International Journal of Engineering Science Invention (IJESI)
ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726
www.ijesi.org ||Volume 8 Issue 05 Series. III || May 2019 || PP 16-35

Performance of Dual-Outrigger Structural System in Geometrically Irregular Shaped High-Rise Building

N.G. Gore[1], S. K. Ukarande[2]
[1](*Asst Professor, Department of Civil Engineering, MGM's College of Engineering & Technology, Navi Mumbai, University of Mumbai, India)*
[2](*Principal, K J Somaiya Institute of Engineering and Information Technology, Sion, University of Mumbai, India)*
Corresponding Author: N.G. Gore

Abstract : *The evolution of tall building has been enlarging worldwide and brings up various challenges. When building height increases, the stiffness of the structure largely reduces. For lateral load resisting outrigger system is very much effective to control the lateral Drift. Thus, to boost the performance of the structure under various lateral loading such as in wind or earthquake outrigger structural system plays very efficient role.In present paper an investigation has been focused on performance of dual outrigger structural system in geometrically irregular shaped building. Static and dynamic behavior of 70 storey irregular shaped building with different outrigger configurations was analyzed by using ETABS Software. Wind analysis and Response spectrum method was carried out. The Parameters discussed in this paper include Storey Displacement, Storey Drift, Base shear, Base moment, Time period and Torsion for static and dynamic behaviour of different outrigger configurations.*

Keywords*-Outrigger, Belt truss, Response Spectrum Method, Geometry irregularity, High-Rise Building.*

Date of Submission: 05-05-2019 Date of acceptance: 20-05-2019

I. INTRODUCTION

Nowadays tall buildings become taller and higher due to less availability of space in metro cities due to increasing population. Due to lesser space and higher land rates high rise building is the only feasible solution to accommodate the demands of developing cities.

But in India various developed cities lie in seismically active regions. Effect of lateral forces such as wind and earthquake become more crucial in design of high-rise frames due to its higher heights. Hence special systems shall be developed for resisting such lateral forces in addition to gravity loads in tall buildings. After study it is observed that there are various lateral load resisting structural systems are employed for designing the high-rise building projects

1.1. Outrigger Structural System

In lateral load resisting structural system outrigger system works efficiently for lateral forces. Basically, in outrigger structural system, central core wall of structure and peripheral columns are connected with a rigid beam which is either in form of deep RCC beam or steel truss. Often in a building there could be some architectural constraints and it is difficult to provide outrigger beam which might obstruct the planning at that time it will be suitable to provide belt truss instead of conventional outriggers

Belt truss is basically a rigid RCC beam or Steel truss which connects all the peripheral columns so as to engage them in unison to resist lateral movements.This lateral load resisting system is used to control excessive story drift due to lateral loads generated either by wind or earthquake.

1.2. Concept of Outrigger

The outrigger concept was originally derived from sailing canoe which runs on wind pressure during its journey in sea. Sometimes even in the high storm these sailing ship withstand to its position. Similarly, tall building can withstand to high lateral load by introducing outrigger in structure.

If we compare the element of sailing ship and building then Central core wall of building behave like a vertical mast of the sailing ship. And outrigger beam or truss is act like a spreader. Similarly, peripheral columns are representing the shrouds of sailing ship. This phenomenon has a great potential to be employed in tall buildings.

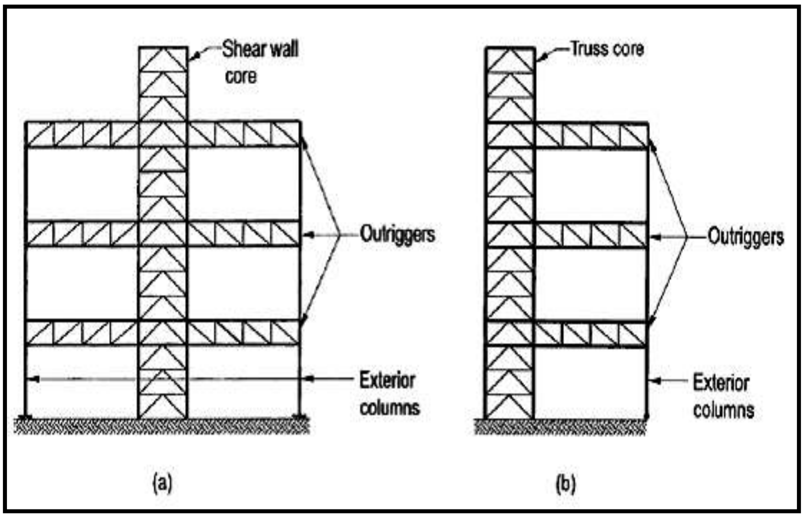


Fig. 1. Outrigger Structural System

1.3 Behaviour of Outrigger

The provision of outrigger structural system comprises of central core wall (i.e. lift shear wall) connected to the peripheral columns by single or double storey deep beam in case of RCC structure or sometime steel truss of that particular storey height is provided. This deep beam or steel truss is commonly referred as outrigger.

