam to lower the lateral displacement. It was observed through this research that there is considerable reduction in Time period when outrigger was introduced in regular and irregular building structure which will improve the overall stiffness of the structure. Base shear will reduce and minimize the inter story drift by incorporating outrigger. Geometric vertical irregularity was more effective due to reduction of self weight compared to regular building and Concrete outrigger are more effective than steel outrigger with X bracing type in reducing lateral story displacement.

Vijaya Kumari Gowda M Ryand Manohar B C (2015) [7]: have worked on lateral load resisting structural system by introducing belt truss at top and mid height of building. This proved to be cost effective to improve the performance of building subjected to earthquake load. Basically belt truss is the truss which is provided along the peripheral columns of structure at certain height of building to improve the stiffness and firmness against lateral loads. In this research work researchers have carried out a comparative study by using different types of belt truss which includes X, V, inverted V diagonal etc. for different seismic zone criteria to understand the importance of belt truss. To execute this study researchers have modelled 30 storied 3- d imensional models by implementing different types of belt truss and analyzed the model by equivalent static analysis and response spectrum method as per the Indian Standard codes. A comparative study has been performed based on percentage reduction of displacement and story drift at the different seismic zones. It is found from the study that for reducing lateral displacement and story drift, Concrete belt truss is more efficient compared to structural steel belt truss as it gives negligible results. Each type of trusses gives different results for different seismic zones, therefore based on economical conditions researchers have concluded that inverted V-type of belt truss is one of the best type of belt truss in all seismic zones to increase the efficiency of the building

ShivshankarK etval. (2015) [8]: presented research involving investigation of the action of outrigger structural system in Tall vertical irregularity structure. Vertical geometric irregularity shall be considered to exist where the horizontal dimension of the lateral force resisting system in any storey is more than 150 percent of that in its adjacent storey. In this study, 30 storey models having vertical irregularity were taken. The building plan changes at 11th and 21st story. These models were analysed with only bare frame and bare frame with one outrigger and belt truss for 6 configuration of outrigger beam by changing their position. Similarly bare frame with two outrigger and belt truss for 5 different configurations and the response of the structure was evaluated under the different parameters i.e. Lateral displacement, building drift, maximum story shear and axial load of different columns. To examine the behaviour of vertical irregularity of outrigger structural system, linear static analysis has been carried out as per the Indian standard. It was recognized through this research that around 28.58% and 27% lateral deflection and building drift was restrain by providing outrigger structural system in high rise vertical irregularity structure when it is provided at 0.67 times its height compare to bare frame as well as 37.7% and 36.11% of the Deflection and drift is
controlled by providing outrigger with belt truss at 0.67 times its height and 0.5 times it’s when compared with bare frame. This study concluded that the optimum location of outrigger was between 0.5 times its height in tall vertical irregularity structure.

III. OBJECTIVES

1. To understand the behavior of the high rise steel structures subjected to earthquake loads.
2. To study the effect of combined shear wall/core wall and outrigger in high rise steel structures.
3. To study the effect of the openings on the behavior of the reinforced concrete shear walls.
4. Here the total six models are analyzed. i.e., steel frame, steel frame with outrigger, steel frame with shear wall, steel frame with shear wall and outrigger, steel frame with shear wall with openings, and steel frame with shear wall with openings and outrigger.
5. Efficiency of high rise steel structures with respect to the storey lateral displacement, storey drift, base shear and time period are found out for all six models.

IV. METHODOLOGY

1. On this study high rise steel structure of 40 stories subjected to lateral earthquake loads is considered.
2. Analysis is carried out using equivalent static method and dynamic response spectrum analysis method using IS 1893:2002 for high seismic zone (V)& for zone (II) by using ETABS software.
3. Efficiency of high rise steel structures with respect to the storey displacement, storey drift, base shear and time period are found out for all type of models.
4. Further analysis is extended with the incorporation of outrigger and RC shear wall separately and responses of the steel structure is extracted.
5. Location of shear wall is selected at the core of the building.
6. Hence total six models are analyzed.
   Model -1: Steel frame.
   Model -2: Steel frame with Outrigger.
   Model -3: Steel frame with shear wall.
   Model -4: Steel frame with shear wall and outrigger.
   Model -5: Steel frame with shear wall openings.
   Model -6: Steel frame with shear wall openings and outrigger.
7. Based on the results extracted from six models, discussions will be made and conclusions will be made by indicating the effect of shear wall and outrigger in high rise steel structures.

V. STRUCTURAL MODLING AND LOAD

The structure is a G+39 story steel structure. The structure is 120m tall, and its length and width is 35m. The story height is 3m. Depth of deck slab is 200mm, thickness of glass is 25mm, type of support is pinned, thickness of shear wall is 300mm, floor finish load is 1.5kN/mm², live load is 4 kN/mm², glazing load is 1.59 kN/mm², poison’s ratio is 0.2. Earthquake zones used for the analysis is zone II and zone V. The soil type is Medium soil. Importance factor is 1.5, response reduction factor is 5, damping ratio is 5%, wind speed for zone II is 33m/s and wind speed for zone V is 50m/s, terrain category is 4, structure class is C.
Fig. 5.1 Plan View and Three Dimensional view of Steel Frame

Fig. 5.2 Plan View and Three Dimensional view of Steel Frame with Shear Wall
Fig. 5.3 Three Dimensional view of Steel Frame with Shear Wall openings with and without outriggers.
VI. RESULTS AND DISCUSSIONS

The behaviour of each model is captured and the results are tabulated. The variation of systematic parameters like story lateral displacement, storey drift, natural time period and base shear has been studied for Equivalent Static method and Response Spectrum method. The results of all the models are observed and the most suitable model is selected by comparing the results of each model.

