International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 9 Issue 8 ǁ 2021 ǁ PP. 78-86

Outrigger Structural System in High-Rise Building

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Abstract
During earthquake almost all the structures in that area will experience the seismic force. When a tall building is subjected to lateral or torsional deflections under the action of seismic loads the resulting oscillatory movement can induce a wide range of response in the building occupants. Hence lateral stiffness is a major consideration in the design of multi-storey structures. The improvement of reinforced concrete frame structure against lateral loading can be achieved by providing shear wall and cross bracing. In this study, a G+40 storey residential RC building with soft storey has to be analysed with cross bracings and shear wall. This analysis was made as per IS 1893:2002 codal provision by using ETABS software. The cross bracings such as X bracing are to be provided at the outer periphery of the column and the outriggers are provided at the corners of the buildings. The building model are analysed by dynamic analysis method using ETABS software. The main parameters compared are lateral displacement, base shear, storey drift.
Keywords: *ETABS, Response Spectrum method, outrigger systems, bracing, seismic force, lateral stability and storey displacement.*

Date of Submission: 12-08-2021 Date of acceptance: 27-08-2021

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.

Tall building development has been rapidly increasing worldwide introducing new challenges. As the height of the building increases, the stiffness of the building reduces. The Outrigger and Belt trussed system is the one of the lateral load resisting systems that can provide significant drift control for tall buildings. Thus, to improve the performance of the building under seismic loading, this system can prove to be very effective. The outrigger and belt truss system is commonly used as one of the structural system to effectively control the excessive drift due to lateral load, so that, during small or medium lateral load due to either wind or earthquake load, the risk of structural and non-structural damage can be minimized. For high-rise buildings, particularly in seismic active zone or wind load dominant, this system can be chosen as an appropriate method. The objective of this project work is to study, the performance of outrigger structural system in high-rise RC Building subjected to seismic load and Wind Load.

The outrigger is the lateral load resisting system in which the external columns are tied to the central core wall with very stiff outriggers at one or more levels. The outrigger system is most commonly used to effectively control the excessive drift due to the lateral load. So that, during lateral load due to either wind or earthquake load, the risk of structural and non-structural damage can be minimized. For high-rise buildings, particularly in seismic active zone or where the wind load is dominant, this system can be chosen as an appropriate method.

Types of Outrigger structural system

Based on the connectivity 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 trusses are connected directly to shear walls or braced frames at the core and to the columns located outboard of the core. Generally, the columns are at the outer edges of the building. The number of outriggers can vary from one to three or more over the height of the building. The outrigger trusses which are connected to the core, restrains the rotation of the core and convert part of the moment in the core into a vertical couple at the columns. Shortening and elongation of the columns and deformation of the trusses will allow some rotation of the core at the outrigger. In most designs, the rotation is small enough that the core undergoes reverse curvature below the outrigger.

Virtual Outrigger system:

In the conventional outrigger system, outrigger trusses connected directly to the core and to outboard columns to convert the "virtual" outrigger concept. The same transfer of overturning moment from the core to elements outboard of the core is achieved, but without a direct connection between the outrigger trusses and the core. The elimination of a direct connection between the trusses and the core avoids many of the problems associated with the use of outriggers. The basic concept behind the virtual outrigger is to use floor diaphragms, which are typically very stiff and strong in their own plane, to transfer moment in the form of a horizontal couple from the core to trusses or walls that are not connected directly to the core. The trusses or walls then convert the horizontal couples into vertical couples in columns or other structural elements outboard of the core.

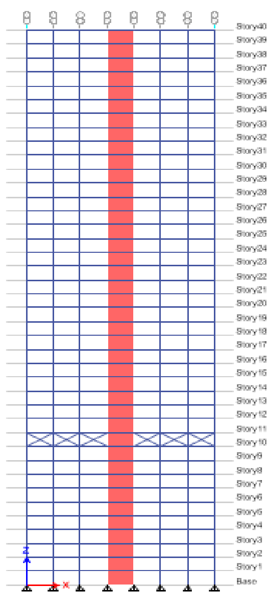
1.1 OBJECTIVES:

