Abstract
Tall building development has been rapidly increasing worldwide introducing new challenges. In tall structures high lateral forces develop due to wind load and earthquake load are crucial. Thus the effects 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 paper is to study, the performance of outrigger structural system in high-rise building subjected to wind load and seismic load as per Indian standards. In the present comparative study, the static and dynamic behavior of the composite structure for different cases for 50 storey structure is modeled by using Finite Element Method. In this comparative study mainly the bare frame is compared with Steel outrigger with core for the structural efficiency is measured by the lateral displacement, storey drift, base shear and time period values. The Provision of outrigger along with shear wall core increases the strength as well as stiffness of the building against wind and earthquake loads and the shear walls without openings gives better results when compared to shear walls with openings and by providing the outriggers at different levels, the more reduction in lateral displacement and inter storey drift can be achieved.
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. The development of tall buildings has rapidly increased in the recent years. Populations from rural areas are migrating in large numbers to metro cities in search of jobs and day today facilities. Due to this, metro cities are getting densely populated day by day in the recent years. As population is getting denser the availability of land is diminishing and cost is also increasing. Hence to overcome these problems multi-storey buildings is most prominent and efficient solution. In developing country like India and increased number of population, the multi-storey building is a suitable option.

The challenges are more for the designer as the height of the building and plan of the building becomes complex and it’s a challenging task in the construction field to design the tall buildings. The design of tall building is based on analysis of models. The self-weight of the building, live load acting, and earthquake loads and along with wind forces are significant factors which play a major role in the design. As the height of the building increases, there will be adequate increase in stress, strain, deflection, lateral displacement and deformation of the building. The lateral deflections due to the loads should be prevented for both structural and non-structural damage to achieve the building strength and stiffness against lateral loads in the analysis and design of tall building.

Shear walls are the vertical members of the horizontal force resisting system. In residential structures, shear walls are straight to external walls that typically form a box which provides the lateral support for the building. If shear walls are designed and constructed properly, the buildings will get the strength and stiffness to resist the horizontal forces. Shear walls are the major lateral load resisting elements in a building in any seismic type of zone. Shear walls may also be provided with the openings due to functional requirement of the building.

In modern tall buildings, lateral loads induced by wind or earthquake forces are often resisted by a system of outriggers. The outrigger structural system is one of the horizontal load resisting systems. Outrigger structural systems not only proficient in controlling the top displacements but also play a substantial role in reducing the inter storey drifts. Outriggers are rigid horizontal structure i.e. truss or beam which connect core wall and outer column of building to improve the strength and overturning stiffness of the building. In outrigger structural system the belt truss ties all the external columns on the periphery of the structure and the outrigger connect these belt trusses to the central core of the structure thus restraining the exterior columns from rotation. When the structure is subjected to lateral forces, the outrigger and the columns resist the rotation of the core and thus significantly reduce the lateral deflection and base moment. To increase stiffness action against wind and seismic load outriggers are provided by the shear core with exterior frames in tall buildings.
Figure-1: Outrigger Braced Structure with Central Core

