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Analysis of G+12 Multistorey Building Introducing With Belt Truss and Outrigger System using a Staad-Pro-Software.

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Abstract— *The rapid growth of infrastructure to accommodate modern civilization is demanding tall structures in cities. As structures are becoming gigantic, their lateral stability and undulation have to be tackled by engineering judgment. Structural system evolution has evolved without interruption to surmount the complications related to lateral stability and undulation, There are many strategies to flourish and adopted now these days to surmount this. One such structural system is the outrigger and belt truss structural system also in this project we are adopting the Shear wall method. The outrigger and belt truss structural system has proved to be the most promising structural system in resisting lateral stability and sway problems. The present study is conducted on 14 storied high-rise buildings with shear walls in the centre of the building's outer periphery. High-rise building with a floor plan of 35m x 28m in addition to the shear wall of 5 m x 4 m is considered on both sides of the building. Static Earthquake analysis is accomplished to study parameter's maximal storey displacement, Base shear, Base moment, Axial Force, and Bending Moment to compare the building with the application of concrete and steel outrigger at various positions varying with the height of the building and the software used for this analysis is staad-pro V8i version.*

Keywords— *Tall building, outrigger, belt truss, shear wall, lateral stability, sway, displacement, Base shear, Base moment, Axial Force and Bending Moment.*

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I. Introduction

In today's modern era it has become a need to undertake development in tall structures to accommodate the present population as the cities are growing fast and land availability is becoming lesser for human beings, so there is a need for the 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 an efficient and economical solution for the problems related to tall structure development. Ductility towards lateral deformation refers to the ratio of the maximum deformation and the idealized yield deformation the ductility of a building is its capacity to accommodate large lateral deformations along with the height. It is quantified as the ratio of maximum deformation that can be sustained just before collapse (or failure, or significant loss of strength) to the yield deformation. Thus, a ductile building exhibits large inelastic deformation capacity without significant loss of strength capacity. In a ductile building, the structural members and the materials used therein can stably withstand inelastic actions without collapse and undue loss of strength at deformation levels well beyond the elastic limit. Ductility helps in dissipating input earthquake energy through hysteretic behaviour. Earthquake-resistant design of buildings relies heavily on ductility for accommodating the imposed displacement loading on the structure.

Outrigger (OT) and belt truss (BT) structural System

The outrigger and belt truss system comprises a main concrete core connected to exterior columns by relatively stiff horizontal members such as bracings termed outriggers. The bracing can be of different shapes. The basic structural response of the system is based on a very simple concept. When the structure is subjected to lateral loads, the columns on which the outriggers rest combining the column restrained by the outrigger resist the rotation of the core, causing the mitigation in the 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 the combined action of bending the core and the axial tension and compression of the exterior columns connected to the outriggers.

Concept of Outrigger

Outriggers have been effectively used in the sailing ship industry for a long-time which was used to resist wind. The outriggers like the spreaders and the exterior columns like the shrouds or stays. Engineers had observed this behaviour of sailboats 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 the outrigger and belt truss system was a coin from the arrangement of mast, spreaders and shrouds in sailboats.

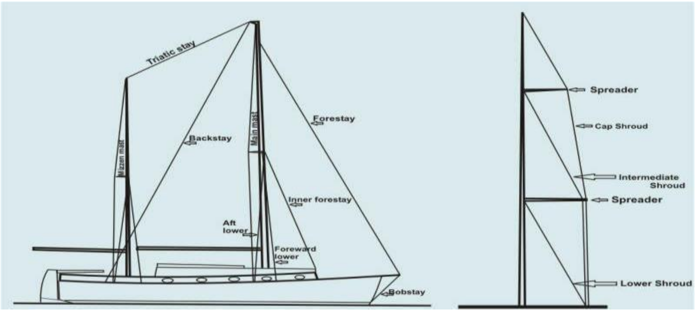

Fig.1. Sailboat with mast, spreader and shroud.

