Lateral Stability Analysis of High Rise Structure with variation of plan configuration with respect to height and the Effect of Outrigger and Belt Trusses Systems

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***Abstract* - The outrigger and belt truss system is one of the most efficient systems used 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 structure. This paper studies the efficient use of outrigger and belt truss system for high-rise concrete building subjected to wind or earthquake load. Seven 44-storey models of outrigger and belt truss system are subjected to wind and earthquake load, analyzed and compared to find the lateral displacement reduction related to the types of outrigger and belt system. The analysis has been carried out to study the effect and performance of outrigger system in 40-storey building. The outrigger system is provided at different levels along the height of the building. The depth of the Outrigger and belt trusses is equal to the height of the typical story and maintained same in all the models. The key parameters discussed in this paper include lateral deflection, storey drifts, base shear and fundamental time periods. Loads are considered as per Indian Standards IS: 875(Part1)-1987, IS: 875(Part2)-1987, IS: 875(Part3)-1987 and IS: 1893(Part-1) - 2002. The modeling and analysis were performed using finite element software ETABS 16.**

***keywords* - Outrigger and belt truss system, lateral load, lateral displacement, storey drifts, base shear and fundamental time periods**

I. INTRODUCTION

Improvement of the large structures has been rapidly increasing the general knowledge of new challenges that need to be met through building judgement. In present high constructions, wind or earthquake often induce lateral loads by arranging paired shear walls. However, when structure increases in height, the stiffness of the structure turns out to be increasingly important to provide the structure with sufficient lateral stiffness. The lateral load resisting system effectively controls over the top drift because of lateral load, so that, amid little or medium lateral load because of wind or earthquake load, the danger of auxiliary and non-basic harm can be limited. For tall structures, especially either in wind load or seismic zone overwhelming, these frameworks are chosen as a suitable structure. Outrigger and belt truss system have recently been widely used to minimize lateral drift. In order to attain the necessary rigidity of the large structure bracing sizes, extra lateral load resistant system such as outriggers and belt truss was needed. Outriggers and belt truss was required. The location of the outrigger truss increases the structure's efficient depth and improves the lateral stiffness owing to horizontal load effectively. Conventionally high buildings are built for the goal of office buildings, commercial, shopping malls and hotels, suburban. Improvement of tall buildings includes Different composite elements for instance economic matters, necessities, construction regularities, technology and so on. The challenges increments for the designer with the unpredictability of the height of the building and building plan. Without considering the detailed forbearance of denoting factors that affect the selection of tall buildings for the structural system, economic and adequate tall buildings cannot be intended. Building self-weight, live load, and seismic loads and along with wind forces will play valuable role as significant variables of the design. Adequate increases in the building's deflection, stress, strain, lateral displacement and deformation will result in elevated construction costs owing to the size and composition of the building components.

II. OUTRIGGER AND BELT TRUSS STRUCTURAL SYSTEM

Outriggers are rigid horizontal structure i.e. beam or truss which connects to the core wall and outer column of building for improving building strength and overturning stiffness. Outriggers are being utilized in tall structures from nearly half century, but innovative design framework has improved its proficiency. Outrigger system is the sort of structural system that is created from a horizontal cantilever part linking to the internal and outer columns of the structure. The moment arm of the core rises with the connection leading to greater lateral rigidity of the system. The central core of a structure acts as a cantilever; the outriggers are positioned to decrease the moment of overturning in the heart and transfer moment from core to exterior column by linking the core and column. Wall frame outrigger trusses are the found they connected to the foundation through outer columns is Wall frame outrigger trusses .The wall and outrigger trusses will rotate, causing downwind column compression and upwind side column tension, these axial forces will withstand the wall rotation when the structure is performed with horizontal forces.

Outriggers and columns withstand core rotation and thus considerably decrease the base moment and lateral deflection that would have occurred in a free core when the structure is subjected to lateral forces. A belt truss can be used at the outrigger concentrations to mobilize the extra axial stiffness of various columns and ensure torsional stiffness. As building height rises, column decrease is the critical issue in building methods, belt truss plays much effective in the control of settlement of columns. Belt trusses helps in limiting differential elongation and shortening of columns. Outrigger behavior with belt truss shown to be more effective when compare to the outrigger without belt truss. The outer columns and belt truss system resist rotation of central shear core and reduce the lateral deformation including bending moment at base of the structure.