The working principle of outrigger structural system is very simple. When lateral loading either wind or earthquake load applied on the structure the rotation of central core wall is reduced due to the originating of axial forces in peripheral columns. Specifically, Tensile force is developed in windward columns and similarly compressive force will develop in leeward columns.

The result is the bending moment at a specific location where outrigger beam is provided is drastically reduced. As shown in fig.2. For restraining the rotation of outriggers peripheral columns are also connected.

This can be possible by connecting the all peripheral columns with steel truss which is generally referred as belt truss or sometime single or double storey deep wall around the structure. Sometime it referred as "belt wall".

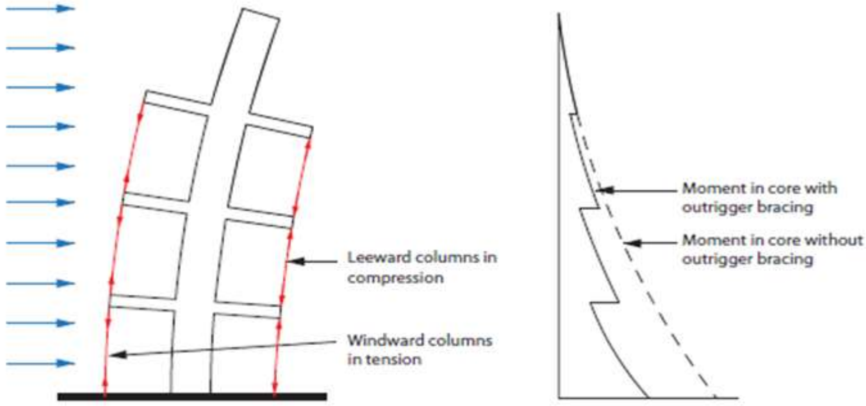


Fig. 2. Behaviour of Outrigger

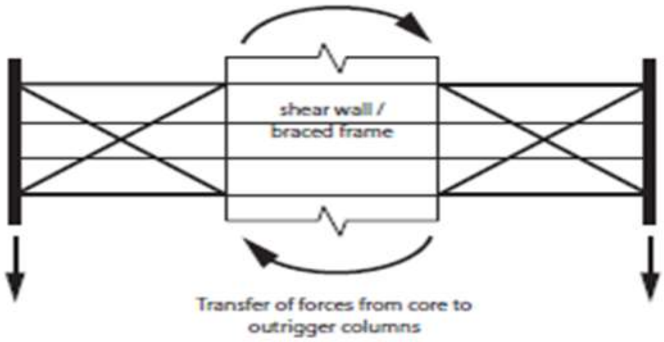


Figure 3. Behaviour of Outrigger

II. OBJECTIVES OF RESEARCH

1. Finite Element models of reinforced concrete multistoried building prototypes with geometrically irregular and unsymmetrical L shaped plan layouts with different outrigger configurations are modelled in ETABS.
2. To perform Static analysis of Geometrically irregular L shaped building models for earthquake analysis as per IS 1893 (Part 1) 2002
3. To perform Dynamic analysis of geometrically irregular L shaped building models by response spectrum method using software ETABS. Furthermore, Dynamic analysis for earthquake assessment shall be performed by response spectrum method.
4. To determine the optimum location of belt-truss and outriggers arrangement by comparison of results for static and dynamic actions.
5. To perform a parametric study which include Storey Displacement, Storey Drift, Base Shear, Base Moment, Time Period and Torsion.

III. MODELS CONSIDERED FOR ANALYSIS

In current study, three-dimensional G+70 storied building with plan dimension 108.5 m x 106m are modelled (Fig 4). The typical floor height is 3.5m giving a total height of 252m. The beams, columns and shear walls are modelled as RC elements and outrigger is modelled as structural steel truss. Column and beam sizes considered in the analysis are 1200mm x 1200mm and 600mm x 800mm respectively.
A total 9 Different outrigger configurations by varying the position has been modelled and analyzed.