Classification of Outrigger structural system

Based on connection to the core there are two types of outrigger truss;

1) Conventional Outrigger system
2) Virtual Outrigger system

1.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 and shear walls are connected with outrigger bracings. The outrigger can be applied simultaneously on multiple floors. The outrigger bracings connected to the core and external columns convert the MO convert core to a vertical couple in columns. The problem of axial shortening and elongation of the columns and deformation of the trusses causes rotation of the core at the outrigger at a minor level, maximum times it is found that there is reverse curvature due to small rotation in the core.

2. Belt Trusses as Virtual Outriggers

The floor diaphragm action restricts the rotation of the core and is resisted by the floor diaphragms at the top and bottom of the belt trusses which results in the conversion of the moment in the 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. A three-dimensional elastic analysis is used to determine forces and moments created in all components. The lateral load resisting system consists of ashear wall core, external columns, belt truss bracings and floor diaphragm action. The belt truss is connected to the external columns; the belt truss is bracing connected to the external column that ties down the periphery of the building.

Simplified mathematical model of outriggers

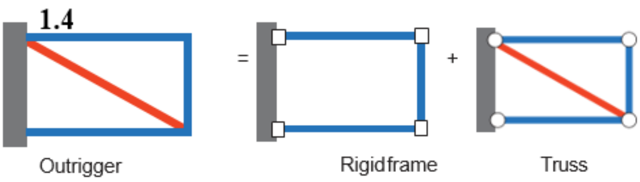

Fig 2. Simplified mathematical model of outriggers.

Shear Wall

A shear wall is a structural member positioned at different places in a building from foundation level to top parapet level, used to resist lateral forces i.e., parallel to the plane of the wall. When lateral displacement is large in a building with moment frames only, structural walls, often commonly called shear walls, can be introduced to help reduce the overall displacement of buildings, because these vertical plate-like structural elements have large in-plane stiffness and strength. There are different materials by

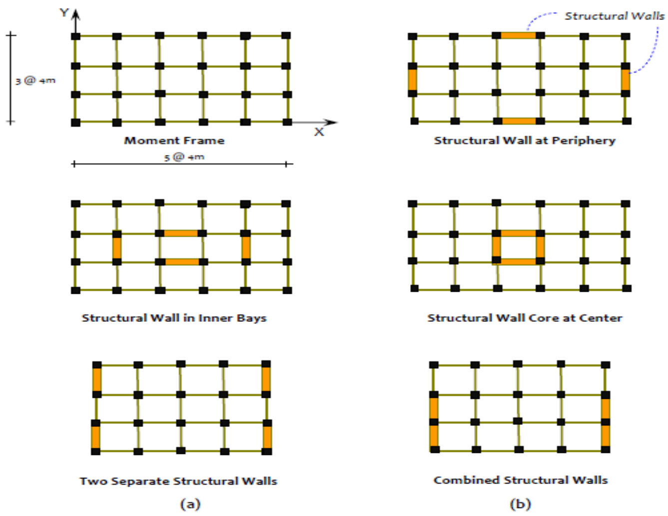

Fig 3. Position of shear walls in a moment-resisting frame building.

Which shear wall can be constructed but reinforced concrete (RC) buildings often have vertical plate-like Reinforced concrete walls (Figure 1.4) in addition to slabs, beams and columns. Their thickness can be as low as 150mm, or as high as 400mm in high rise buildings.
Shear walls are usually provided along both the length and width of buildings. Shear walls are like vertically-oriented wide beams that carry earthquake loads downwards to the foundation. Therefore, the structural system of the building consists of moment frames with specific bays in each direction having structural walls (Figure 1.4.1).

Classification of shear walls

1) Simple rectangular types and flanged walls (barbell type)
2) Coupled shear walls
3) Rigid frame shear walls
4) Framed walls with infilled frames
5) Column supported shear walls
6) Core type shear walls

Types of shear walls based on the materials used for construction:-
Based on materials used for construction shear walls are classified as follows,

1) RCC Shear Wall.
2) Plywood Shear Wall.
3) RC Hollow Concrete Block Masonry Wall.
4) Steel Plate Shear Wall.