II. LITERATURE REVIEW

Technical papers of various journals are studied to understand the importance and necessity of this research in consideration of wind and seismic resistant design. It presents a brief summary of the literature review. Following review of literature gives an outlook on the effect of combined shear wall with outrigger in high rise steel structures. M. R. Suresh [1] has been carried out to evaluate the most common structural systems that are used for reinforced concrete tall buildings under the action of wind and gravity loads. These systems include Rigid Frame, Shear Wall/Central Core, Wall-Frame Interaction and Outrigger. There is a great increase in flexural stiffness with respect to rigid frame and Outrigger system. It reduces the overturning moment in the core structures. The outrigger structural systems are not only efficient in controlling the top displacements but plays a substantial role in reducing the inter storey drifts also. A S Jagadheeswari and C Freeda Christy [2] made investigation on the performance of multi-outrigger structural system for a 40 storey building. The equivalent static and dynamic analysis of various models are examined using SAP2000 software for concrete outrigger with the central shear wall or core wall without outrigger and with outrigger bracing with belt truss. Here the stiffness and stability is increased and there is a reduction in lateral displacement on earthquake and wind loads in both the direction. And there is a considerable reduction in the storey drift and lateral deflection while adding a multi-outrigger system in the structure. Spoorthi D C and Sridhar R [3] investigated on the static and dynamic behavior of the reinforced concrete structure for different cases of regular and irregular building of 9x9 bays 40 storey RC structure is modeled using SAP2000 software program. In this comparative study, the bare frame is compared with Steel outrigger with core wall for regular and irregular building.
By providing the outrigger along with shear wall or core wall increases the strength and stiffness of the building. The most efficient structure subjected to both wind and earthquake loads is the structure having steel outrigger along with the shear wall or core wall. Shruti B. Sukhdeve [4] investigated on the analysis of tall building which carried out to find the optimum position of the outrigger system by using the lateral loads. The objective of this paper was to study the optimum location of outrigger and to check the efficiency of each outrigger when three outriggers are used in the structure found i.e. at mid height of building, at 3/4th of height and at 1/4th of height of the building. The use of outrigger structural systems in high-rise buildings results in the increase of stiffness and also makes the structural form efficient under lateral loads. Ajinkya Prashant Gadkari, and N. G. Gore [5] made a study on the performance of the outrigger structural system in tall buildings subjected to seismic load and wind load. By studying on various lateral load resisting structural systems such as rigid frame system, rigid frame with shear wall system, shear wall system with opening and outrigger system, it was found that outrigger structural system is not only proficient in controlling lateral displacement but also plays an important role in reducing the inter story drift. Outrigger performs an essential role in improving the structural flexural stiffness by reducing base shear. And there is a considerable reduction in Time period when outrigger is introduced which will improve the overall stiffness by reducing lateral displacement and inter story drift. Shivacharan K, Chandrakala S and Karthik N M [6] used to study the use of outrigger and belt truss placed at different location subjected to wind and earthquake load. Considered the vertical irregularities structures with 30 stories 7x7 bay from 1st to 10th floor, 5x5 bay from 11th to 20th floor, 3x3 bay from 21st to 30th floor with outriggers at different stories were analyzed. It can be concluding that the optimum location of the outrigger is between 0.5 times its height. For the second optimum position of outrigger base shear is significantly high compared to first optimum position and bare frame with shear wall. Vishal A. Itware and Uttam B. Kalwane [7] investigated on the effect of openings in shear wall on seismic response of structures. For parametric study 6 and 12 storied 7x3 bays apartment buildings with typical floor plan of 35mx15m and floor height of 3m with different openings sizes and location in shear walls were modeled by using STAAD pro. From the results, it is concluded that for opening area < 20% of shear wall area, the stiffness of shear-wall structure is more affected by the size of openings than their arrangement in the shear walls. However, for opening area>20% of shear wall area, the stiffness of the system is significantly affected by the openings arrangement in shear walls. G. Muthukumar and Manoj Kumar [8] made a study on the dynamic behavior of shear walls under various opening locations using nonlinear finite element analysis using degenerated shell element with assumed strain approach. On the basis of displacement time history responses of shear walls with different opening locations and with various damping ratios. It has been concluded that shear walls are penetrated by large number of small openings than small number of large openings. P.M.B. Raj Kiran Nanduri and B.Suresh [9] used to study the use of outrigger and belt truss placed at different location.
subjected to wind or earthquake load. The ETABS software program is selected to perform analysis. The present study is limited to reinforced concrete (RC) multi-storied symmetrical building. All the building models analyzed in the study have 30 storey with constant storey height of 3 meters. The use of outrigger and belt truss system in high-rise buildings increase the stiffness and makes the structural form efficient under lateral load. It is concluded that the optimum location of the outrigger is between 0.5 times its height. Dhanaraj M. Patil and Keshav K. Sangle [10] made a study to investigate the seismic behaviour of outrigger braced buildings to find out the optimum location of outrigger in high rise 2-D steel buildings. In this study, the position of outriggers varies from a first storey to top storey in outrigger braced buildings of particular storey height. It is observed that the position of outriggers, lateral load patterns, and height of building significantly influences the seismic performance of the high rise building. The position of outriggers in high rise building significantly influences the seismic performance by increasing strength and stiffness, which are measured in terms of base shear, storey displacement, inter-storey drift ratio, and performance point.

III. MODELING AND ANALYSIS

On this study high rise steel structure of 50 stories with 8 bays along X-direction and 7 bays along Y-direction of 5m each. The typical storey height is 3m and total height of 150m. Analysis is carried out for equivalent static method and dynamic time history analysis method using IS 1893:2002 for high seismic zone (V) by using ETABS-2015 software. The time history function considered for dynamic time history analysis method is EL CENTRO. The beams and columns of size ISMB450 are assumed as steel members of grade Fe350. Core shear wall thickness is 0.3m which is modeled as shell thin and thickness of deck is 0.2m, which is modeled as membrane. Steel outrigger is used and it is considered at 1/3rd height of the structure.