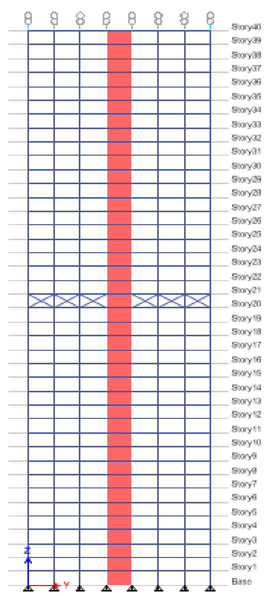
- To study efficiency of outriggers under seismic forces.
- To obtain the optimum location of outrigger to reduce lateral displacement.
- To compare building with outrigger at different locations.
- In this total four models are analyzed. i.e., RCC frame with outrigger at $1/4^{th}$ height of structure, RCC frame with outrigger at $1/2^{nd}$ height of structure, & RCC frame with outrigger at $3/4^{th}$ height of structure.
- 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 the three models.

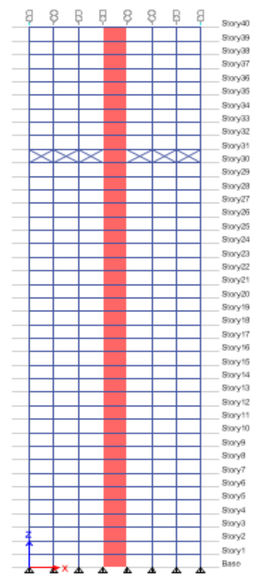
1.2 SCOPE:

- Modelling of the building using ETABS
- Predominantly concerned with structural improvement to reduce seismic hazard.

II. METHODOLOGY:







Elevation view of RCC frame with
Elevation view of rcc frame with
outrigger at $1/4^{th}$ height of structure

Elevation view of RCC frame with

outrigger at $1/2^{nd}$ height of structure

outrigger at $3/4^{th}$ height of structure

2.1: MODELLING IN ETABS:

- Model-1: RCC frame with Outrigger at 1/4th height of the structure.
- Model-2: RCC frame with Outrigger at 1/2nd height of the structure.
- Model-3: RCC frame with Outrigger at 3/4th height of the structure.

2.2: ANALYSIS IN ETABS:

In the 3D analysis of various types of models following methods are studied.

- Equivalent Static Method
- Response Spectrum Method

2.3: LOADS ON THE STRUCTURE:

1) DEAD LOAD: The dead loads are taken from IS 875 Part 1(Dead Loads). The dead loads comprise the weights of walls, partitions, floor finishes, false ceilings, false floors and other permanent constructions in the buildings.

2) LIVE LOAD: The live loads are taken from IS 875 Part II(Live Loads).

3) SEISMIC LOAD: Seismic design shall be done in accordance with IS: 1893:2002. The building is situated in earthquake zone II.

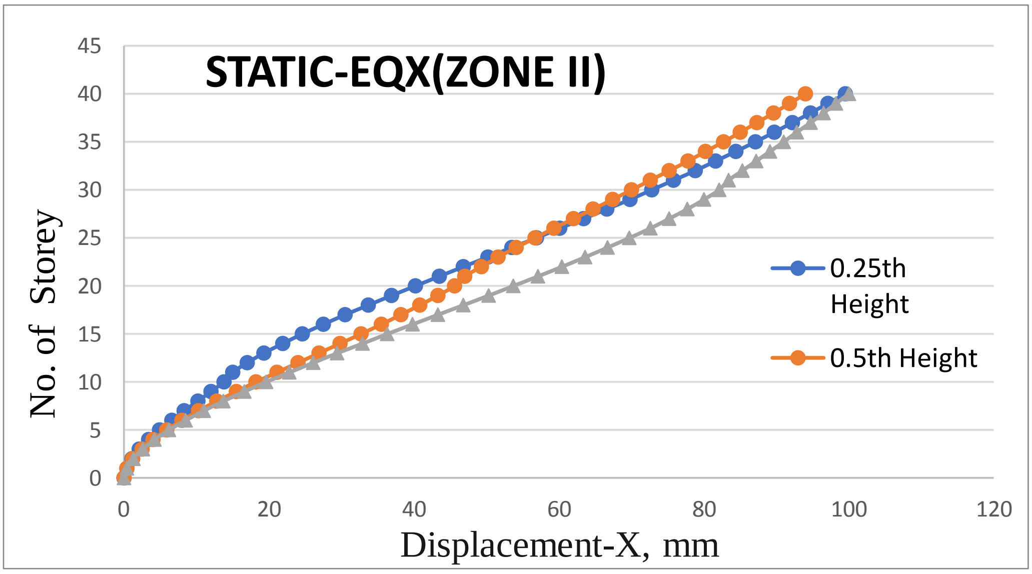
4) WIND LOAD: The wind loads are taken from IS 875 Part III(Wind Loads).