III. OBTECTIVES

- To study the effect of introduction of Outriggers in high-rise building subjected to dynamic wind loading.
- To study the impact of X braced outriggers with core wall and braced core wall.
- To examine the parameters with various types of Plan Configurations with Outriggers, i.e. X Bracings and belt truss systems.
- To study the impact of steel outrigger in comparison with concrete outrigger.

IV. SCOPE OF PRESENT STUDY

The research aims to understand the seismic qualities and steadiness of the structure of the frame. The Outrigger and Belt Truss System can be used to increase this. Steel outriggers are used to counter seismic forces in steel framed structures. Steel options to use Steel Outriggers for RC frame buildings. This technique seeks to study and compare storey displacement, storey drift and base shear with distinct kinds of Outrigger Plan Configurations, i.e. X Bracings systems and belt trusses. The present research is useful for multiple academics involved in thin designing the tall structures by using outrigger and belt truss system.

V. PARAMETERS OF STUDY

- Effect of Outriggers with RC frame building when applied with Earthquake and dynamic wind loading for various Plan Configurations with Outriggers, i.e. X Bracings and belt truss systems for zone V.
- Lateral Displacement: The study emphases on the improvement of the RC frame building in terms of lateral displacement with most proficiently use of Outriggers and belt truss systems.
- Story Drifts: This parameter is considered in this research for the Optimum utilization of the Outriggers.
- The Base shear and Fundamental periods are considered as the parameters in this study.

VI. MODEL DESCRIPTION

The structures are modelled as a sequence of components that resist load. The lateral loads applied to the construction are based on the codal norms of India. The research is conducted according to IS 1893 (Part1): 2002 for seismic areas V. The adopted construction comprises of components of reinforced concrete and brick masonry. It is presumed that the structures are strongly fixed at the bottom floor and the interaction of the soil structure is overlooked. The building's complete height was set at 123.2 m (i.e. 40 stories) while the size of the members was distinct. Initially, the frame parts were intended to meet the requirements for stress analysis.

Table 1 : Y Shape Model geometry

Plan Configuration	Plan /Shape Area (sq.m)	No of Storey
Y Shape	1659.46	GF to 10
Y Shape	1315.66	10-20
Y Shape	1129.37	20-30
Y Shape	914.79	30-40

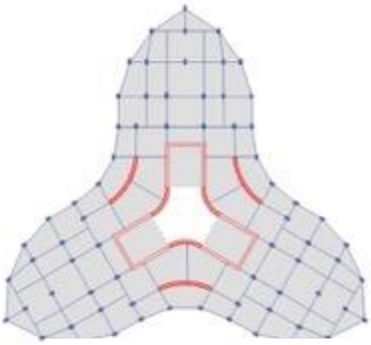

Fig 1 : Y Shape layout Plan

Table 2 : Circular Shape Model geometry

Plan Configuration	Plan /Shape Area (sq.m)	No of Storey
Circular Shape	1659.01	GF to 10
Circular Shape	1315.11	10-20
Circular Shape	1129.34	20-30
Circular Shape	914.34	30-40

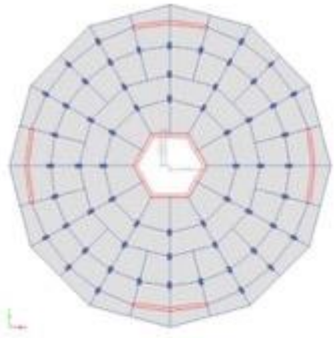

Fig 2 : Circular Shape layout Plan

Table 3 : Fillet Shape Model geometry

Plan Configuration	Plan /Shape Area (sq.m)	No of Storey
Fillet Shape	1659.46	GF to 10
Fillet Shape	1315.66	10-20
Fillet Shape	1129.37	20-30
Fillet Shape	914.79	30-40

