An RC Structure competitive analysis of with and without Outrigger using steel bracing

J Rex [1,a], Damera Uday Kiran[,2 b]

[1] Associate Professor Department of Civil Engineering, Malla Reddy Engineering College, Hyderabad, India

[2] PG Student Department of Civil Engineering, Malla Reddy Engineering College, Hyderabad, India

[a)] rexdindigul@gmail.com
[b)]udaykirandamera214125@gmail.com

Keywords: Seismic loading, Outrigger system, Stiffness and efficiency of Lateral displacement, Drift, Base shear, Stiffness against static and Dynamic loads.

Abstract. Tall building development has been rapidly increasing worldwide introducing new challenges that need to meet through engineering decision. To increase the performance of the structure under seismic loading, outrigger system is proposed in the current study of work. The modeling of the structure is done using "ETABS" program. The analysis of the model is carried out by equivalent static method and response spectrum method. The stiffness and efficiency characteristics of the structure is measured in terms of lateral displacement, storey drift, base shear and fundamental natural period for different types of buildings to provide stiffness against static and dynamic loads.

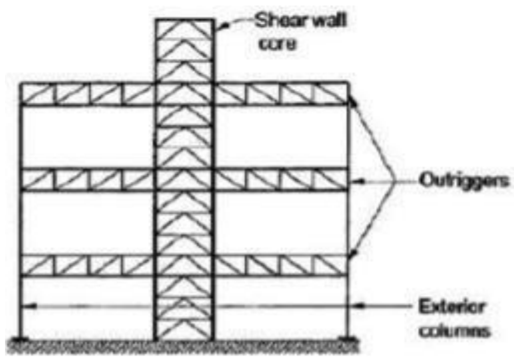
INTRODUCTION

Tall structures have always captivated people's imaginations, inspiring them to dream big and driving technological innovation to better their ideas, which have spread around the globe. Because of the rapid growth in technical skills associated with urbanisation, towering structures have emerged as a viable option for office and residential construction. Tall structures are often employed for a variety of purposes, including residential, office, and commercial uses. As a result of rapid urbanisation and the resulting demand, businesses have devised strategies to ensure that they are there to secure as many more people as possible as soon as possible.

A significant portion of India is prone to a dangerous degree of seismic hazard. As a result, the seismic load employed for the purpose of a tall building should be taken into consideration. Because lateral stresses caused by earthquakes are a source of worry in high-rise buildings, several lateral load-resisting technologies are used in these structures. These lateral forces have the potential to induce critical stresses in the structure, resulting in undesired strains and vibrations that cause the structure to sway excessively to the side.

Introduction of outrigger

The outrigger and belt truss system is one of the lateral load resisting systems in which the external columns are tied to the central core wall with extremely stiff outriggers and belt truss at one or more levels, with the outriggers and belt truss being attached to the central core wall at multiple levels. The belt truss connected the building's periphery columns, while the outriggers connected them to the building's main or central shear wall. The outrigger and belt truss systems are commonly used as one of the structural systems to effectively control the excessive drift caused by lateral load, so that the risk of structural and non-structural damage can be minimised during small or medium lateral loads caused by either wind or earthquake load. This system may be used as an acceptable structure for high-rise structures, especially those located in seismically active zones or those subjected to strong wind loads.



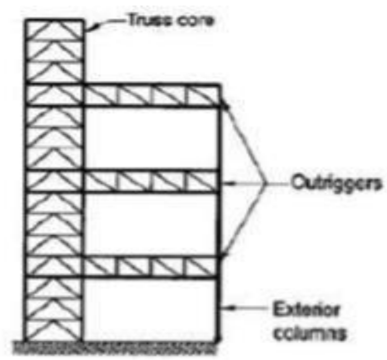


Figure 1(a). Outrigger with central core **Figure1(b).** Outrigger system with offset core

Objectives of the Study

a) To model and analyze the structure and to get mainly effective structure to resist lateralloads.
b) To study the use of outriggers in an regular and vertical irregular structure under seismicforce.
c) The buildings with and without outrigger are compared.
d) To acquire behavior of outrigger introduced as a steel bracing in a R.C tall structure.
e) To compare the effect of outriggers by both Equivalent static

method and DynamicAnalysis method (Response spectrum method) as per IS 1893 – 2002.

f) To study parameters such as storey shear, displacement, storey drift, storey stiffness, fundamental natural time period and base shear.