1. M1 Without outrigger
2. M2 Outrigger at top
3. M3 Outrigger at top and 0.4 H
4. M4 Outrigger at top and 0.45 H
5. M5 Outrigger at top and 0.5 H
6. M6 Outrigger at top and 0.55 H
7. M7 Outrigger at top and 0.6 H
8. M8 Outrigger at top and 0.65 H
9. M9 Outrigger at top and 0.7 H

Where, H is the height of building

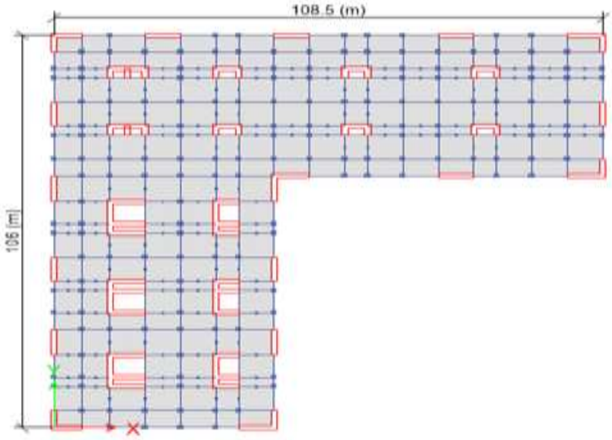


Fig.4. Typical Plan of Building

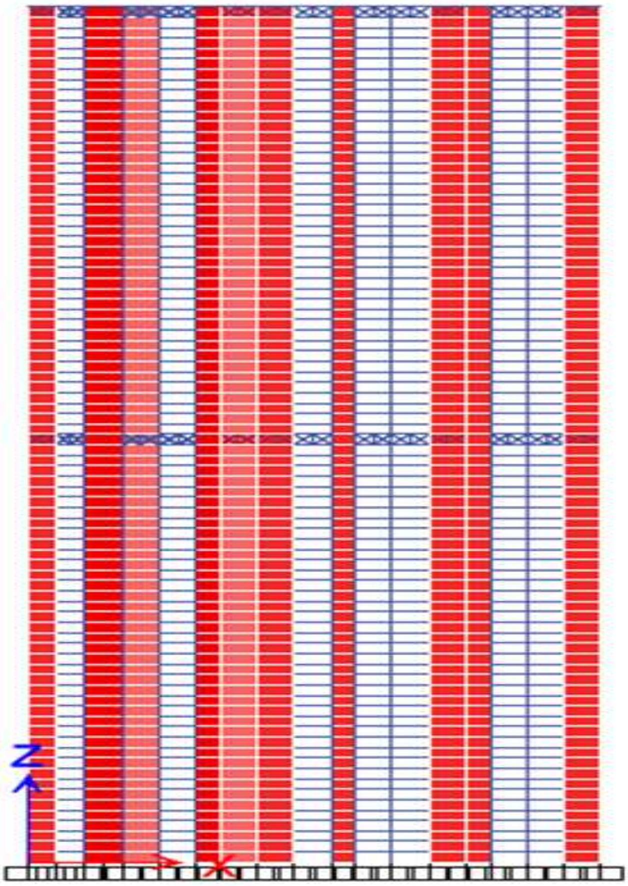


Fig.5. Elevation (Model No 5- OUTRIGGER AT Top & 0.5H i.e. height of building)

The assumptions behind modelling this system are that the connection between shear wall core and foundation is rigid. The outrigger truss is rigidly connected to the stiff core on one side and simply supported on the peripheral column other side. Simple support condition is achieved through releasing major and minor moments (M33 & M22) of truss element at the peripheral column junction such that bending moments are not transferred and only axial thrust is exerted to the columns. The columns are sized and shall be designed such that it can safely carry the extra axial force (weather compression or tension) caused due to outriggers. The material behavior for analysis is considered to be linearly elastic. The outrigger trusses are kept very stiff so as to act as a rigid arm to transfer moments of core to the external column with minimum loss of forces due to distortion and flexure of outrigger itself.

IV. LOAD CONSIDERATION & ANALYSIS OF THE FRAME

Equivalent static analysis method as per IS code is employed for assessing the static behavior of the models. Response spectrum and Wind analysis methods are employed to assess the linear dynamic behavior of the models. Basic wind speed is selected from wind data of Mumbai region.

Finite element software ETABS is used to carry out the above-mentioned analysis. In ETABS, shear walls and slabs are modelled as four nodded thin shell elements with default auto meshing. Beams, columns and truss elements are modelled as two nodded line elements. In addition, the truss members are released for moments on both of its ends to get exclusive axial brace behavior. Semi rigid diaphragm is assigned to all the floor elements to engage all columns in resisting lateral forces.