II. Objectives

1) To study the effect of the introduction of Outrigger as tall structures are subjected to Static seismic loading.
2) To study the influence of braced core divider with X braced outriggers.
3) To study the effect of Outriggers with Peripheral Belt Truss.
4) To study the different configurations of the building under Conventional concrete material, with X-braced, V-Braced, Inverted-V Braced& Single Diagonal Braced Outriggers.
5) Analyze the results of all models as their axial force, Bending Moment, Base Shear, Base Moment & Nodal Displacement parameters.

Composite structure

In the past structural engineers have d the choice of masonry buildings and multi-stories buildings with RCC framed structures or steel structures. Recently the trend of going towards composite structure has started going.

Nowadays in India to fulfil the requirements and needs of high rise buildings the composite is best suited for infrastructural growth other than the RCC and steel structures, and steel-concrete composite systems have become quite popular in recent times because of their advantages against convention construction, composite construction combines the better properties of both material such as concrete and steel.

Advantages of Composite structure

1) Increased strength for a given cross-sectional dimension.
2) Increased stiffness, leading to reduced slenderness and increased buckling resistance.
3) Good fire resistance in the case of concrete encased.
4) Corrosion protection in encased members.

2. Models

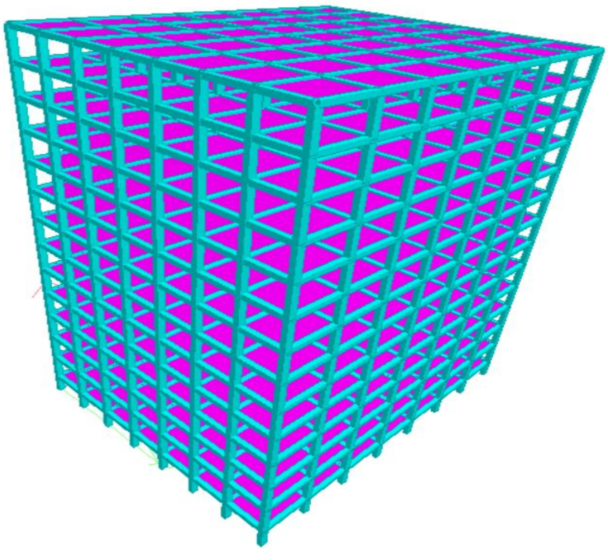

Fig 4. Conventional Concrete Structure

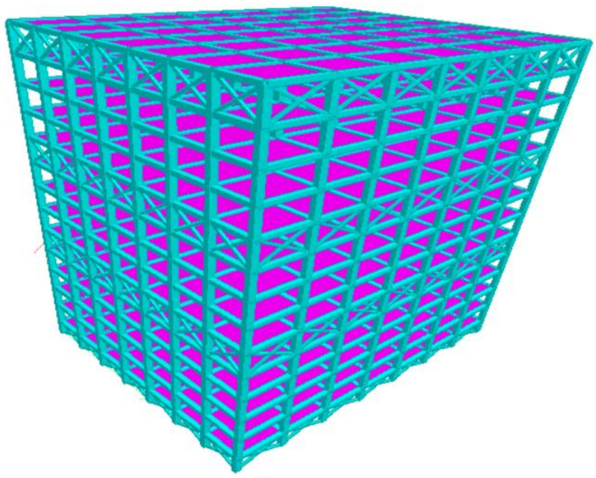

Fig 5. Structure With Belt Truss Of Outrigger

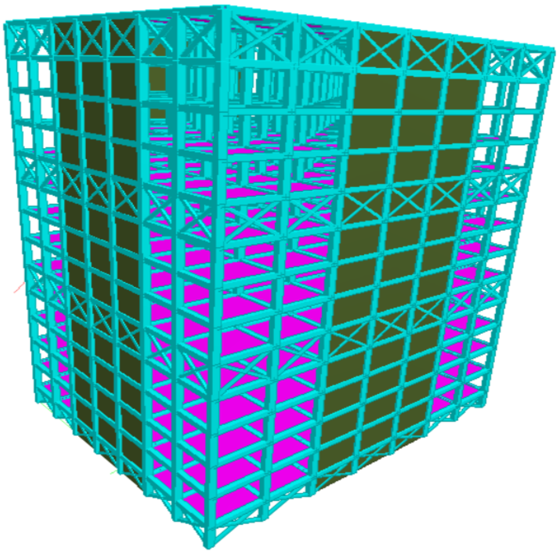

Fig 6. Structure With Belt Truss Of Outrigger Introducing With Shear Wall.