METHODODLGY

Subsequent is to adopted for analysis of outrigger with steel bracing and without outrigger

1. R.C Structure is considered for study having 30storey of height 90m each floor is 3mheight.
2. The regular R.C concrete moment resisting frame of square plan with core in centerlocation is measured as base.
3. The floor height as kept steady for all floors to get accurate results.
4. Outrigger has adopted an steel bracing frame, comparing with geometric models.
5. To understand the behavior under lateral loads applied as per IS 1893-2002 are usedrespectively.
6. Based on the results and response from earthquake load applied conclusions are made.

Basic model specifications

Structure	OMRF
No. of stories	G+30
Storey height	3.0 m
Base storey	3.0 m
Plan dimension	2704 m (for regular building) 2421 m (for irregular building)
Grade of concrete	M30 and M25
Grade of steel	Fe500
Thickness of slab	150 mm
Beam size	550*300 mm450*300 mm
Column size	1000*1000 mm900*900 mm
Outrigger Steel Bracing	ISA 150*150*15 mm
Shear wall thickness	0.3 m
Type of soil	medium soil
Wind Load:	IS- 875 (part 3): 1987

Wind Speed V_b	50 m/s
Terrain Category	4
Structure Class	B
Risk Co-efficient	1
Topography Factor	1

Modeling

a) Rectangular without outrigger

b) Rectangular with outrigger with steel bracing

c) Hexagonal without outrigger

d) Hexagonal with outrigger with steel bracing

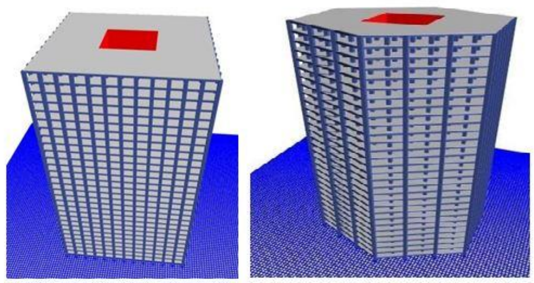


Figure2. 3D models

Building Modeling and Loading Data's

Type of Structure – Concrete Moment Resisting Outrigger with Steel Bracing Plan Configurations -Rectangular and Hexagonal.

No of Stories - G+30 (30 Storied)

Height of each floor - 3 m

Height of building - 90 m

Building type- Commercial

Grade of concrete fck – M30

Grade of steel fy -500

Density of Concrete – 25KN/m3

Damping Ratio – 5%

Gravity and Lateral load consideration

a. Live-load - 4 kN/m^2 (IS-875 (part 1) :1987)

b. Floors-finish - 1 kN/m^2 (IS-875 (part 2): 1987)

c. Seismic load - IS-1893 (part 1): 2002

Earthquake inputs as per IS 1893 (Part 1): 2002

- Soil type- Type II
- Importance factor- 1.0
- Response reduction factor - 5.0
- Seismic Zone- IV (0.24)

RESULTS AND DISCUSSIONS

The behavior of each model is described in detail in this chapter, and the findings are shown in a table. For the corresponding static technique, the change of systematic parameters such as storey lateral displacement, storey drift, Storey stiffness, Storey shear, and base shear has been investigated. The outcomes of all of the models are observed, and the most appropriate model is chosen by comparing the results of each model to the observed results.

Storey Displacement

The lateral displacements obtained for equivalent static method (EQS) for G+30 storey building models of different geometric shapes, along both X and Y directions are listed in the tables below.

