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Effect of Damped Outrigger Structural System on High-rise Structures, Subjected to Lateral Loads

Khushboo Mishra¹, N.G. Gore²

P.G. Student, Department of Civil Engineering, MGM College of Engineering & Technology, Kamothe, Navi Mumbai, Maharashtra, India¹

Associate Professor, Department of Civil Engineering, MGM College of Engineering & Technology, Kamothe, Navi Mumbai, Maharashtra, India²

ABSTRACT: There are several elements which have made it requisite for world to go for high-rise structures and the skyscrapers. One of such factors is rapidly augmentation in population in urban areas. But it is a big challenge to build a high-rise structure as number of aspects to be considered are more as compared to low-rise structures. Therefore, along with the advantages, a high rise structure brings huge difficulties with it. The main problem associated with these structures is its stability against lateral forces. Earthquake and wind forces are highly dominating forces on any high-rise structure. It's a big challenge for engineers to satisfy the structure for deflection as well as strength criteria. Generally, to deal with such problems, initially, a core is provided at the centre of the building. Since the structure cannot be and need not be taken to null deflection, IS Code provides the lateral deflection limits for wind and earthquake loads. As per Indian standard code 875-2015 part3, "Under transient wind load, the lateral sway at the top, should not exceed $H/500$, where H is the total height of the building". Also, "The storey drift in any storey due to the minimum design lateral force, with partial load factor of 1.0 shall not exceed 0.004 times the storey height

KEYWORDS: Lateral Force, High-Rise building, Etabs, Response Analysis, Damped outrigger, Conventional Outrigger.

I. INTRODUCTION

The CTBUH defines "Supertall" as a building over 300 meters (984 feet) in height, and a "Mega tall" as a building over 600 meters (1,968 feet) in height. Although number of floors is a poor indicator of defining a tall building due to the changing floor to floor height between different buildings and functions. As the height of the building increases, core wall alone is not effective enough to resist wind load and seismic forces. And hence there is a need of additional structural system to the building which are used as per the requirement of the building. Since, so many structural systems are being used in the field, these structural systems have been divided as shown below.

Interior Structures

By clustering steel columns and beams in the core, engineers create a stiff backbone that can resist tremendous wind forces. The inner core is used as an elevator shaft and the design allows lots of open space on each floor. The following interior structures are possible.

1. Rigid Frame
2. Braced Frame and Shear-walled Frame
3. Outrigger Structures

Exterior Structures: In newer skyscrapers, like the Sears Tower in Chicago, engineers moved the columns and beams from the core to the perimeter, creating a hollow, rigid tube as strong as the core design, but weighing much, much less. The following exterior structures are possible:

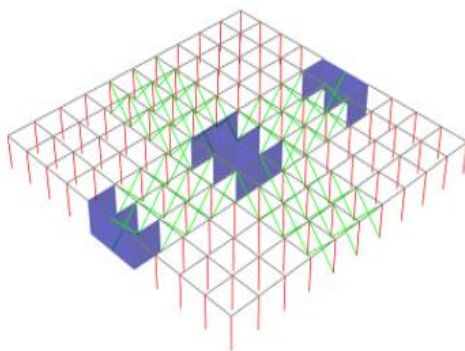
1. Tube
2. Diagrid
3. Space Truss
4. Exoskeleton
5. Super frame