Loading:

- For slabs, of 1.5kN/m2 floor finish load and 4kN/ m2 of live load is considered as per IS-875 part 2 for commercial buildings.
- For beams, uniform line load of 6kN/ m2 load is considered for partition walls made up of light weight blocks.
- From IS 1893 (PART-1) 2002 seismic load is considered. The following parameters have been considered for seismic analysis-

Seismic Zone = Zone IV (Z= 0.24)
Importance Factor = 1.0
Type of Soil = Medium Soil (Soil Type II)
Response Reduction Factor = IV
Damping Ratio = 5%
Wind speed = 44 m/s
Diaphragm = Semi Rigid

As per IS: 875 (part 5), load combinations are considered and structure is analysed.

1.5(DL + LL)
1.2(DL + LL + EQX)
1.2(DL + LL - EQX)
1.2(DL + LL + EQY)
1.2(DL + LL - EQY)
1.5(DL+ EQX)
1.5(DL - EQX)
1.5(DL+ EQY)
1.5(DL - EQY)
0.9DL + 1.5EQX
0.9DL - 1.5EQX
0.9DL + 1.5EQY
0.9DL - 1.5EQY

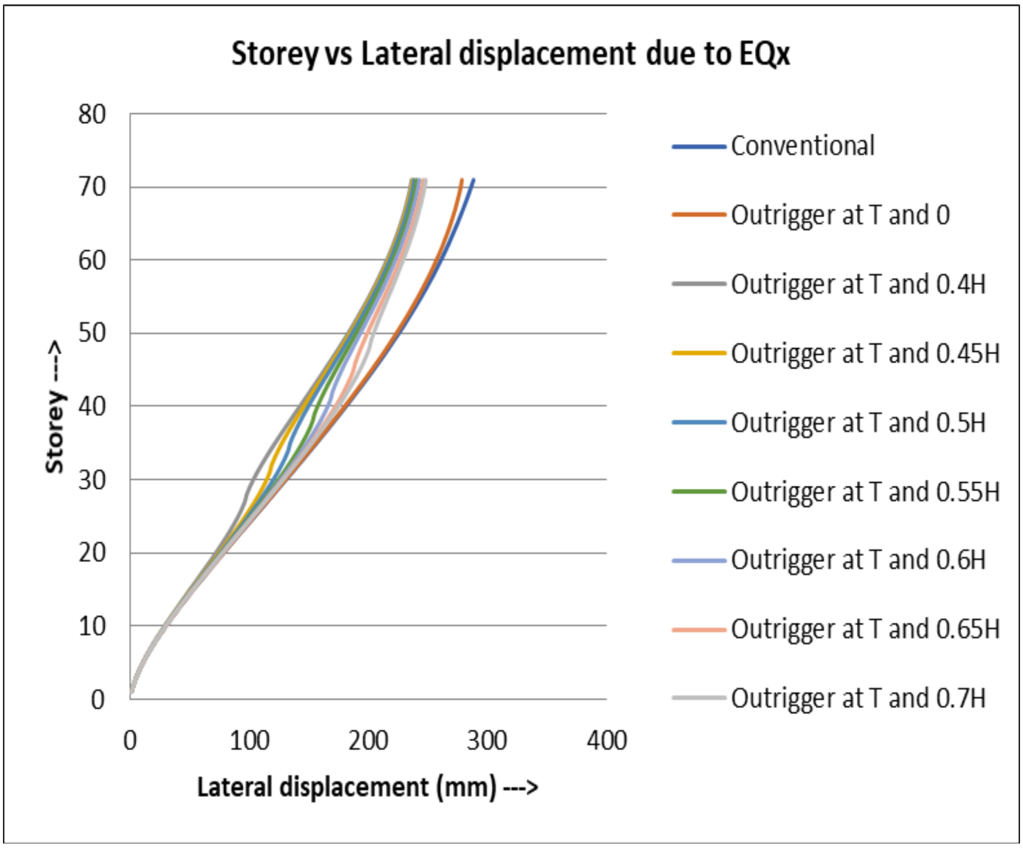
V. RESULTS AND DISCUSSIONS

G+70 storey building is studied and following parameters are discussed which includes variation of Storey Displacement, Storey Drift, Base shear, Base moment, Time period and Torsion for static and dynamic behaviour of different outrigger configurations.