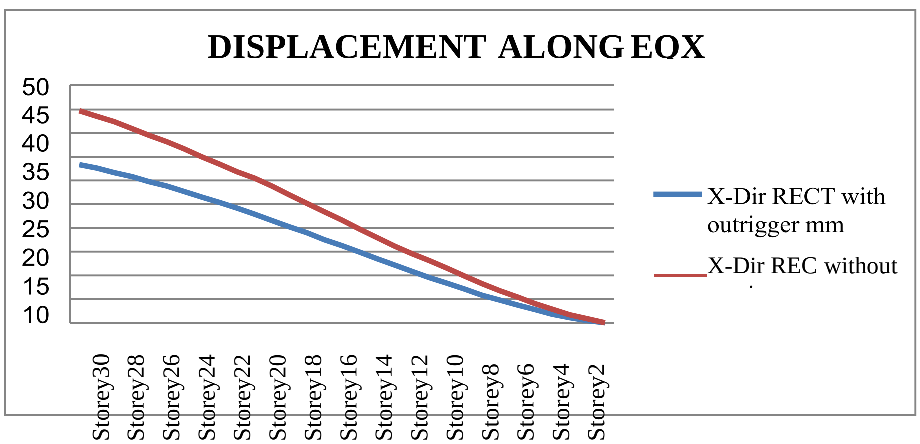


Figure 3. Plot of Rectangular Storey Displacement vs. Storey Number EQX –IV

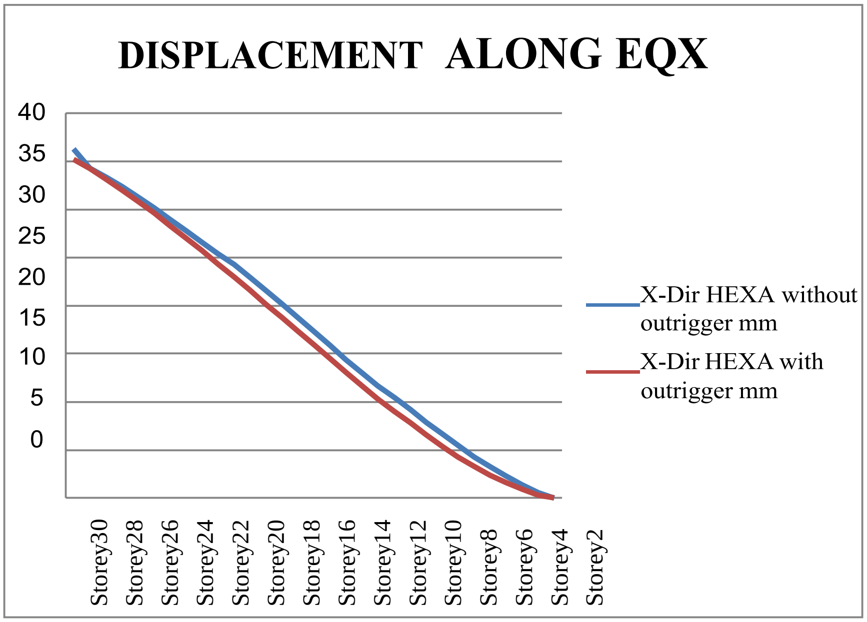


Figure 4. Plot of Hexagonal Storey Displacement vs. Storey Number EQX IV

Observations and Discussions on Storey Displacement

By studying from in figure. 3 to 4 we can see that displacement increases as storey height increases. We can clearlysee that there is increased of lateral displacement for with outrigger compare to without outrigger structure Increased by 3.68% along both X and Y direction. Compare to without outrigger structure rectangular frame with outrigger rectangular structure is increased by 24%, 25% along X and Y direction and hexagonal structure increased by 10.02%, 19.48% along X and Y directions respectively for equivalent static analysis.

By studying from comparing values by response spectrum storey displacement increased of lateral displacement for rectangular increased 16.6% and hexagonal it increased 4% by dynamic analysis.

Storey Drift

Storey drift obtained for G+30 storey all building models along both X and Ydirections are listed for Equivalent static methods.