II. RELATED WORK

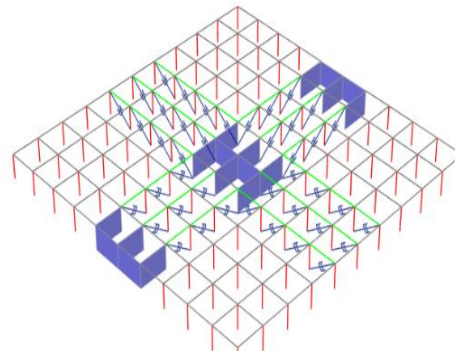
The most effective outrigger structural system is conventional outrigger. But there exists number of problems regarding connection as well as space in conventional outrigger system. The whole floor becomes useless for work when this outrigger is provided. To deal with these problems, a new system was proposed that is called Damped Outrigger structural system. In this system, only damper is provided with some modification as stated by [1,7]. In this thesis, 2 nos. of Conventional outrigger is provided on corresponding floors. And in case of Damped outrigger, the modification done in addition of link as damper having mass 168kg and weight 750 kg. In addition to that, these outriggers are two storey deep. Because of the absence of the direct connection to core, the conventional outriggers are weaker in function. These two modification have not proved themselves to be effective enough to compete with conventional outrigger with belt truss system in X-direction. Therefore, it is again modified with cross sectional area which is 2.5 times the conventional outrigger with belt truss' area. Now, it can give rise not only comparable but somewhere more acceptable results. The absence of trusses on the floors in this system has provided a quality space on the floor. Also, since the outriggers are two storey deep, there are not much problems regarding ventilation and hence these floors can be used exactly like other floors. No modification in floor diaphragm is required one more model is prepared of conventional outrigger with damper FVD750 to bring out the comparative performance of conventional and damped outrigger. All outriggers are X-braced. The performance of conventional steel outrigger has been carried out for SHS 525X525X40 mm First modification is to remove one system of conventional outrigger at one storey hence provided the FVD 700 damper as link property. Since the area becomes so huge when removal of outrigger at one level is done a damper system which is connected to outrigger which is already in connection with core.

Types of Outrigger-

- Conventional Outrigger
- Virtual Outrigger
- Damped Outrigger



Conventional Outrigger



Damped Outrigger

III. OBJECTIVE OF WORK

1. To study the behaviour of tall RC structure subjected to lateral loads, having different storey 60, 65,70 storey in zone V.
2. To analyse the structure with and without the lateral force resisting system .
3. To compare conventional outrigger and damped outrigger system .
4. To analyze the structure With Gust Factor Method .
5. To analyze the structure by Response Spectrum Method .
6. To examine the most effective yet economical system of outrigger.
7. To compare the results of models in respect of following.
 - i. Base shear
 - ii. Base moment

- iii. Time period
- iv. Storey displacement
- v. Storey drift
- vi. Overturning moment
- vii. Rotation

IV. METHODOLOGY

In this project 60storey, 65 Storey,70 storey structure of a commercial building with 3.5m floor to floor height has been analysed by Finite Element Method using ETABS software in different zones (III, IV and V). The plan selected is square in shape. It is not the plan of any existing or proposed building but is an architectural plan. The structure has been analysed for both static and dynamic wind and earthquake forces. Two outriggers have been provided throughout height of the structure. Soil condition-II has been selected for the structure.

Methods of analysis of the Structure:

- Wind analysis
- IS Code method
- Wind Gust Method
- Seismic analysis
- Equivalent static analysis
- Response spectrum method

Geometrical Details:

Type of the Building / Floor dimensions: Commercial / 50mX50m

Height of the building / Floor to Floor height: / 3.5m

No. of Storeys: 60,65,70

Depth of slab: 150mm

Size of Beam: Varying cross section from 300mmX800mm to 350mmX900mm

Size of Column: 800mmX800mm and 1100X1100mm

Size of Core wall: Varying thickness from 500mm to 700mm

Size of Steel Outrigger and Steel Belt Truss: SHS 525mmX525X40mm

Link Property: FVD 750

Grade of the Materials: Concrete grade for Beams/Slabs: M40

Concrete grade for Columns: M40,M50,M60,M70

Grade of Rebar: 415N/mm² and 500N/mm²

Grade of Structural steel: Fe 345 Density of infill walls: 22kN/m³

Gravity loads on structure:

Live load on floor/terrace: 4kN/m² , 1.5 kN/m²

Floor finish/terrace: 2kN/m² ,3kN/m²

Wall load on external beams/parapet load on terrace: 17.82 kN/m² , 7.92 kN/m²

Lift Machine load: 10kN/m²

Data for analyses: Seismic zone/Seismic zone factor: V-0.36

Response Reduction Factor/Importance factor: 5,

Soil type: II

Terrain category/ Wind speed: IV, 44m/s (for all zones)

Modal load case type: Ritz

Mass source: 1DL+0.5LL (excluding terrace live load, including NRLL of Lift machine with load factor 1)