III. RESULTS AND DISCUSSIONS:

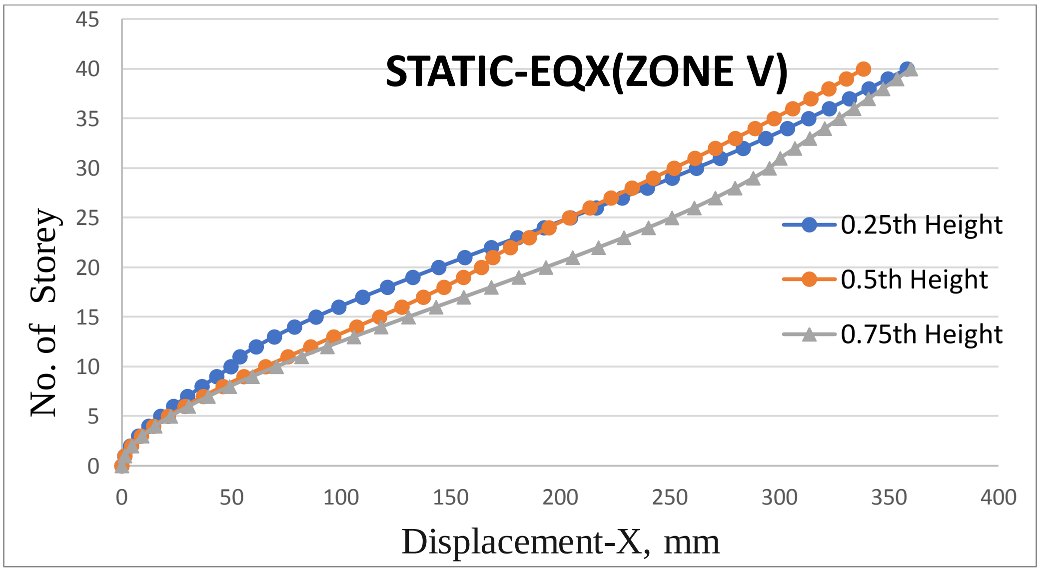
GRAPHICAL REPRESENTATION:

STOREY DISPLACEMENT:

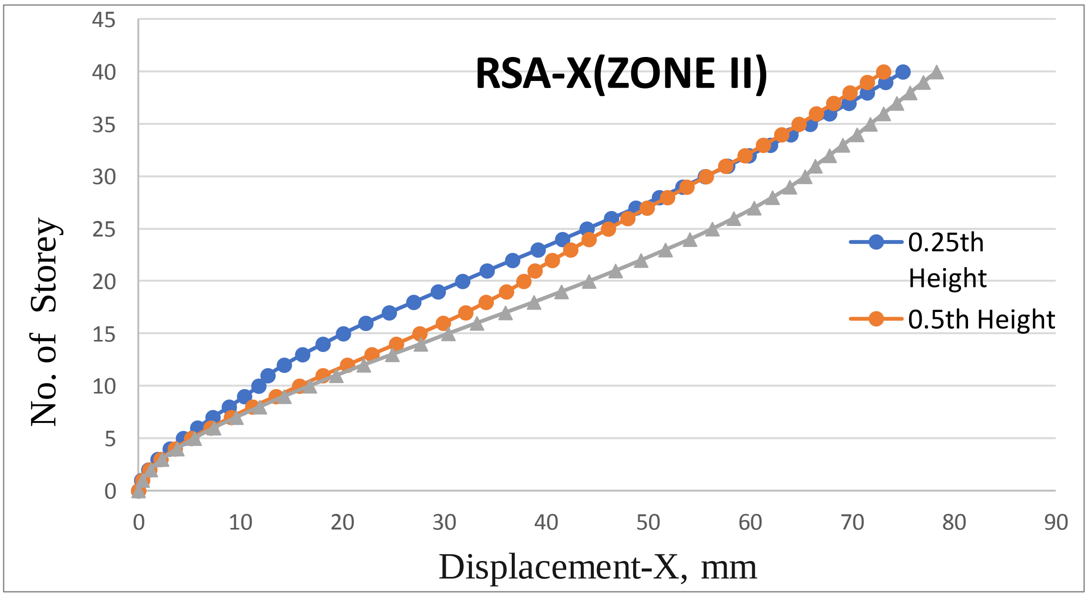
Story displacement is defined as total displacement of any storey with respect to ground. Maximum allowable displacement is calculated from IS:1893-2002, maximum permissible storey displacement is limited to H/500.