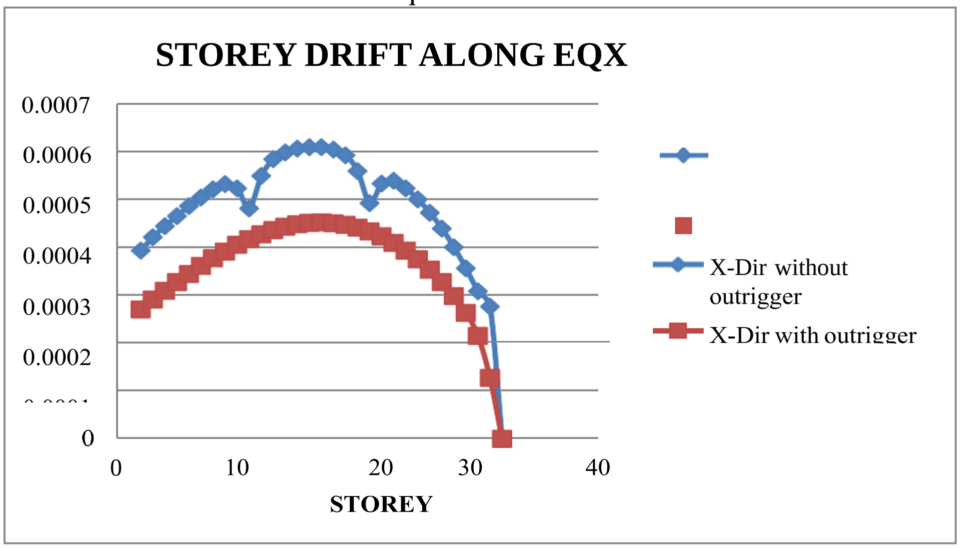


Figure 5. Plot of Rectangular Storey Drift vs Storey Number EQX Z-IV

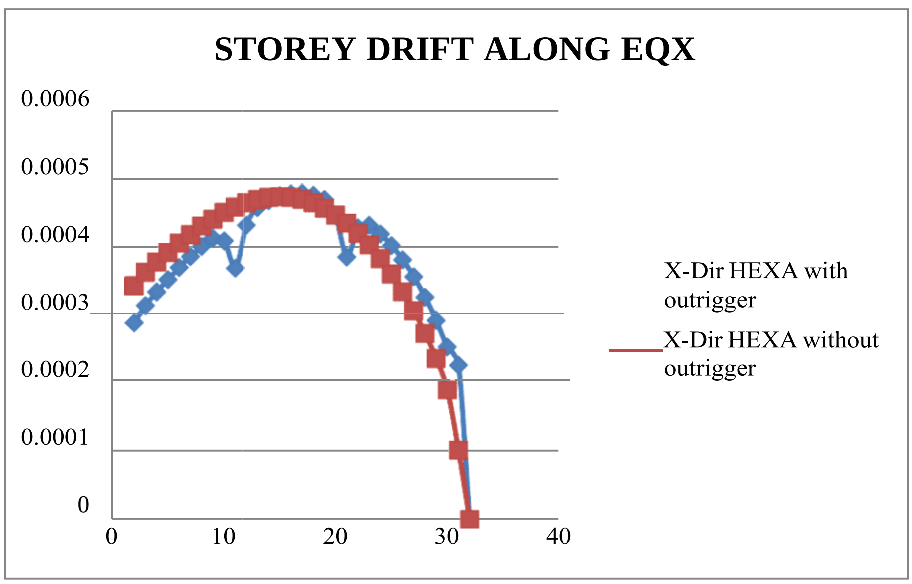


Figure 6. Plot of Hexagonal Storey Drift vs Storey Number EQX Z-IV

Observations and Discussions on Storey Drift

By studying from figure. 5 to 6 we can see that Drift increases as storey height increases. We can clearly see that there is Increased of Storey Drift. Compare to without outrigger structure rectangular frame outrigger rectangular structure is increased by 7.4%, 2.8% and hexagonal structure increased by 10.02%, 19.48% alongX and Y directions respectively for equivalent static analysis.

By studying comparing values by response spectrum by storey drift rectangular increased 7% and hexagonal it increased 4% by dynamic analysis.

Storey Shear

Storey shear obtained for G+30 storey all building models along both X and Y directions are listed for Equivalent static methods.