P-Delta combination: 1.2DL+0.6LL

IS Codes: 875 (part I), 875 (part II), 875 (part III)-2015, 1893 (part I)-2016

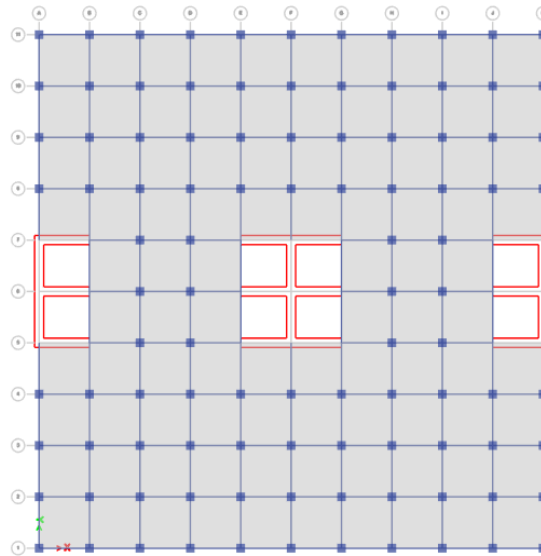
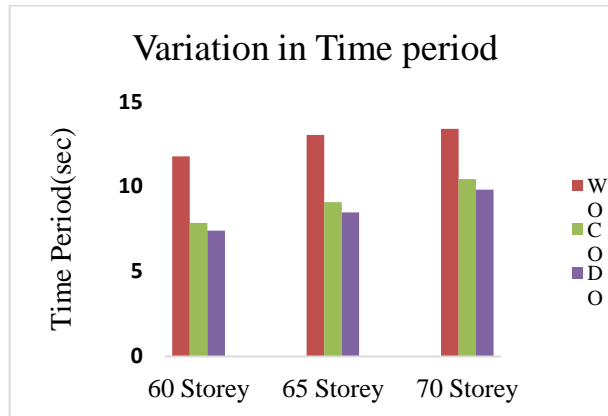


Fig Plan of building

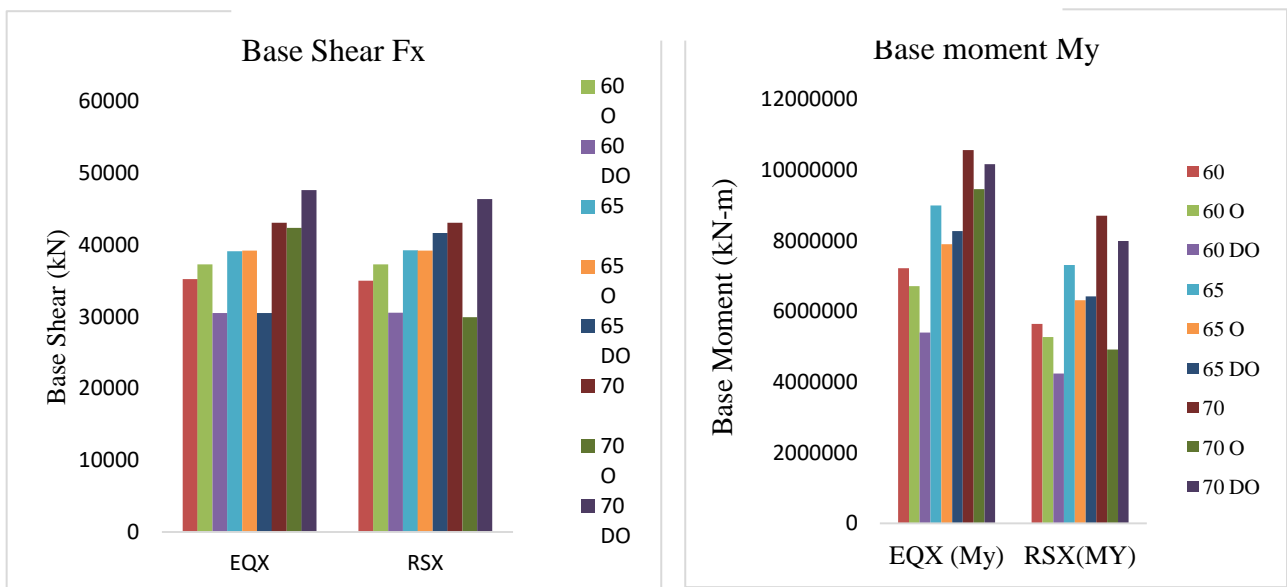
V. RESULT

The results obtained from above models are presented. Result of time period in shown below.