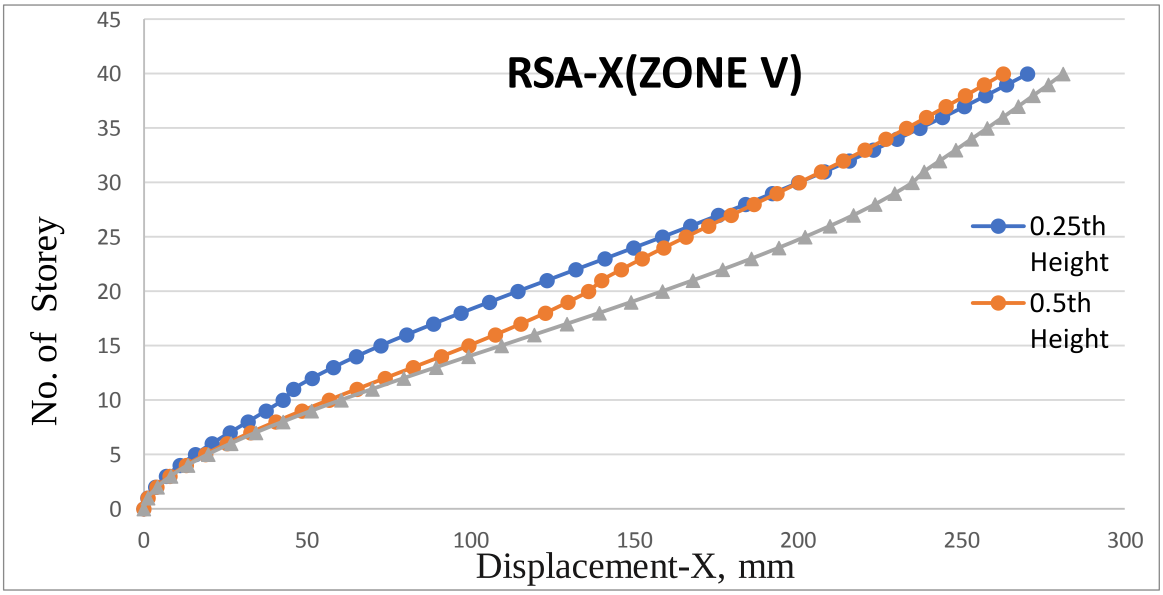
Variation of Storey Displacement vs No. of storey for Equivalent Static method along X-direction (Zone II)



Variation of Storey Displacement vs No. of storey for Equivalent Static method along X-direction (Zone V)



Variation of Storey Displacement vs No. of storey for Response Spectrum method along X-direction (Zone II)