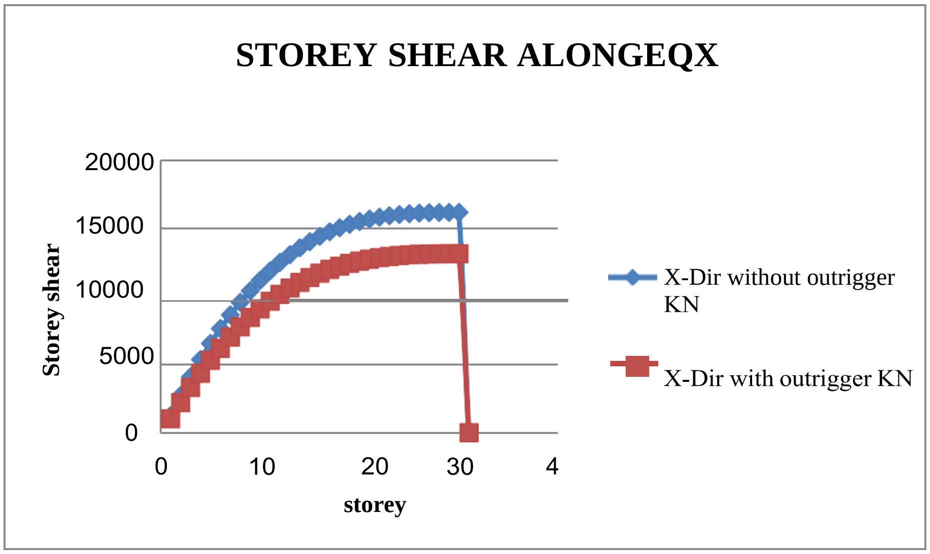


Figure 7. Plot of Rectangular Storey Shear vs. Storey Number EQX Z-IV

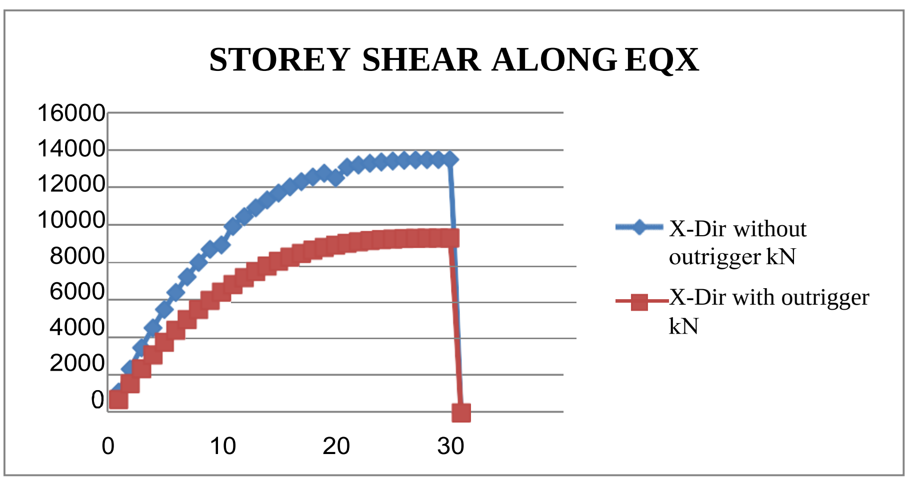


Figure 8. Plot of Hexagonal Storey Shear vs. Store Number EQX Z-IV

Observations and Discussions on Storey Shear

By studying from figure. 7 to 8 we can see that variation in Storey shear as storey height increases. we can clearly see that there isa reduction of Storey shear from bottom storey to top storey for rectangular frame compare to bare frame tube structure decreased by 2.2% along both X and Y direction. Compare to Hexagonal without outrigger frame rectangular frame is decreased by 19%, 24.5%, and hexagonal structure increased by 31%, 28% along X and Y directions respectively for equivalent static analysis.

By studying comparing values by response spectrum storey shear increased for rectangular increased 19.6% and hexagonal it increased 15.5% by dynamic analysis.