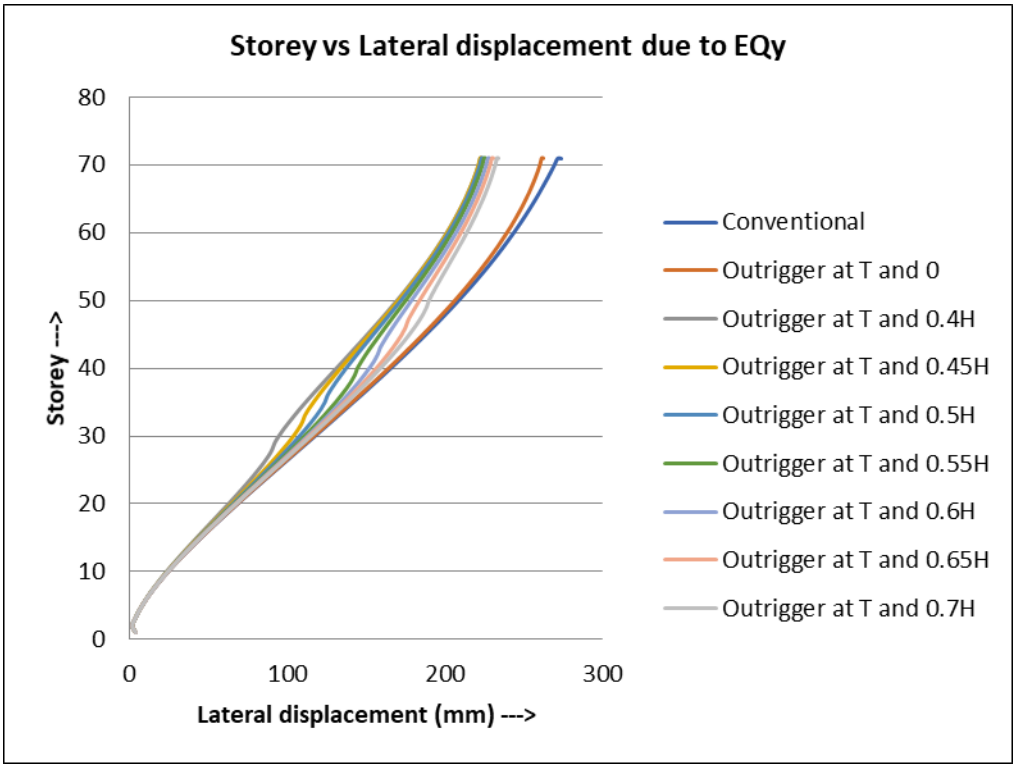
5.1 Storey Displacement

Graph 1 to 8 shows profiles for variation in storey displacement as well as graph 9 shows variation of top storey displacement in different outrigger configurations for equivalent static analysis, response spectrum analysis, wind analysis and gust factor analysis. From result obtained in Table no.1 maximum reduction is observed for M3 model where outrigger is provided at top and 0.4H i.e. height of the building. The reduction in top storey displacement observed is as follow

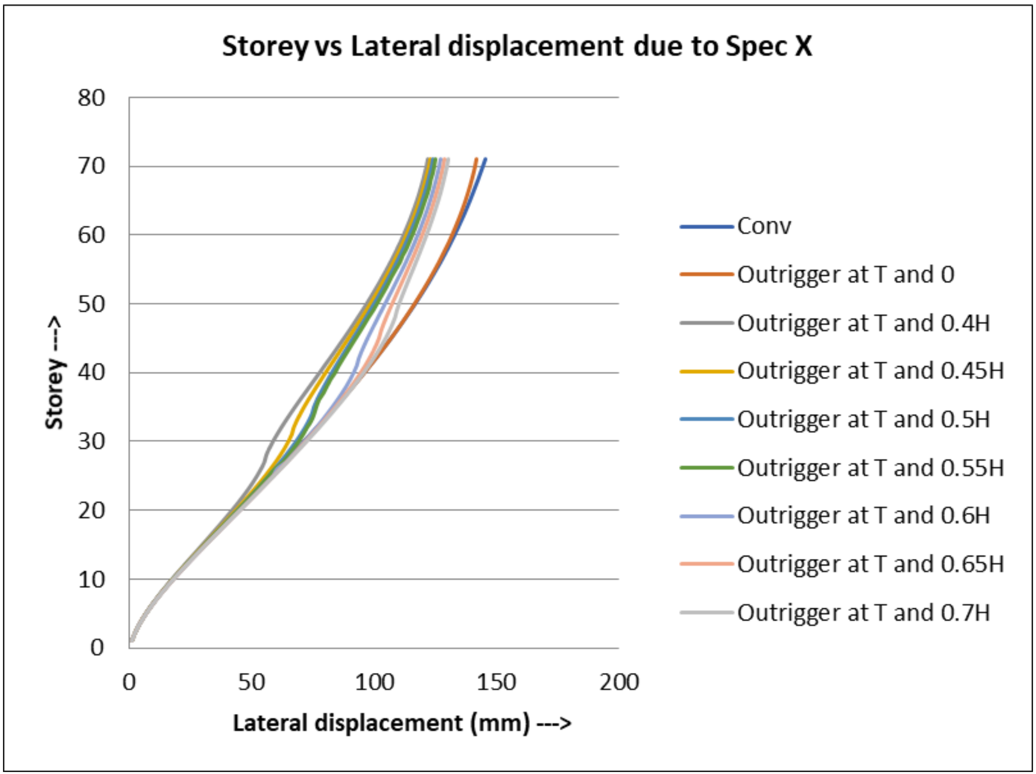
1. 18.13% in X-direction and 18.46% in Y-direction for Equivalent Static analysis.
2. 16.39% in X-direction and 19.64% in Y-direction for Response Spectrum analysis
3. 18.56% in X-direction and 18.11% in Y-direction for Wind analysis
4. 18.82% in X-direction and 19.22% in Y-direction for Gust Factor analysis