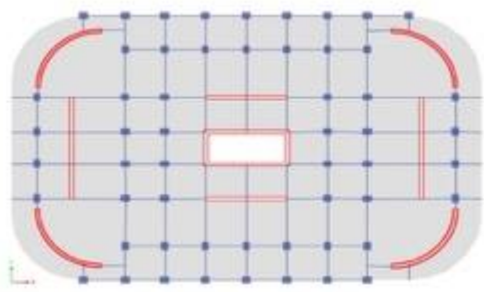

Fig 3 : Fillet Shape layout Plan

Models

The models that were chosen for the study are listed as follows,
Model 1 – Y Shape Bare frame model without Outrigger.
Model 2 – Y Shape Model with Concrete Core wall and braced Outriggers (Concrete X Bracings).
Model 3 – Y Shape Model with Concrete core wall and braced Outriggers (Steel X Bracings).
Model 4 – Circular Shape Bare frame model without Outrigger.
Model 5– Circular Shape Model with Concrete Core wall and braced Outriggers (Concrete X Bracings).
Model 6 – Circular Shape Model with Concrete core wall and braced Outriggers (Steel X Bracings).
Model 7 – Fillet Shape Bare frame model without Outrigger.
Model 8 – Fillet Shape Model with Concrete Core wall and braced Outriggers (Concrete X Bracings).
Model 9– Fillet Shape Model with Concrete core wall and braced Outriggers (Steel X Bracings).

VII. ABOUT THE ANALYSIS

The building analysis is done using widely used design software ETABS.

The design data used in the analysis are the following:

Design Data

Material Properties:

Grade of Concrete = M25 for all members
= M25 for columns
Grade of Rebar = Fe 415 Grade
Grade of Steel = Fe 345 Grade
Young's modulus of concrete (M45) = 33.541×10^6 KN/m^2
Young's modulus of concrete (M60) = 38.729×10^6 KN/m^2
Density of Reinforced Concrete = 25 KN/m^3
Poisons' ratio of concrete = 0.2
Modulus of elasticity of brick masonry = 3500x103 KN/m2
Density of brick masonry = 8 KN/m3
Poisons' ratio of masonry = 0.15

Member Properties:

Slab = 150mm thick
Column = 500mmX1000mm
Beam = 300mmX600mm
Masonry wall (Brick) = 230mm thick
Reinforced Concrete Shear/Core wall = 400mm thick
Concrete Outriggers = 300mmX1000mm
Steel Outriggers = ISA 130X130X12mm

Load Calculations:

Assumed dead load intensities
Floor finishes = 1.5 KN/m^2
Live load on floor = 3 KN/m^2
Live load on roof = 1.5 KN/m^2
Wall load on roof = 1x0.15x8 = 12 KN/m
Wall load on other levels = (3.2-0.6) x0.23x8 = 5 KN/m
Earthquake Live Load on slabs as per clause 7.3.1 and 7.3.2 of IS 1893 (Part-1)-2002
Roof = 0.5KN/m^2
Floor = 0.5x3 =1.5 KN/m^2

Seismic Data:

Structure = SMRF
Seismic Zone = V
Zone factor = 0.36
Importance factor = 1.5
Response reduction factor =5

Soil type	= Medium
Basic Wind Speed	= 44 m/s
Terrain Category	= 3
Terrain Class	=C

VIII. ANALYSIS RESULTS AND DISCUSSIONS

In this section, the results of the selected buildings are presented and discussed in detail. The consequences of base shear, lateral displacement, story shear, and vibration and in general execution for the distinctive structure models are displayed and thought about.

In this examination, an endeavor has been made for assessing the seismic exhibition of RC structures with focal center divider with outrigger and without outrigger. The outriggers of shape like 'X', of concrete and steel materials are contrasted in this examination with assess their adequacy in lessening horizontal removals and different parameters. Likewise Braced center divider is supplanted with strong center divider in the examination, and the effectiveness is watched. The idea of virtual outrigger or belt support truss was additionally contrasted and the customary outrigger for their general execution. From this examination we will likewise come to know the effectiveness of steel outriggers when contrasted with solid outriggers.

In the accompanying part, the outcomes are processed with proportional static technique for examination, reaction range investigation and static investigation. The modeling and analysis of various building models are carried by the use of ETABS software package. After the analysis, the results of base shear, lateral displacement for different models of the building are accumulated and analyzed.