Storey Stiffness

Storey stiffness obtained for G+30 storey all building models along both X and Y directions are listed for Equivalent static method

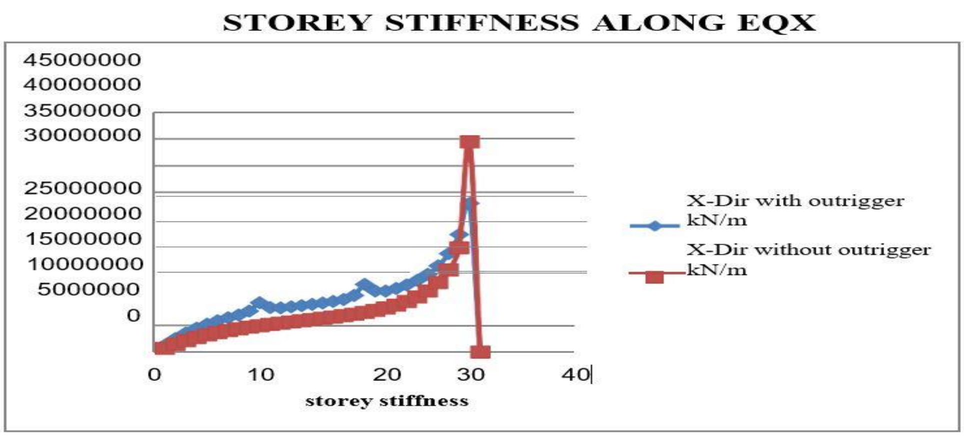


Figure 9. Plot of Rectangular Storey Stiffness vs Storey Number EQX Z-IV

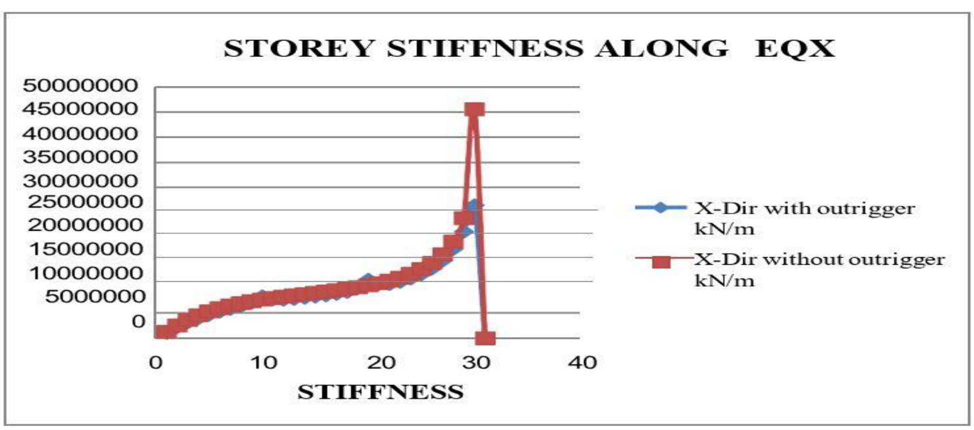


Figure 10. Plot of Hexagonal Storey Stiffness vs Storey Number EQX Z-IV

Observations and Discussions on Storey Stiffness

By studying from figure. 9 to10 we can see that variation in stiffness as storey height increases. we can clearly see that there is areduction of storey stiffness for rectangular frame with outrigger compare to without outrigger frame structure decreased by 1.7%, 1.6 along both X and Y direction. rectangular frame with outrigger structure is increased by 7%, 17%, and hexagonal structure increased by 6.57%, 30.31% along X and Y directions respectively for equivalent static analysis. By studying comparing values by response spectrum storey stiffness increased for rectangular increased 19.2% and hexagonal it increased 39.5% by dynamic analysis.

Time period

Time period obtained for different geometric models are shown below By default, software will calculate for 12 modes and we were considering only first three modes along first mode along X-direction, second mode along Y-direction, third mode is along rotational. From the above plotted graphs we observed that rectangular shape has maximum time period 2.397 sec due to slenderness and geometry. In hexagonal type of geometry are same but in other structures each mode has different time period due to irregularity.

Time period for rectangular outrigger structure decreases by 2.6% compared to hexagonal structures. Compare to rectangular, the hexagonal structure is increased by 22.44%, 7.38%, respectively.