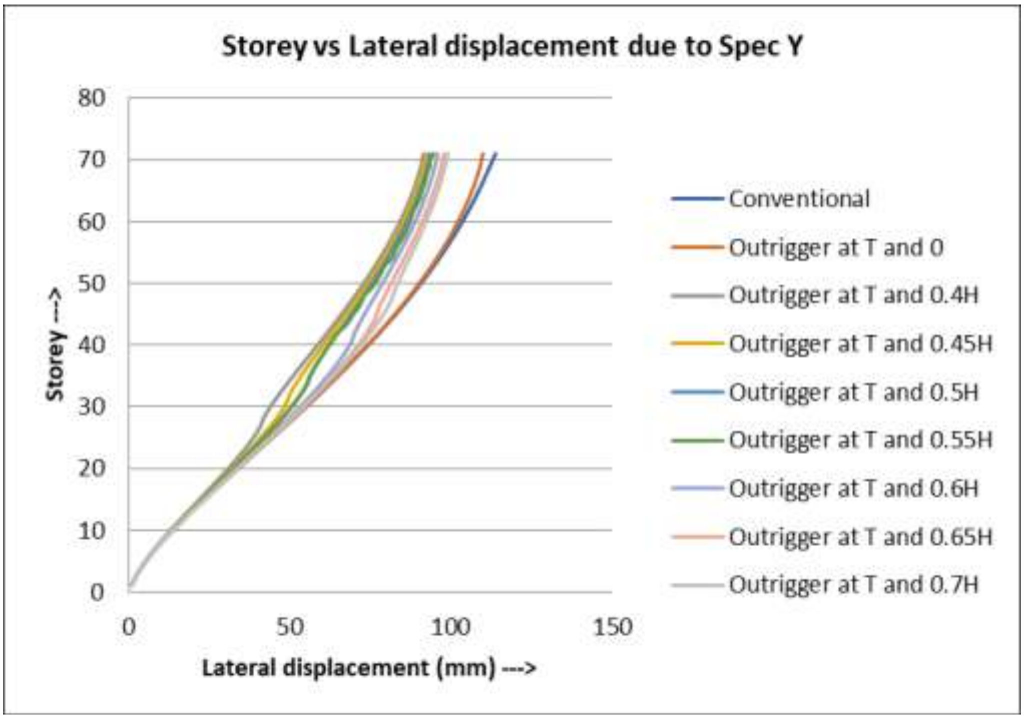
Graph 1. Equivalent Static Analysis (X Direction)