6.1 STOREY DISPLACEMENT:

Fig. 6.1 Variation of Storey Displacement vs No. of storey for Equivalent Static method along X and Y direction (Zone II)

Fig. 6.2 Variation of Storey Displacement vs No. of storey for Equivalent Static method along X and Y - direction (Zone V)
By comparing their values in fig 6.1 to 6.4, Out of all the considered models, steel frame with shear wall and outrigger gives the good result in the reduction of displacement. Steel frame with shear wall and outrigger gives 33% to 43% of reduction in lateral displacement when compare to steel bare frame. We can see that the displacement increases as the storey height increases. Compare to steel bare frame, steel frame with the outrigger gives 10% to 22% of reduction in displacement for equivalent static method and when compare to steel frame with the outrigger, steel bare frame gives 10% to 22% for response spectrum method along X-direction and Y-direction. Similarly, as compare to steel frame with shear wall, steel frame with shear wall and outrigger gives the 15% to 26% of reduction in displacement for equivalent static method and 15% to 25% for response spectrum method along X-direction and Y-direction. Similarly as compare to steel frame with shear wall with the openings, steel frame with shear wall openings and outrigger gives the 16% to 26% of reduction in displacement for equivalent static method and 25% to 35% for response spectrum method along X - direction and Y - direction. The displacement along Y-direction will be greater when compare to displacement in X-direction. Out of all the considered models, steel frame with shear wall and outrigger gives the good result in the reduction of displacement.
6.2 STORY DRIFT:

**Fig. 6.5 Variation of Storey Drift vs No. of storey for Equivalent Static method along X and Y-direction (Zone II)**

**Fig. 6.6 Variation of Storey Drift vs No. of storey for Equivalent Static method along X and Y-direction (Zone V)**

**Fig. 6.7 Variation of Storey Drift vs No. of storey for Response Spectrum method along**
Fig. 6.8 Variation of Storey Drift vs No. of storey for Response Spectrum method along X and Y-direction (Zone V)

By comparing their values in fig 6.5 to 6.8, out of all the considered models, it can be observed that the storey drift reduces more at the location of outrigger where it is placed. We can see that the story drift increases as the storey height increases. Compare to steel bare frame, steel frame with the outrigger gives the 5% to 30% of reduction in storey drift for equivalent static method and when compared to steel frame with the outrigger, steel bare frame gives 25% to 50% of reduction in storey drift for response spectrum method along X – direction and Y – direction. Similarly, as compare to steel frame with shear wall, steel frame with shear wall and outrigger gives 3% to 21% of reduction in storey drift for equivalent static method and 6.5% to 25% for response spectrum method along X – direction and Y – direction. Similarly, as compare to steel frame ith shear wall with the openings, steel frame with shear wall openings and outrigger gives 24% to 32% of reduction in storey drift for equivalent static method and 24% to 32% for response spectrum method along X – direction and Y – direction.

6.3 BASE SHEAR:

From Fig. 6.9 it can be observed that the steel frame structure has lower base shear values when compared to the steel frame with shear wall and outrigger structure. Steel frame structure with shear wall and outrigger is having 4% to 22% more base shear hen compared to bare steel frame. It is
also observed that the base shear will be same for both X – direction as well as Y – direction for both equivalent static method and response spectrum method.

**6.4 MODAL TIME PERIOD:**

![Chart showing variation of time period for different modes](image)

**Fig. 6.10 Variation of Time Period for different modes**

It is observed that the time period is significant higher for steel frame with outrigger system when compared to all other models. If we consider the for the first three of the modes, the time period is increased by 30% to 33% for bare steel frame hen compared to steel frame with shear walls and outrigger.

**VII. CONCLUSION**

The present study is to compare the behaviour of steel structure with and without outriggers by using shear walls subjected to lateral loads. The significant parameters considered for study are storey displacement, storey drift, base shear and time period. To analyse the seismic behaviour of structure models are subjected to seismic load as per IS:1893 (part I):2002 for zone II and zone V. Similarly, the structure as subjected to wind load as per IS:800 part III. Following conclusions are made for different cases considered in the steel structures. By considering the obtained results, the steel frame with shear wall and outrigger gives the better result when compare to all other models. The steel frame with shear wall and outrigger gives 33% to 43% of reduction in storey displacement when compared with bare frame. The steel frame with shear wall and outrigger gives 35% to 50% of reduction in storey drift when compared with bare frame for 20th storey where the outrigger has been placed. The steel frame structure with shear wall and outriggers is having 4% to 22% more base shear when compared to bare steel frame. The time period is increased by 30% to 33% for bare steel frame when compare to steel frame with shear walls and outrigger by considering first 3 modes. Introduction of shear wall greatly reduces lateral displacements as well as storeys drift and shear wall also results in the increase of stiffness to the structures. The most proficient structure is the structure having steel outrigger along ith shear wall core for both wind and earthquake loading. Proving the outrigger along with shear wall/core wall increases the strength as well as stiffness of the building against wind and earthquake loads. There is considerable reduction in the lateral deflection, storey drift while adding an outrigger system in the structure. The outrigger structure systems not only control the top displacements but also helps in reducing the inter storey drift. By providing the outriggers at different levels, the more reduction in inter storey drift can be achieved. Maximum base shear at the base of the building increase with the increase in number of stories. Hence it can be concluding that base shear depends mainly on seismic weight of the building.
REFERENCES