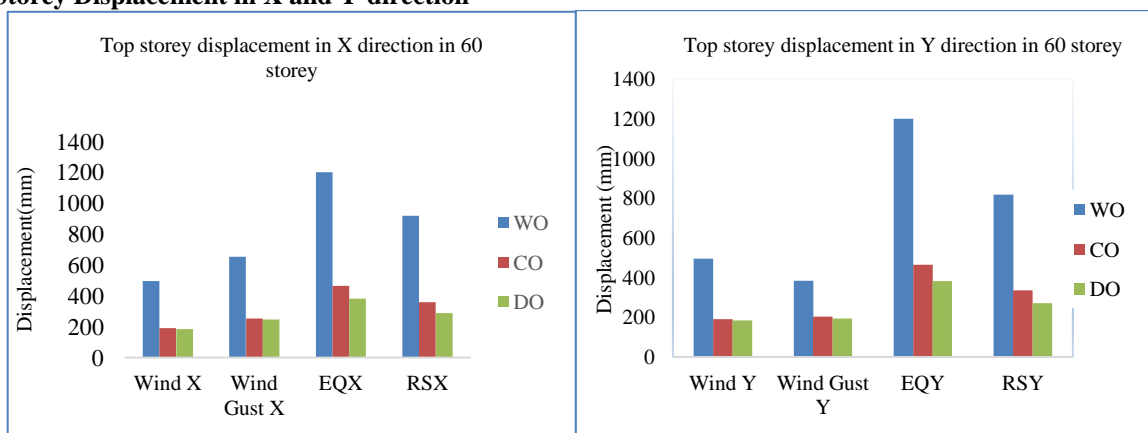
Table: Time Period		
Models	Time Period (sec)	Reduction in Time Period (%)
60 Without Outrigger	11.785	-----
60 Conventional Outrigger	7.865	33.26
60 Damped Outrigger	7.411	37.11
65 Without Outrigger	13.045	-----
65 Conventional Outrigger	9.098	30.25
65 Damped Outrigger	8.842	35.66
70 Without Outrigger	13.407	-----
70 Conventional Outrigger	10.453	22.033
70 Damped Outrigger	9.831	26.672