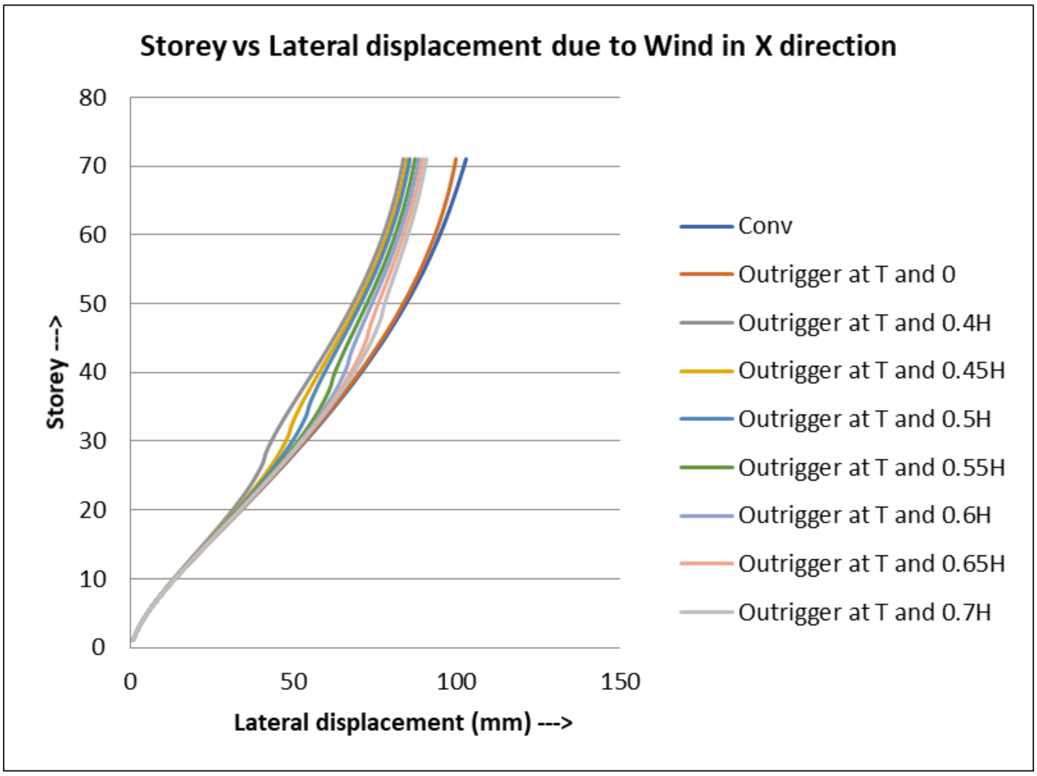
Graph 2. Equivalent Static Analysis (Y Direction)



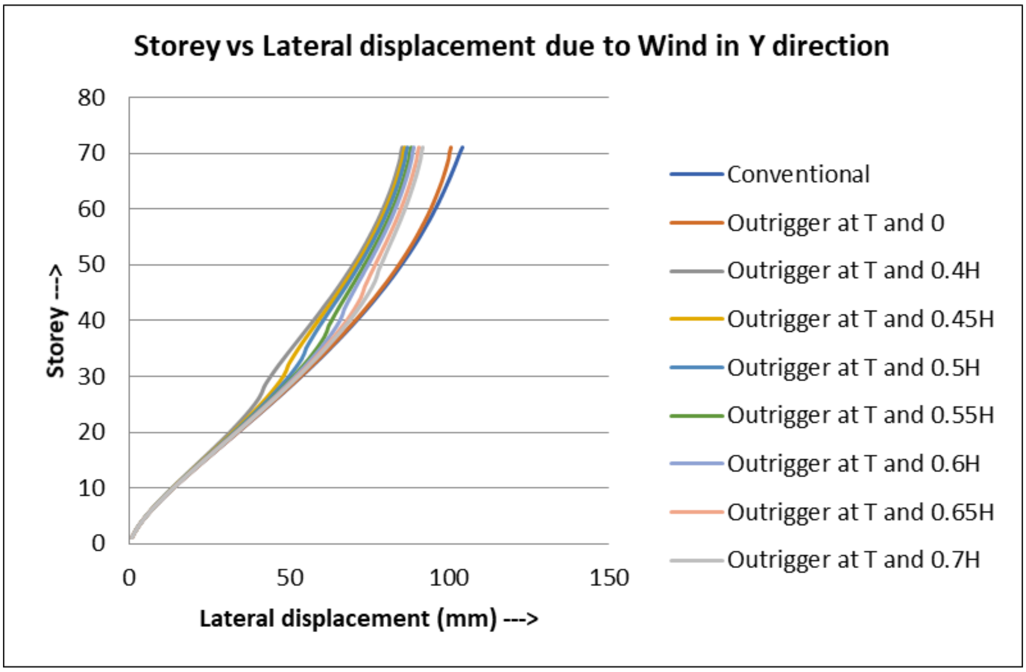
Graph 3. Response Spectrum Analysis (X Direction)