III. Methodology

The proposed work is planned to be carried out in the following manner

1) Create computer models of building with fixed base Using Belt Truss And Outrigger System in Staad-pro Software.
2) To study and analyse conventional concrete method, the same building with belt truss and outrigger system & another model with the shear wall. For the results parameter of Deflection, Truss, 3D Analysis
3) For the study reinforced concrete structure is considered, having G+12 stories. Each floor is considered as 3 m in height.
4) A regular reinforced concrete moment resisting bare frame model is considered for the reference base model. One Structure is modelled with Fixed support and the other concerning the base model by using STADD PRO Software.
5) The floor height is kept constant for all models to get consistent results.
6) Model without Belt truss and Outrigger.
7) Model with belt truss and outrigger.
8) Model with belt truss and outrigger introducing with the Shear wall.
9) These three models are analysed for all seismic zones.
10) Discuss the comparative result and find the conclusion.

IV. Results & Discussion

A G+12 Multi-storied RCC building for all Seismic Zones is modelled using STADD-Pro software and the results are computed. The configurations of all the models are discussed in the previous chapter. Three types of models were created to analyse the structure of all seismic zones. Model Type I - A regular reinforced concrete moment resisting bare frame model is considered for the reference base model. Model Type II – The base model introduces the Model with a belt truss as an outrigger. And Model Type III – Model with belt truss and outrigger introducing Shear wall. Equivalent Static Earthquake analysis is carried out to study parameter's maximum storey displacement, Base shear, Base moment, Axial Force and Bending Moment to compare the building with the application of a concrete outrigger at various positions varying with the height of the building and the software used for this analysis is Staad-pro V8i version. These models are analyzed and designed as per the specifications of Indian Standard codes IS1893, IS 13920, IS 875 and IS 456: 2000. The equivalent static method or seismic coefficient method had been used to find the design lateral forces along with the storey in the X and Z direction of the building since the building is unsymmetrical. All the results parameters are mentioned in graphical form enlisted below:

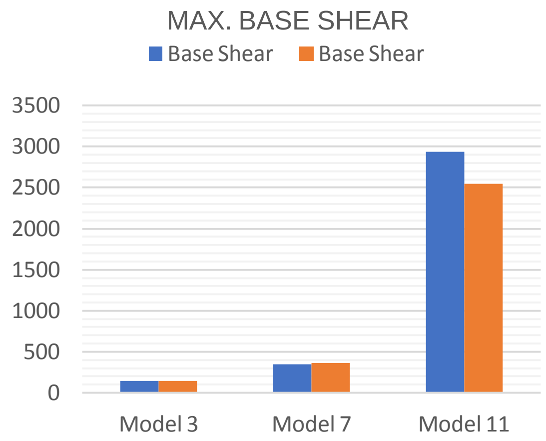

Fig 7. Lateral force or Base shear along X & Z direction for Zone IV.