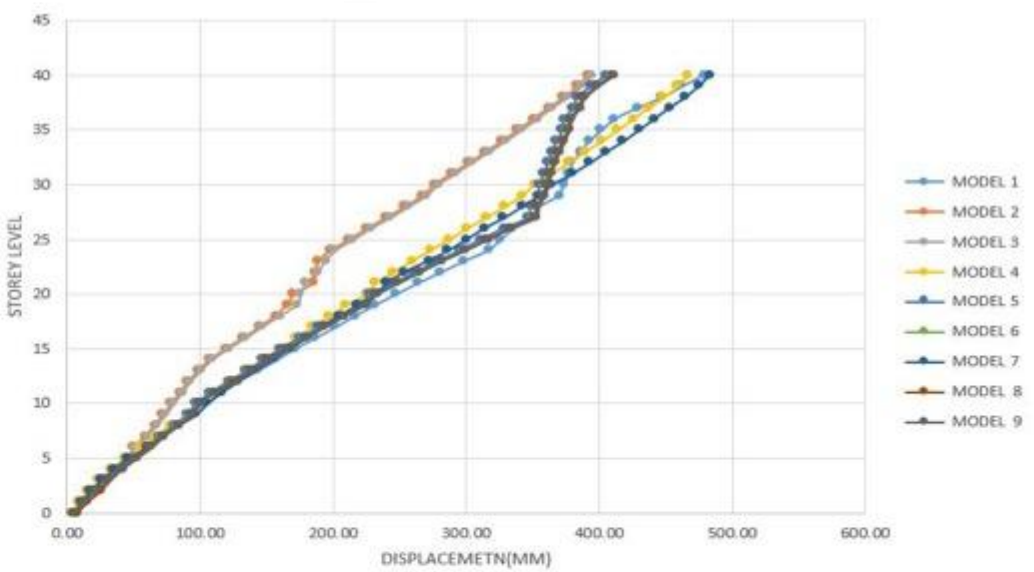

Fig 4 : Lateral Displacement for Response spectrum method along longitudinal direction for Zone V

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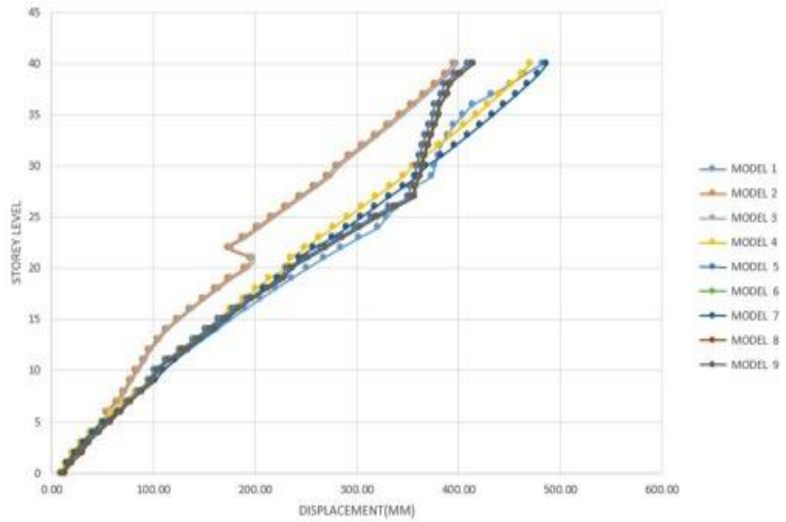

Fig 5 : Lateral Displacement for Response spectrum method along transverse direction for Zone V