Graphs of Base Shear and Base Moment:-

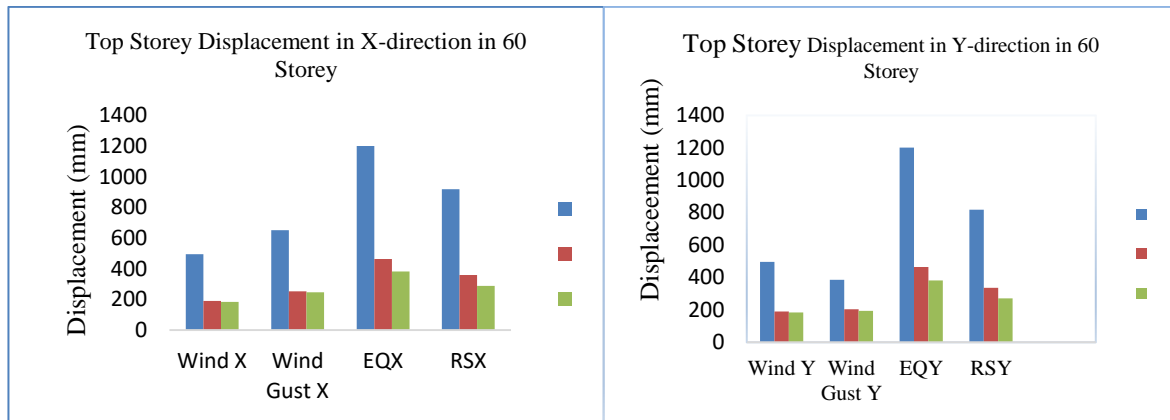


Top Storey Displacement in X and Y-direction-

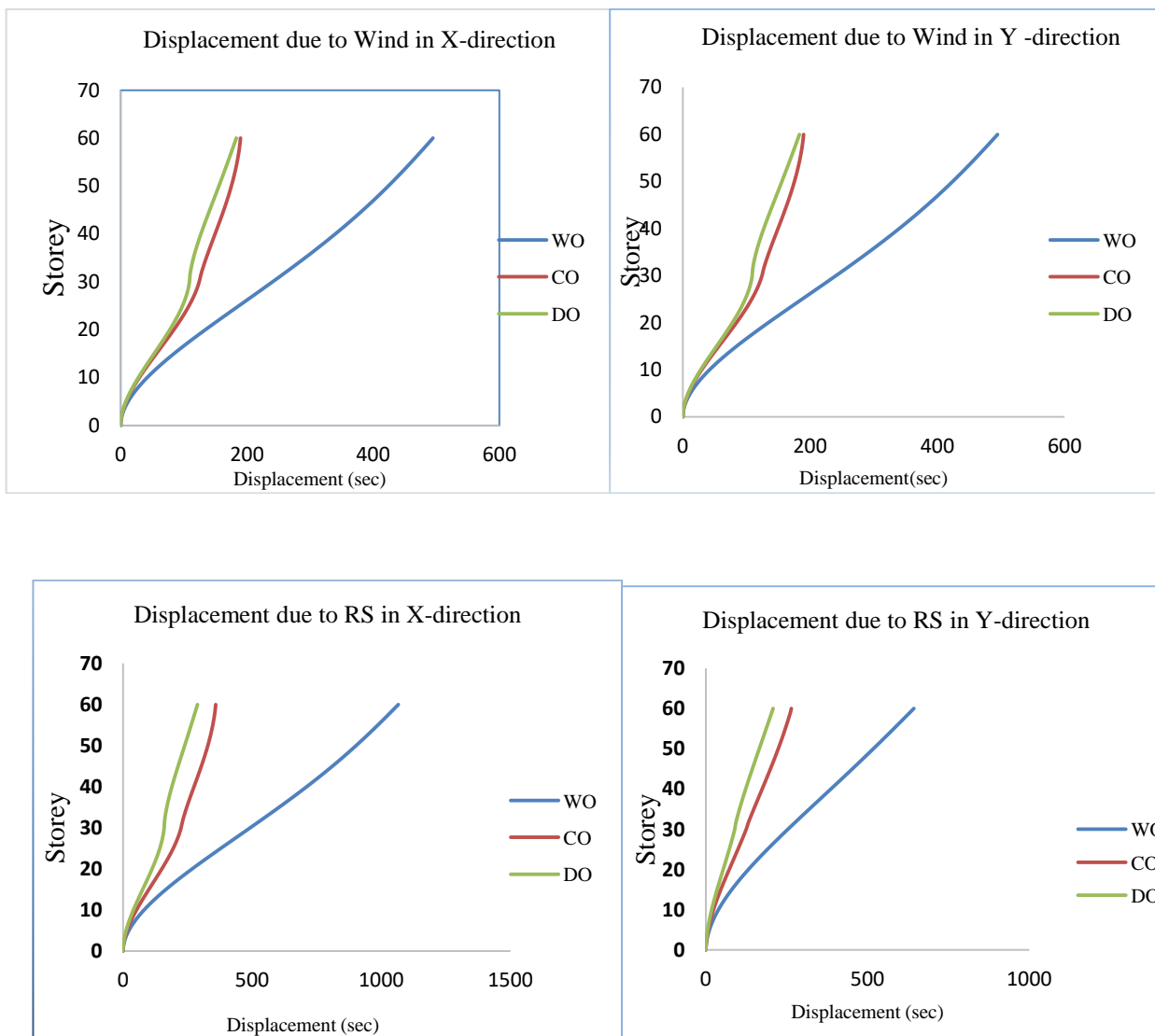




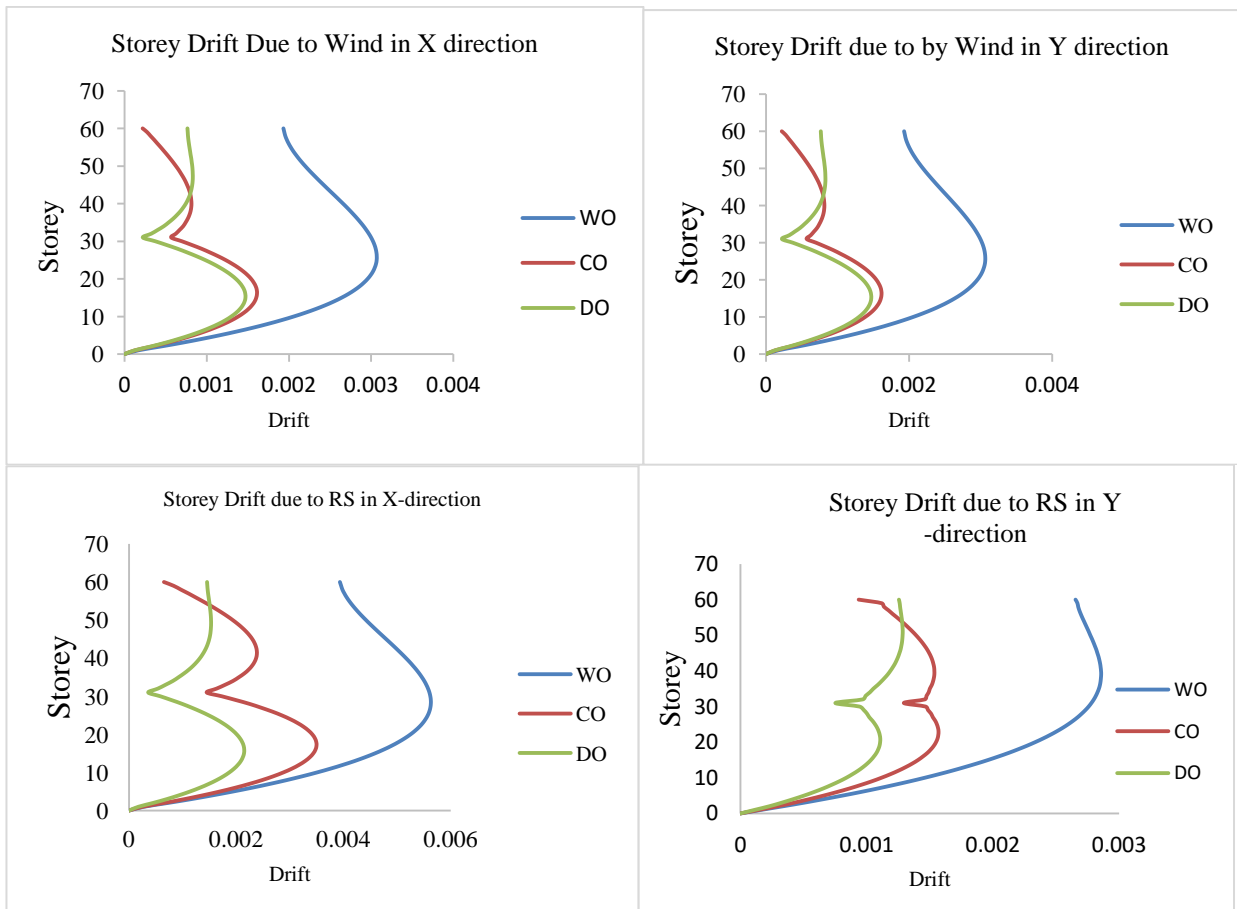
Displacement Graph-



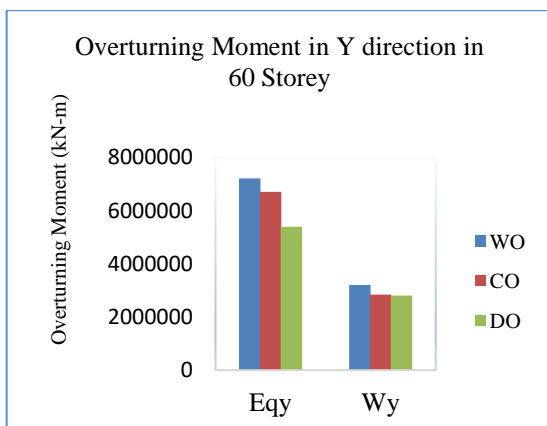
Storey Displacement Graph-



Drift Graphs-



Overturning moment Graph-



Rotation-

Mode	Rotation		
	WO	CO	DO
1	0	0	0
2	0	.70	0
3	.67	0	.72

VI. DISCUSSION

In this project, two types of outrigger structural system in respect of design have been studied in detail. Three different storey building i.e. 60 storey, 65 storey and 70 storey are studied without outrigger, conventional outrigger and damped outrigger case. It is the secondary aim of the project to convey the fruitfulness of outrigger structural

system. The foremost aims of the project are to estimate the performance of damped outrigger and to compare the performance with conventional outrigger. To get the precise idea of the work, two outriggers are introduced in the structure in the manner mentioned above. From all the literatures and results of present study, it is noticed that damped outrigger structural system is the most effective type of outrigger system. When it comes to consumption of floor space for the system, conventional outrigger system has an immense disadvantage. In this case, damped outrigger system has proved itself to be one of the best alternatives because by applying damped outrigger number of conventional outrigger decreased. Since the conventional outrigger alone is not sufficient enough to provide the equal stiffness to the structure as that of conventional outrigger. It is stated from