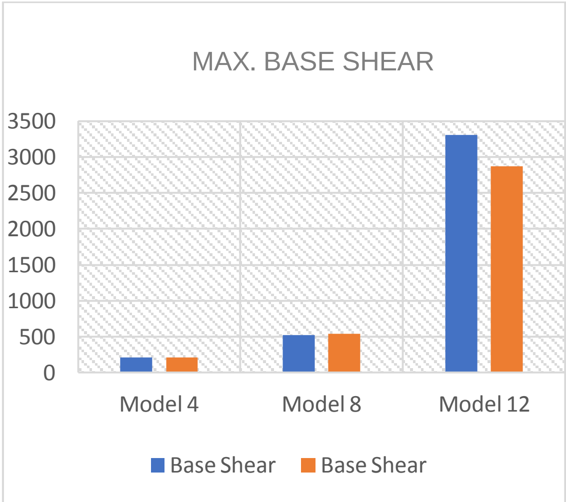

Fig 8. Lateral force or Base shear along X & Z direction for Zone V

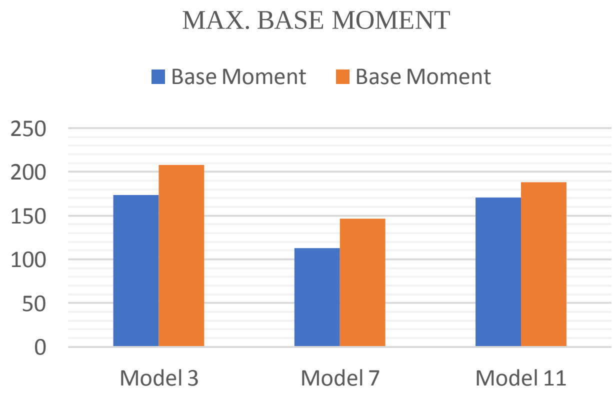

Fig 9. Lateral force or Base Moment along X & Z direction for Zone IV.

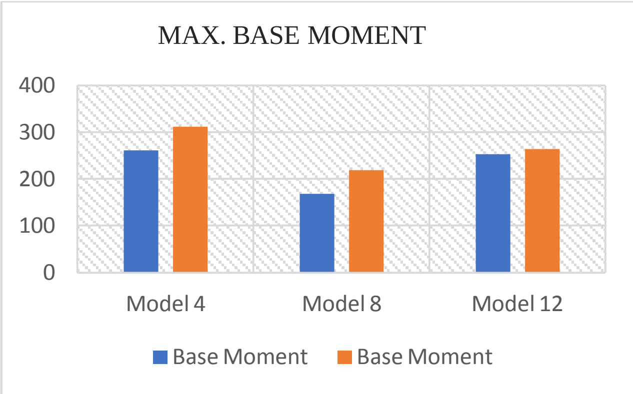

Fig 10. Lateral force or Base Moment along X & Z direction for Zone V.

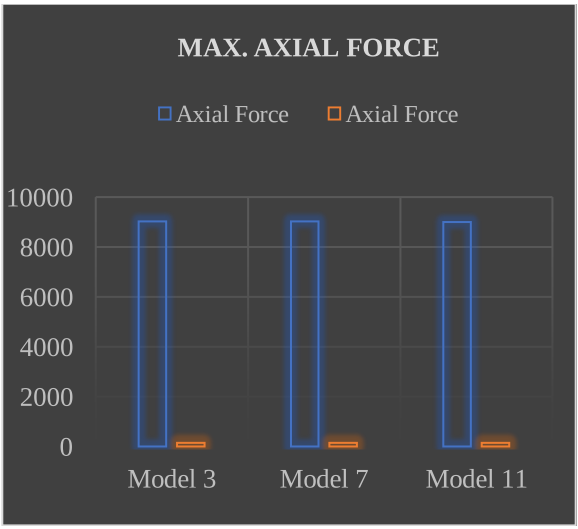

Fig.11. Axial force in X & Z direction for Zone IV.

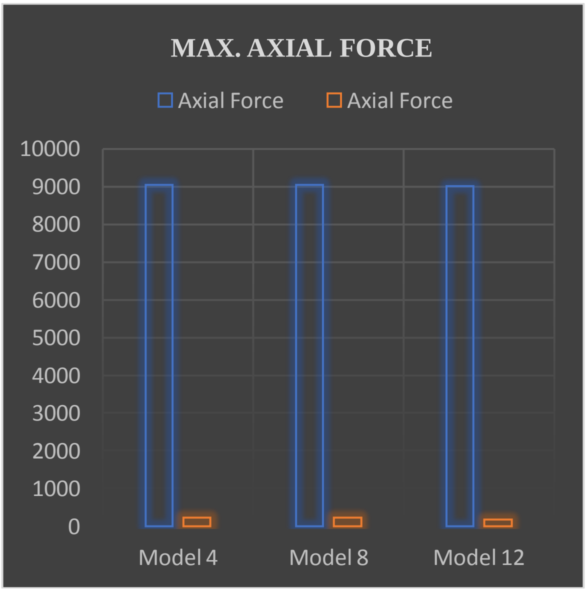

Fig 12. Axial force in X & Z direction for Zone V.