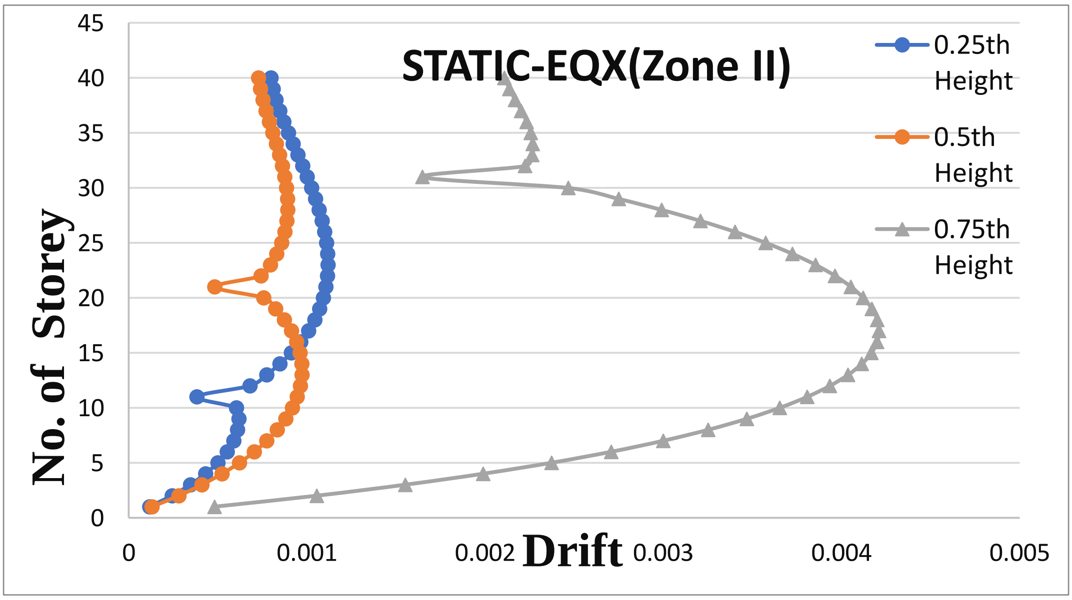
Variation of Storey Displacement vs No. of storey for Response Spectrum method along X-direction (Zone V)

Observations and Discussions on Storey Displacement

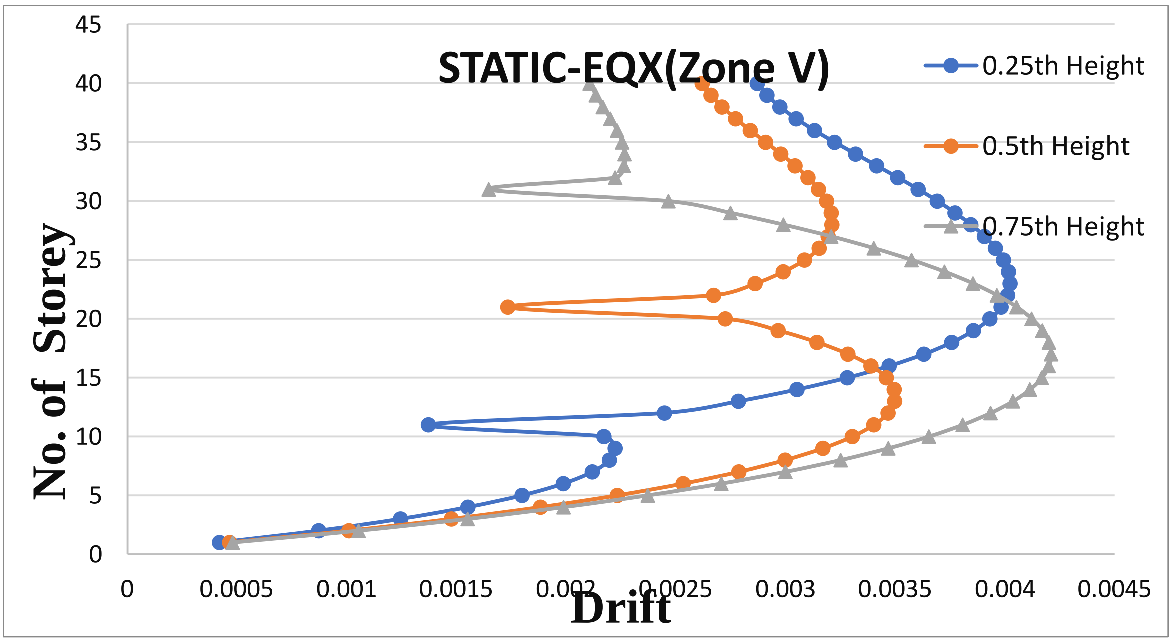
By comparing their, out of all the considered models, the outrigger located at 1/2nd height of the structure gives good result in the reduction of displacement. The outrigger located at 1/2nd height of the structure gives 3.3% to 6.5% of reduction in lateral displacement when compared to the outrigger located at 3/4th height of the structure. The outrigger located at 1/2nd height of the structure gives 0.5% to 4.21% of reduction in lateral displacement when compared to the outrigger located at 1/4th height of the structure.