the results that the damped outrigger can provide the desired results and somewhere even much better results. Model 60 DO, 65DO and 70 DO are having damped outrigger at mid height. Base moment is decreasing after applying damped outrigger system. Maximum time period of 11.785 sec is noted in model 60 storey Without Outrigger which reduced to 7.865 sec for 60 CO model and 7.411 sec for 60 DO model i.e. 33% and 37% reductions in time period are observed.

Maximum deflection is seen in Y-direction 494.78 mm without outrigger which drops down up to 183.4mm after addition of damped outrigger to the structure hence reducing the deflection to 61%. Up to 60% reduction in drift is achieved in both X and Y-direction and utmost reduction in drift is observed at damped outrigger levels. Maximum reduction in drift is seen when damped outriggers are put. As Overturning moment is reduced by 26% by applying damped outrigger. Though deflection is controlled by applying outrigger up to great extent but rotation occur in 2nd mode which is unacceptable according to IS code 1893(part 1):2016 in Zone V the first three modes together contribute at least 65 % mass participation factor in each principal plan direction. In Conventional Outrigger in 65 storey rotation comes in mode 2 due to major deflection controlled. But as Damped outrigger is applied rotation as well as deflection come under control.

A building is said to be torsionally irregular, when,

- 1) the maximum horizontal displacement of any floor in the direction of the lateral force at one end of the floor is more than 1.5 times its minimum horizontal displacement at the far end of the same floor in that direction; and
- 2) the natural period corresponding to the fundamental torsional mode of oscillation is more than those of the first two translational modes of oscillation along each principal plan directions

VII. CONCLUSION

Other than Equivalent wind and Equivalent seismic analyses, all the models are analysed with and without the outrigger system in zone V for various method such Wind Gust method and Response spectrum method. Few conclusions are made on the basis of all the results obtained from the analyses which are listed below.

1. Outrigger structural system provides stiffness to the structure hence making it one of the most effective systems against seismic as well as wind forces.
2. Orientation of the shear wall affects the deflection and therefore deflection in Y-direction is more as compared with X-direction which is having more shear walls along it.
3. Out of all load cases, wind and earthquake are the governing force in zone V being to have maximum base shear as well as creating maximum deflection.
4. Damped outrigger should be preferred over conventional outrigger since conventional outrigger required more cross section to pass the design check while providing the same deflection.
5. Damped outrigger is one of the best alternatives to deal with the problems associated with conventional outrigger system.
6. Deflection and time period are seen to be higher in zone V. After applying outrigger system, up to 50% reduction is seen in both X and Y-direction.
7. More reduction in drift is observed on the level of damped outrigger. % reduction observed in average is up to 50%.



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