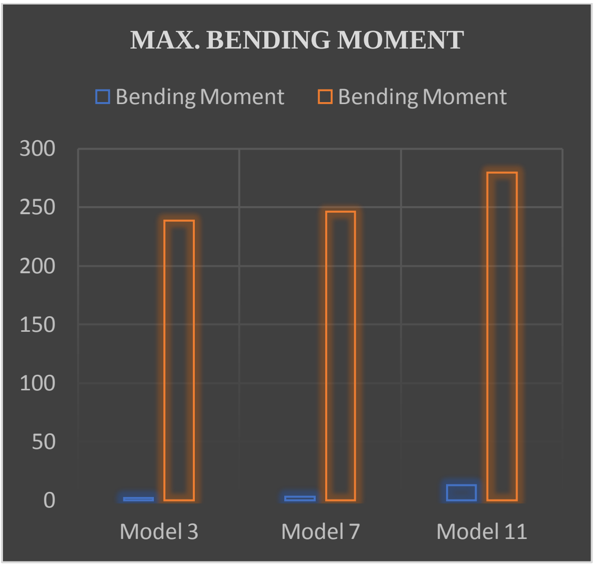

Fig 13. Bending Moment in X & Z direction for Zone IV.

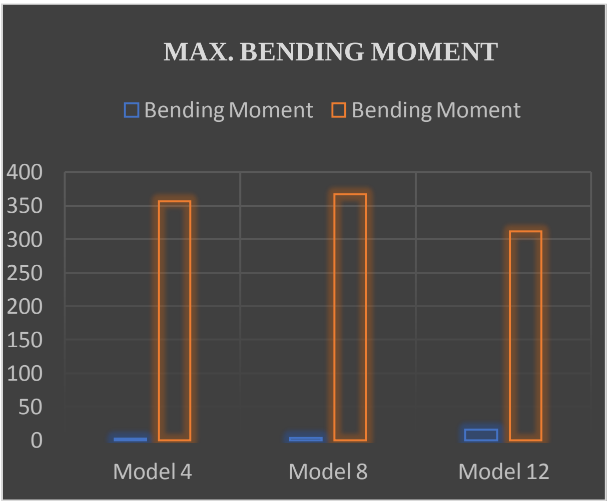

Fig 14. Bending Moment in X & Z direction for Zone V.

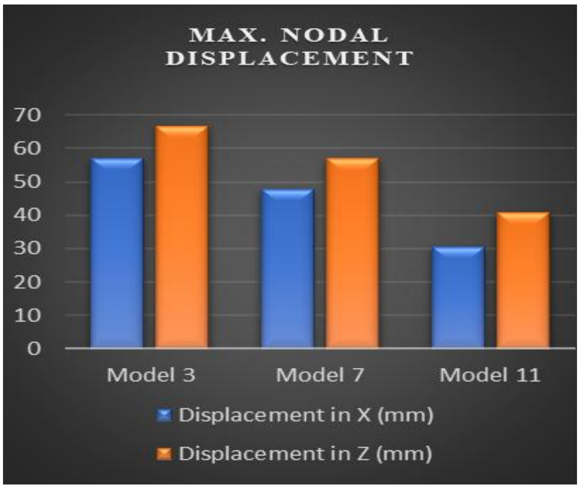

Fig 15. Maximum Node displacement for ZIV.