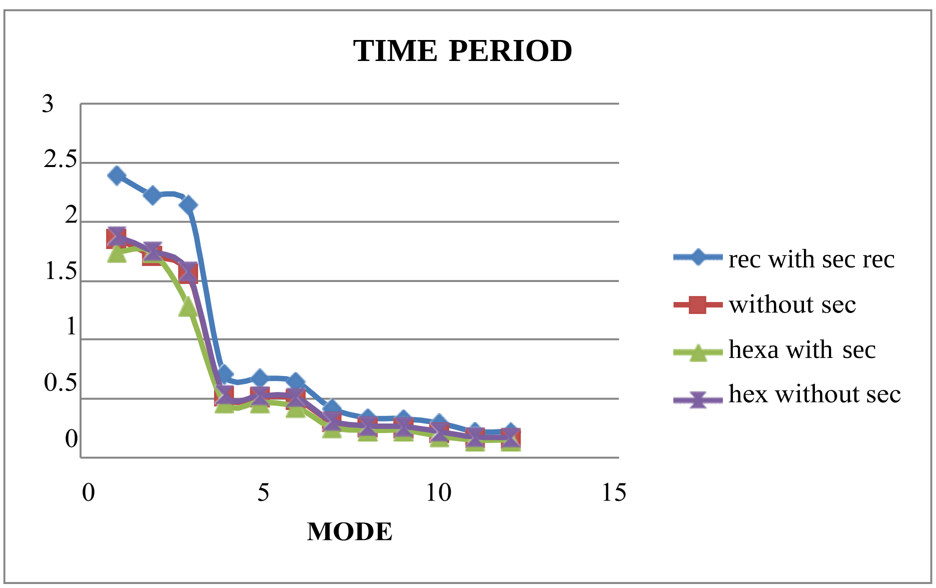


Figure 11. Plot of MODE vs TIME Period in Z-IV

Base Shear

The shear force at base of structure for all four models in X and Y direction with response spectrum and equivalent static method both values as get similar as per table.

Table 1. Base Shear in EQX for Z-IV

ZONE	REC WITH OUTRIGGER	REC WITHOUT OUTRIGGER	HEXA WITHOUT OUTRIGGER	HEXA WITH OUTRIGGER
BASE SHEAR	16352.2	13122.512	9305.25	13615.768

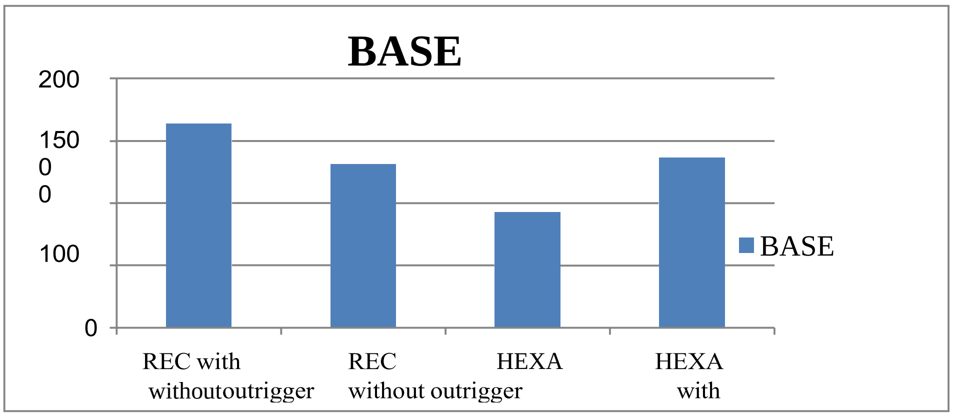


Figure 12. Plot of BASE Shear in Z-IV

Table 2. Base Shear in EQY for Z-I

ZONE	REC with outrigger	REC without outrigger	HEXA without outrigger	HEXA with outrigger
BASE SHEAR	15210.2	12094.977	9314.611	12689.737