Storey Drift

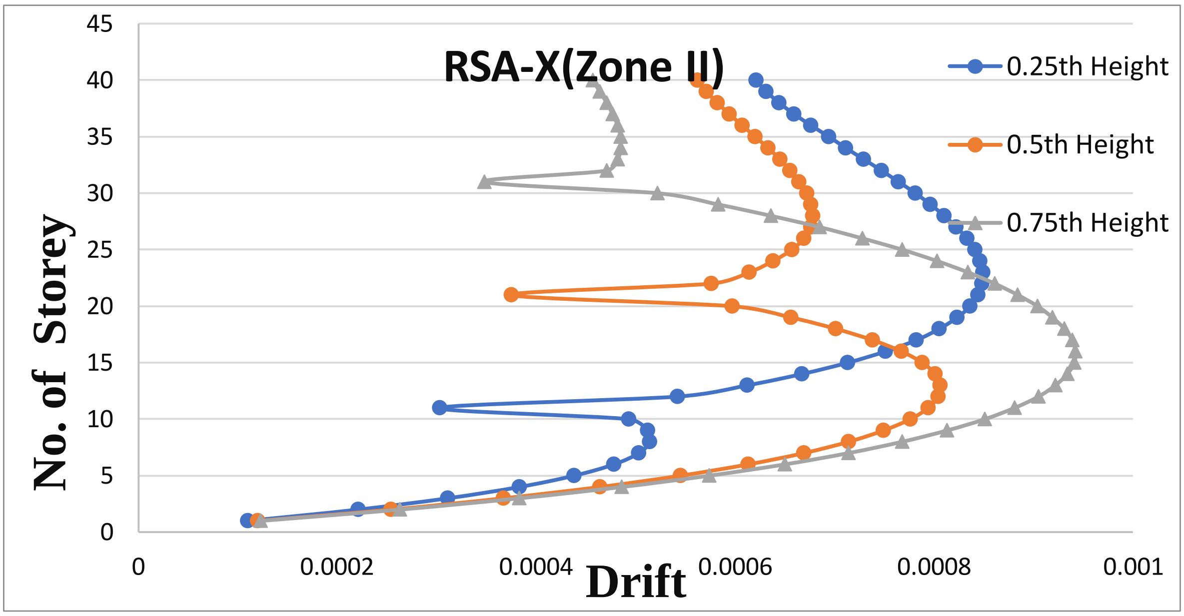
The storey drifts obtained for equivalent static method and Response Spectrum method for all the building models along X direction is listed below. The graphs are plotted for all the models with respect to the results obtained.