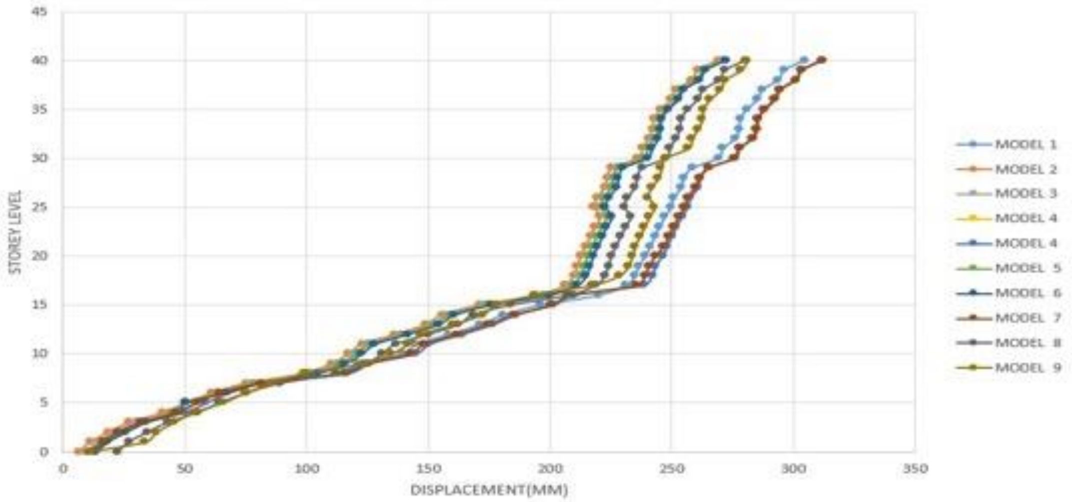

Fig 6 : Lateral Displacement for Static Wind Analysis along Longitudinal direction for Zone V

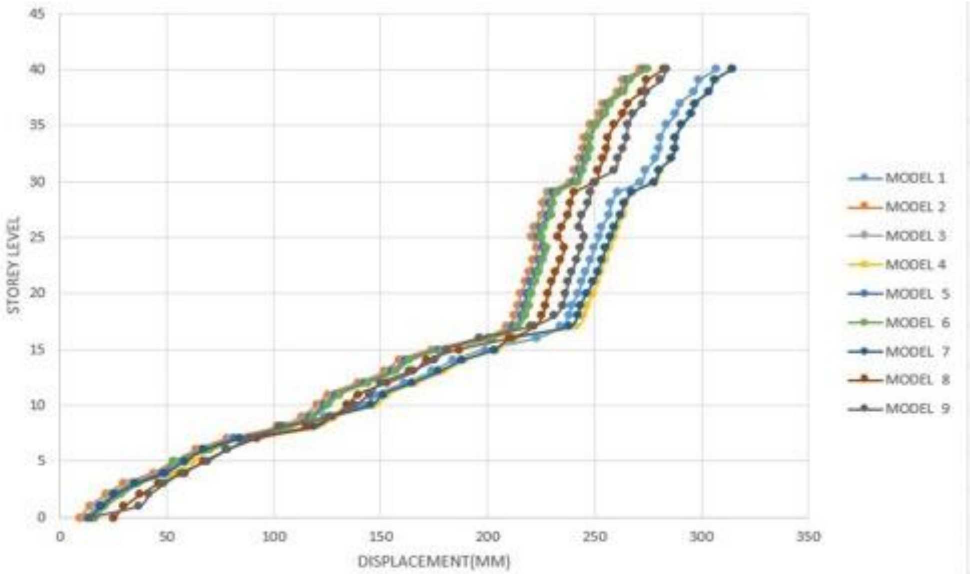

Fig 7 : Lateral Displacement for Static Wind Analysis along Transverse direction for Zone V

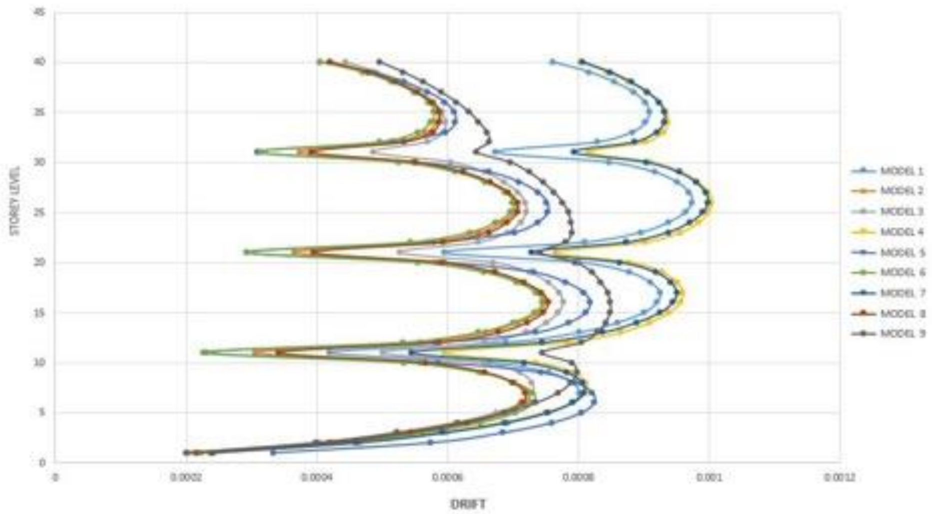

Fig 8 : Storey Drift for Response spectrum analysis along longitudinal direction for zone V