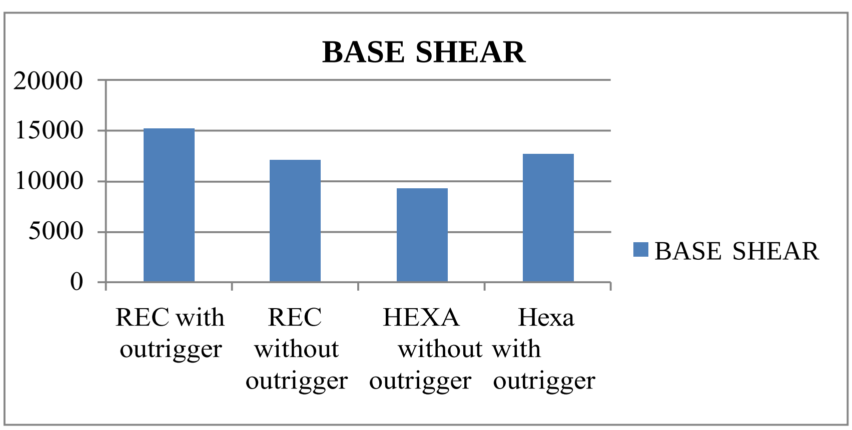


Figure 13. Plot of BASE Shear along EQY in Z-IV

CONCLUSIONS

The present work is focused on the study of behavior of tall structure subjected to lateral loads for various geometry with varying the forms of structures like with Outrigger and without outrigger at center of wall are studied and displacement, drift, Storey stiffness are the parameters considered for all geometryof structures.

1. From above study we can observed that the displacement is depending on the geometry ofthe structures.
2. In the present study we can see that all the results obtained are within the limits as per thecodal limitations.
3. The system of outriggers in the structure increases the effectiveness of the structure when compare to structure without outrigger in the action of lateral loads.
4. The structure increases flexural stiffness with providing outrigger, it plays the major role in structure while reducing base shear in static and dynamic loads.
5. The outrigger member increases their sizes, displacement in tall structure system decreases.The shear wall provided at center core with adopting outrigger in tall structure decreases forces in core.
6. The behavior of structure in the seismic loads is various for different structure.
7. The upper storey of structure get reduction in displacement is less compare at outrigger adopted at $1/3^{rd}$ of floors.
8. The outriggers are used various zones as per seismicity.
9. The outriggers are adopted as X-steel bracing as it gives better output on tall structure it minimizes lateral load.
10. The outrigger in tall structure it reduced storey drift.
11. The symmetry and asymmetry of floor its minimized its self-weight of structure.
12. The current research evaluates the variations in the behaviour of the building when an outrigger is employed vs. when it is not.
13. As lateral loads are applied to a structure, the use of an outrigger system improves the efficiency of the building when compared to a building that does not have an outrigger system in place.
14. When seismic static and dynamic stresses operate on a structure, the outrigger plays a critical function in strengthening structural flexural stiffness by lowering base shear.
15. The displacement in the tall building structural system diminishes as the size of the outrigger members rises. The provision of a shear wall at the central core of the structure, in conjunction with the use of outriggers, reduces the stresses in the core.
16. When comparing the outrigger given on the top level of the building to the outrigger provided on the intermediate floors, the displacement reduction on the top floor is smaller.

17. With the use of outriggers in both the regular and irregular building structures, there is a decrease in the amount of time required, which contributes to the overall rigidity of the structure.
18. Because of the strength properties of outriggers, the load-bearing capability of a tall building structure is increased when outriggers are installed.
19. In comparison to the regular construction, the irregular building with vertical floor irregularity as a result of the lower self-weight is more effective.
20. The use of outriggers in tall buildings will help to reduce the amount of inter-storey drift that occurs.
21. Compared to all kinds of geometry in rectangular with outrigger of structure will carry outhigher for lateral loads and hexagonal geometry is the most inclined for lateral loads.
22. For quarter-IV from results received in evaluation is more compare to all other systems sothis geometry of shape isn't always advocated and we have become glad effects consistent with codal calculations of geometry of structure considered for analysis.

23. Comparing to all geometry of structures rectangular gives surest outcomes so this type of geometry is greater suitable to region-I