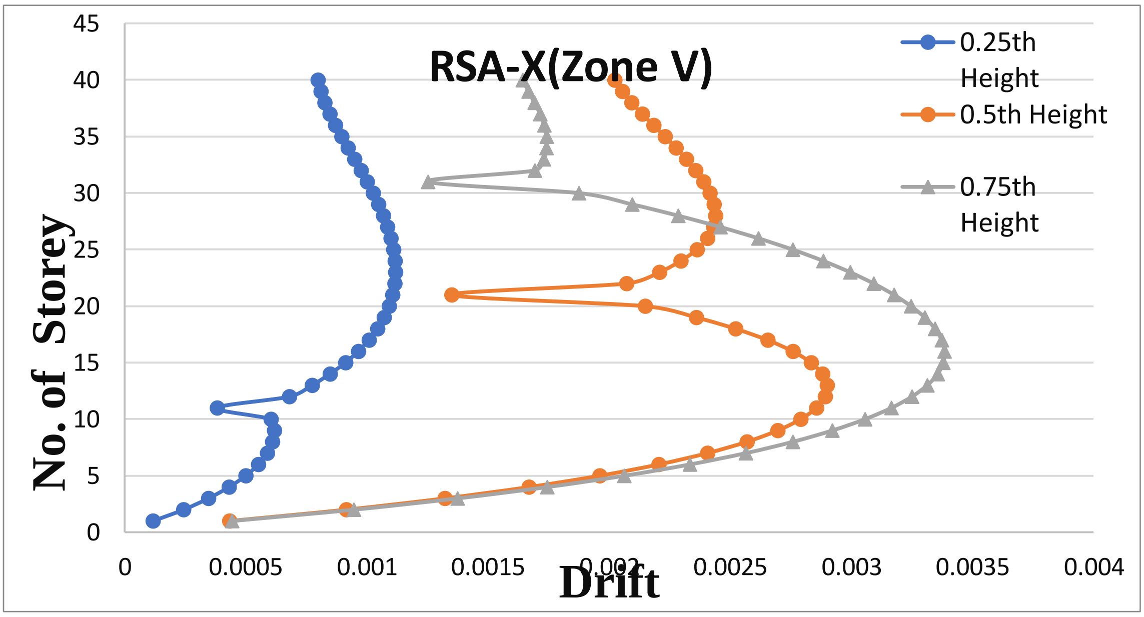
Variation of Storey Drift vs No. of storey for Equivalent Static method along X-direction (Zone II)



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



Variation of Storey Drift vs No. of storey for Response Spectrum method along X-direction (Zone II)



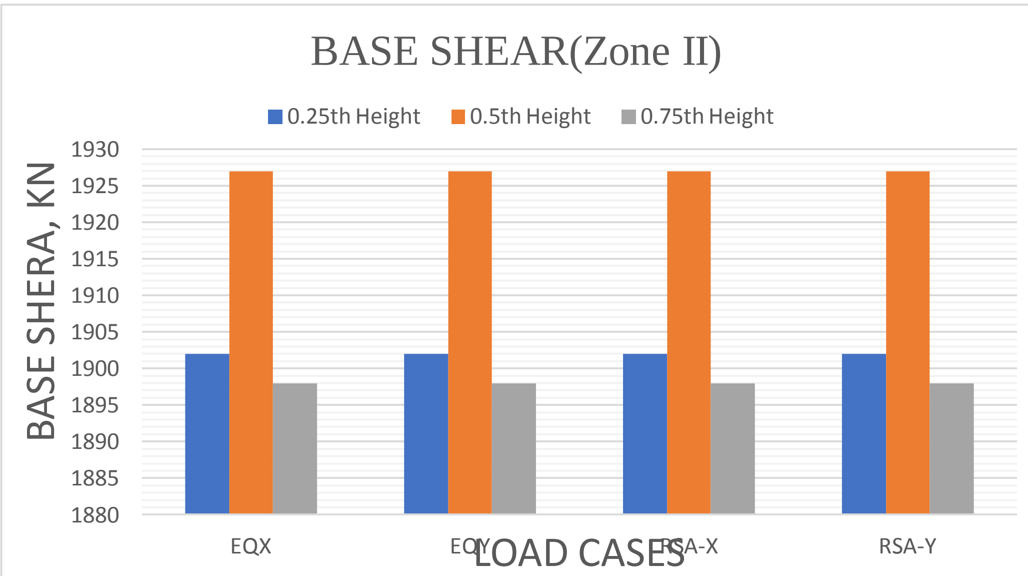
Variation of Storey Drift vs No. of storey for Response Spectrum method along X-direction (Zone V)