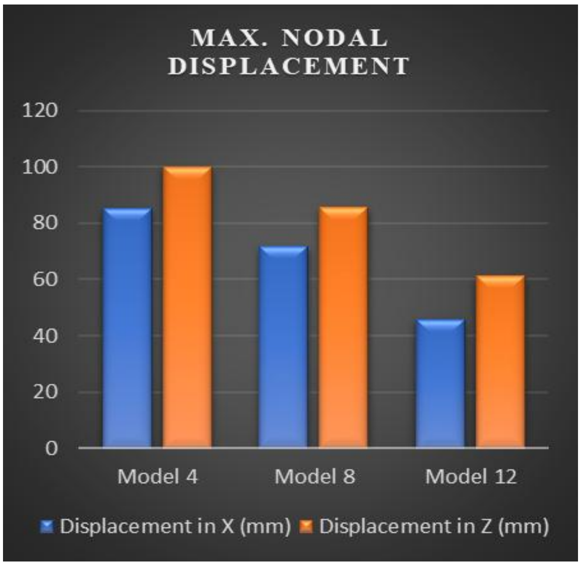

Fig 16. Maximum Node displacement for ZV.

V. Conclusion

This study is conducted for 12 storied high rise buildings with the shear wall in the centre of the building's outer periphery. High rise building with a floor plan of 35m x 28m in addition to the shear wall of 35 m x 41 m is considered on both sides of the building. Three types of models were decided to analyse the structure of all seismic zones. Model Type I - A regular reinforced concrete moment resisting bare frame model is considered for the reference base model. Model Type II – The base model introduces the Model with a belt truss as an outrigger. And Model Type III – Model with belt truss and outrigger introducing Shear wall. Static Earthquake analysis is carried out to study parameters - maximum storey displacement, Base shear, Base moment, Axial Force and Bending Moment to compare the building with the application of a concrete outrigger at various positions varying with the height of the building and the software used for this analysis is Staad-pro V8i version and the results obtained were satisfactory and following are the concluded remarks that can be established from the results.

1) Lateral force or storey shear at each consecutive storey level for model 1 is more as compared to model 2 and model 3. Model 3 has the least lateral force on consecutive storeys as compared to model 1 and model 2.
2) Approximately an average 10% lateral force or storey shear is decreased by introducing a Shear wall for the same configuration as model 1. Model 2 and Model 3 have 10% less storey shear as compared to Model 1.
3) Base shear for model 1 is higher than for model 2 and model 3. Approximately 10% decrease in base shear is calculated after introducing the shear wall (Model 2) and belt truss of the outrigger (model 3).
4) Storey shear and base shear in both the directions i.e., along X-direction and Z-direction for model 2 and model 3 are decreased by nearly the same amount i.e., approximately 10% when compared to model 1.
5) There is a pattern of reduction in node displacement for model 2 and model 3 when compared with model 1. This briefly states that the building is stiff with shear walls and belt truss of the outrigger. Whereas model 3 becomes economical as the concrete is reduced being approximate similar stiffness is acquired due to less consumption of concrete.

Future Scope

The present study is conducted for G+12 storied high rise buildings. High rise building with a floor plan of 35m x 28m of building. Three types of models were decided to analyse the structure of all seismic zones. Static Earthquake analysis is carried out to study parameters - maximum storey displacement, Base shear, Base moment, Axial Force and Bending Moment to compare buildings with the application of concrete outrigger at various positions varying with the height of the building. Later all models are generated in STADD-Pro and analyzed and compared. This study can be further extended in the following broad sense,

1) The position of the shear wall can be moved and placed at corners and on the other side i.e., along Z-Direction and then the results shall be compared.
2) The positions of the Shear-wall shall be changed to the inner core of the building for finding a relation between the outer and inner comparison of the shear wall for the same configuration buildings.

3) This work can be further extended to design the same buildings and compare the concrete quantity and steel quantity. For further experimentation, a relation can be established between the strength and stiffness along with the economic structure.
4) In this present work belt truss of the outrigger is on the outer periphery of the structure at a specific Storey. Experiments can be conducted by introducing on either side at some different specific Storey for more stiffness to the structure.
5) The present study is based on the Equivalent static load method, this work can be further extended to the Response spectrum method, time history analysis etc. for further comparison among the models and establishing a relation between the strength and stiffness and stability of the models.

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