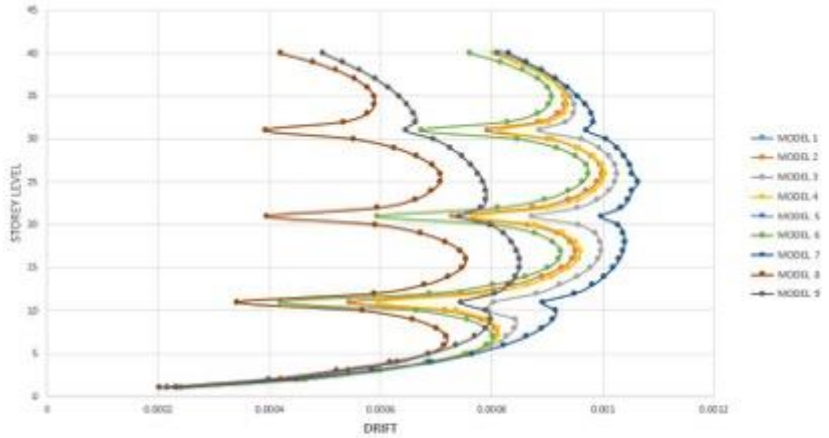

Fig 9 : Storey Drift for Response spectrum analysis along transverse direction for zone V

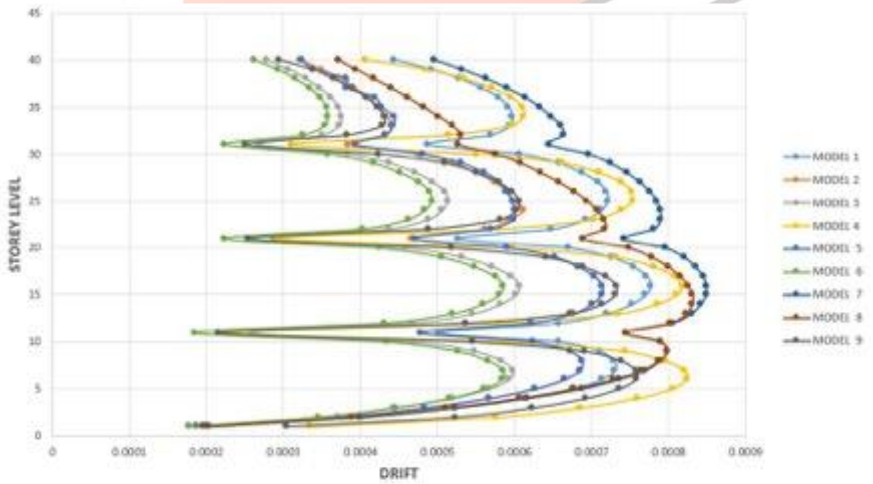

Fig 10 : Storey Drift for Static wind analysis along longitudinal direction for zone V