Observations and Discussions on Storey Drift

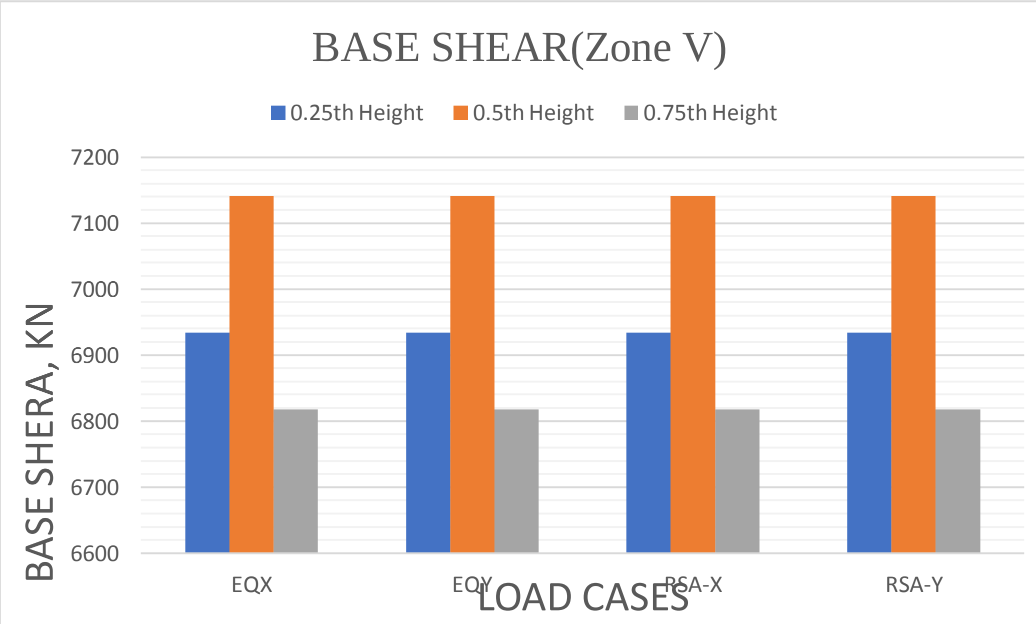
By comparing their values, Out of all the considered models, the outrigger located at 1/2nd height of the structure gives good result in the reduction of storey drift. The outrigger located at 1/2nd height of the structure gives 8% to 17% of reduction in storey drift when compared to the outrigger located at 3/4th height of the structure. The outrigger located at 1/2nd height of the structure gives 11.5% to 23% of reduction in lateral displacement when compared to the outrigger located at 1/4th height of the structure.

Variation of Base Shear

The base shear obtained for equivalent static method and Response Spectrum method for all the building models along both X and Y directions are listed in the tables below. The graphs are plotted for all the models with respect to the results obtained.



Variation of Base Shear (Zone II)



Variation of Base Shear (Zone V)

Observations and Discussions on Base Shear

From Table 6.17 and Fig 6.18 it can be observed that the outrigger located at 3/4th height of structure has lower base shear values when compared to the other models. The outriggers at 3/4th height of structure is having 1.5% to 4% more base shear when compared to outrigger located at 1/2nd height of the building.

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 dynamic response spectrum method.

IV. CONCLUSION

The present study is to optimum position of outrigger subjected to lateral loads. The significant parameters considered for the study are 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. Similarly, the structure was subjected to wind load as per IS 875 Part III for different wind speeds 33m/s for zone-2 and 50m/s for zone-5. Following conclusions are made for different cases considered in the steel structures:

1. By considering the obtained results, the outrigger located at the 1/2nd height of the structure is optimum position for placing the outrigger.
2. The outrigger located at the 1/2nd height of the structure gives 3.3% to 6.5% of reduction in storey displacement when compared to other position of outrigger.
3. The outrigger located at the 1/2nd height of the structure gives 8% to 23% of reduction in storey drift when compared to other position of outrigger.
4. The outrigger located at the 1/2nd height of the structure is having 1.5% to 4% more base shear when compared to other position of outrigger.
5. The time period is increased by 5% to 6.5% for outrigger placed at 3/4th height of structure when compared to outrigger placed at 1/2nd and 1/4th height of the structure.
6. Providing the outrigger increases the strength as well as stiffness of the building against wind and earthquake loads.
7. There is considerable reduction in the lateral deflection, storey drift while adding an outrigger system in the structure.
8. The outrigger structural 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.
9. 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.

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