Efficiency of high rise steel structures with respect to the storey displacement, storey drift, base shear, time period and acceleration are found out for all types of models or buildings. Further analysis is extended with the incorporation of outrigger and RC shear wall separately and responses of the steel structure are extracted. Location of shear wall is selected at the core of the building where steel structure is analyzed with and without openings in core wall. Opening is providing for accessing lift at the core wall. 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 with openings and outrigger

And based on the results extracted from six models, discussions will be made and conclusions will be made by indicating the effect of openings in shear wall and outrigger in high rise steel structures.
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| Plan dimension | 40mx35m |
|----------------|---------|
| Grade of steel for beams and columns | Fe350 |
| Grade of concrete for slabs | M30 |
| Beam | ISMB450 |
| Column | Built-up |
| Depth of Deck | 200mm |
| Thickness of Glass | 25mm |
| Type of Support | Pinned |
| Thickness of shear wall | 300mm |
| Floor finish | 1.5kN/m² |
| Live load | 4kN/m² |
| Glazing load | 1.59kN/m |
| Time History Function | ELCENTRO |

Model-1: Steel frame

![Figure-2: Plan View](image1)

![Figure-3: 3D View](image2)
Model-2: Steel frame with Outrigger

Figure-4: Plan View  Figure-5: Elevation View

Model-3: Steel frame with shear wall

Figure-6: Plan View  Figure-7: Elevation View

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Model-4: Steel frame with shear wall and outrigger

Figure-8: Plan View

Figure-9: Elevation View

Model-5: Steel frame with shear wall openings

Figure-10: Plan View

Figure-11: Elevation View

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IV. RESULTS AND DISCUSSION

In this part the behaviour of each model is captured and the results are tabulated. The variation of systematic parameters like story lateral displacement, story drift, base shear and modal time period has been studied for equivalent static method and dynamic time history analysis method. The results of all the models are observed and the most suitable model is selected by comparing the results of each model.

4.1 Lateral Displacement:

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 38% to 45% of reduction in lateral displacement when compare to steel bare frame.
Compare to steel bare frame, steel frame with the outrigger gives 3.4% to 7.2% of reduction in displacement. Similarly, as compare to steel frame with shear wall, steel frame with shear wall and outrigger gives the 11% to 14% of reduction in displacement. Similarly, as compare to steel frame with shear wall with the openings, steel frame with shear wall openings and outrigger gives the 10% to 11.5% of reduction in displacement for time history method.

4.2 Storey Drift:

Out of all the considered models, steel frame with shear wall and outrigger gives the good result in the reduction of drift. Here steel frame produces higher drift values compared to steel frame with shear wall & with the outrigger. Compare to steel bare frame, steel frame with the outrigger gives 2.5% to 3.2% for time history method. Similarly, as compare to steel frame with shear wall, steel frame with shear wall and outrigger gives 0.75% to 4.8% for time history method. Similarly, as compare to steel frame with shear wall with the openings, steel frame with shear wall openings and outrigger gives 0.38% to 3.6% for time history method.

4.3 Base Shear:

![Figure-15: Variation of Storey Drift](image)

![Figure-16: Variation of Base Shear](image)
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 outriggers is having 0.04% to 2.88% more base shear when compared to bare steel frame for dynamic time history method.

4.4 Modal Time Period:

The time period is increased by 2.24% to 16.5% for bare steel frame when compare to steel frame with shear walls and outrigger. Here the steel frame with shear wall and outrigger gives the lowest modal time period when compare to all other models. So the steel frame with shear wall and outrigger seems to be good.

V. CONCLUSION

The steel structures with and without outriggers and shear walls subjected to lateral loads are compared as a function of operating parameters like storey displacement, storey drift, base shear and time period. To analyze the seismic behavior of structure, models are subjected to seismic load as per IS:1893(part I):2002 for zone-2 and zone-5. Following conclusions are made for different cases considered in the steel structures:

1. By considering the obtained results, the steel frame with shear wall and outrigger gives the better result when compare to all other models.
2. The steel frame with shear wall and outrigger gives 38% to 45% of reduction in storey displacement when compared with bare frame.
3. The steel frame with shear wall and outrigger gives 40% to 45% of reduction in storey drift when compared with bare frame.
4. The steel frame structure with shear wall and outriggers is having 0.04% to 2.88% more base shear when compared to bare steel frame.
5. The time period is increased by 2.24% to 16.5% for bare steel frame when compare to steel frame with shear walls and outrigger.
6. Introduction of shear wall greatly reduces lateral displacements as well as storey drifts.
7. With the increase in openings in shear wall lateral displacement increases to greater extent.
8. The shear walls without openings gives better results when compared to shear walls with openings.
9. Providing the outrigger along with shear wall core increases the strength as well as stiffness of the building against wind and earthquake loads.
10. The outrigger structural systems control the lateral displacements and also helps in reducing the inter storey drift.
11. By providing the outriggers at different levels and using more numbers, the more reduction in lateral displacement and inter storey drift can be achieved.

VI. REFERENCES
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