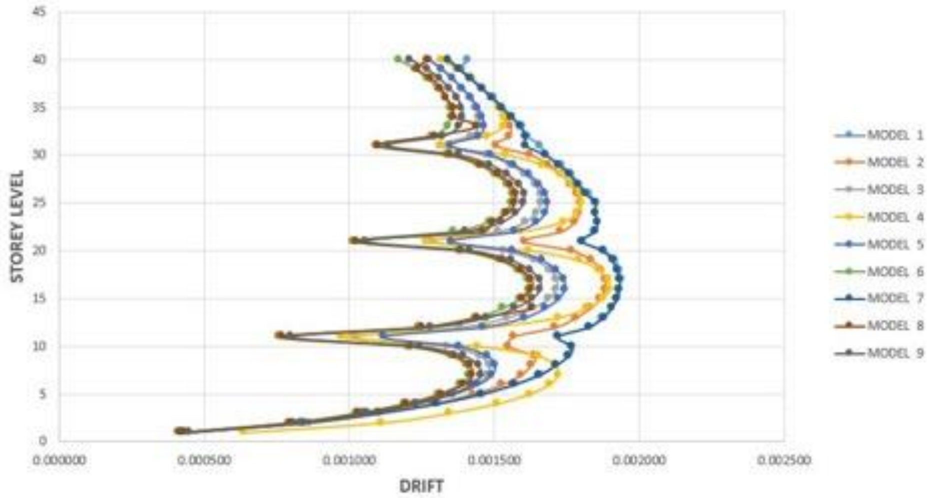

Fig 11 : Storey Drift for Static wind analysis along transverse direction for zone V

Table 4 : Base Shear by Response Spectrum Analysis and Wind Analysis along Longitudinal and Transverse direction

BASE SHEAR (KN)					
Model No.	**Type of Models**	Response Spectrum Analysis		Static Wind Analysis	
		RSA-X	RSA-Y	WIND-X	WIND-Y
1	Y Shape Bare frame model without Outrigger	16428.91	16467.95	12221.26	13541.28
2	Y Shape Model with Concrete Core wall and braced Outriggers (Concrete X Bracings)	17307.96	17937.91	11197.62	11315.69
3	Y Shape Model with Concrete core wall and braced Outriggers (Steel X Bracings)	17907.76	18312.724	11758.44	11812.36
4	Circular Shape Bare frame model without Outrigger	14610.79	14210.21	12267.97	12156.23
5	Circular Shape Model with Concrete Core wall and braced Outriggers (Concrete X Bracings)	15824.02	15924.21	12065.75	12099.73
6	Circular Shape Model with Concrete core wall and braced Outriggers (Steel X Bracings)	15470.13	15670.75	12024.84	12121.94
7	Fillet Shape Bare frame model without Outrigger	15324.22	15413.36	13351.69	13451.21
8	Fillet Shape Model with Concrete Core wall and braced Outriggers (Concrete X Bracings)	16228.86	16031.39	12562.33	12762.31
9	Fillet Shape Model with Concrete core wall and braced Outriggers (Steel X Bracings)	16404.48	16435.67	12758.44	12957.22

IX. OBSERVATIONS

- It is seen that 29.21% of top storey displacement and 26.64% of maximum story drift is constrained by providing Y Shape Plan Configurations, 28.1% of top storey displacement and 25.44% of maximum story drift by Circular Shape Plan Configurations and 22.32%of top storey displacement and 19.50% of maximum story drift is controlled with Fillet Shape Plan Configurations.
- Also 8.22% of displacement and 9.64% of storey drift is controlled if braced core wall is employed with X-braced outriggers (Model 2,3,5,6,8,9) and is compared with X-braced outriggers (Model 1, 4, 7).
- The model with Steel Outriggers demonstrates to be less productive in controlling displacement by 19.49% and of storey drift by 17.27%.This perception validates the literature [10].
- The Outriggers with Belt truss (Model 3) experienced less displacement and controlled lateral displacement by about 34.57% and about 30.75% inter storey drift is controlled.
- The natural period decreases as the stiffness of the building increases and thus leading in increment of frequency.

- The Y Shape building frame with X-braced Outriggers will have least possible lateral displacements in contrast to other building shapes of Outriggers.

X. CONCLUSIONS

The accompanying Conclusions were drawn dependent on the Observations made

- The Y plan Configuration with X-supported Outriggers is particularly powerful; as it indicates least minimum lateral displacement pursued by Circular Plan Configuration Outriggers and Fillet Plan Configuration Outriggers.
- The Outriggers provided with Braced core wall were less viable in reducing lateral displacement compared with Solid Core wall by a small margin, hence it can be employed as the cost effective construction.
- The Outriggers gave in the inside casings of a structure examined are observed to be viable when contrasted with Outriggers gave in the outside edges for example.
- The steel outriggers are discovered least compared to Concrete one. Despite the fact that Steel outriggers can be utilized as the light weight substitute for concrete.
- From the examination it tends to be reasoned that that wind is a dominating factor and outriggers are successful in lessening wind impact as looked at tremor powers.
- Steel Outriggers can be utilized as an option in contrast to the next to the other strengthening techniques available as the total weight of the current structure will remain practically same

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