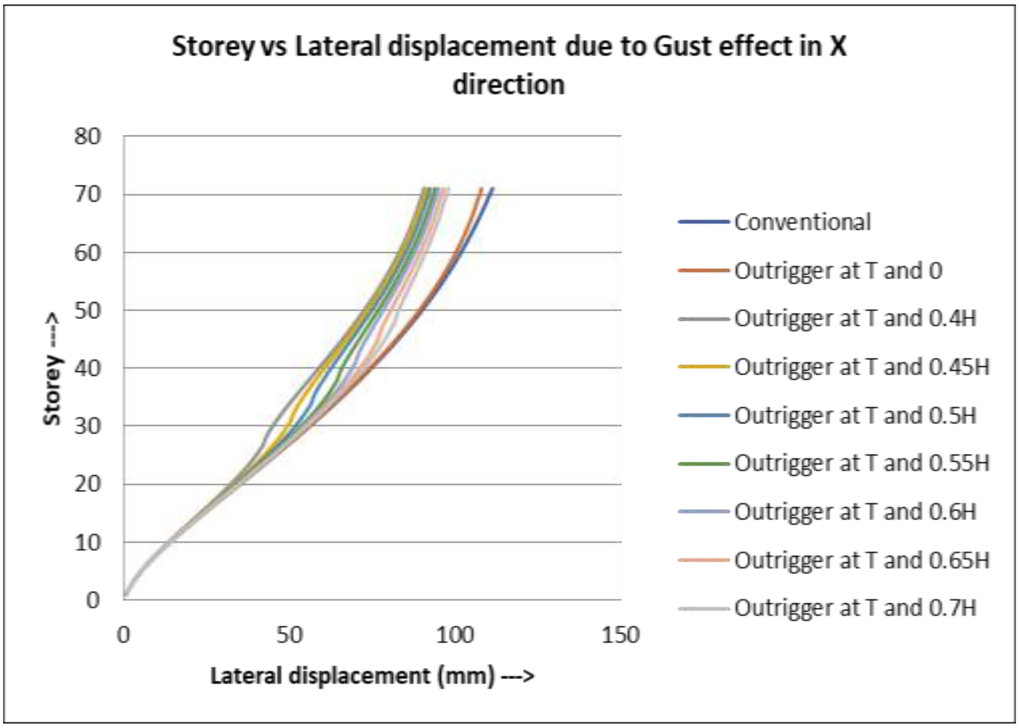
Graph 4. Response Spectrum Analysis (Y Direction)



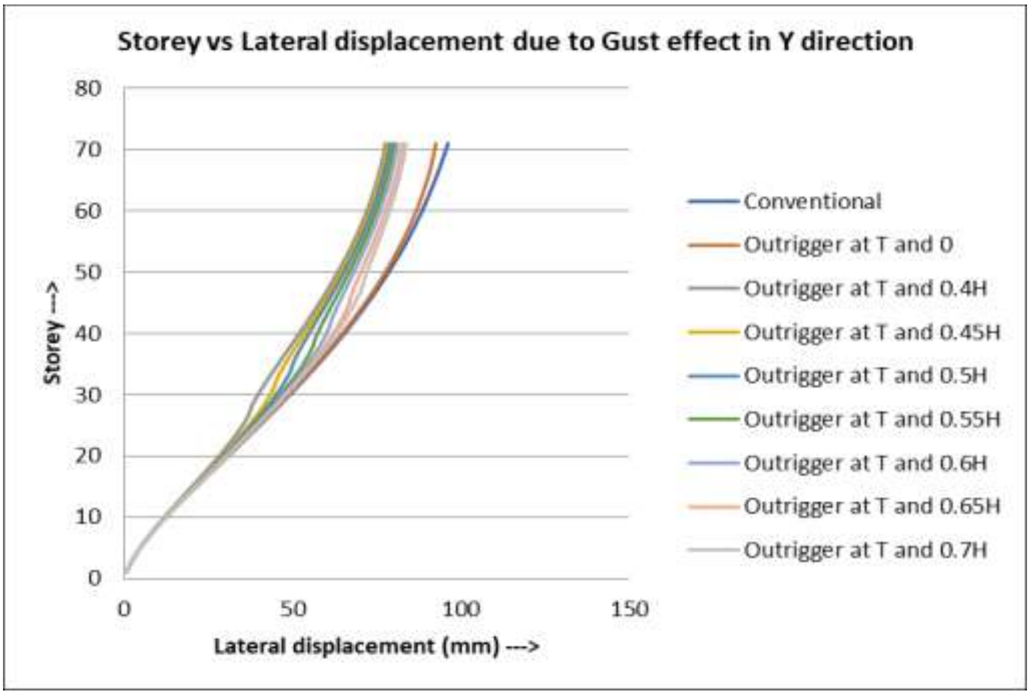
Graph 5. Wind Analysis (X Direction)



Graph 6. Wind Analysis (Y Direction)



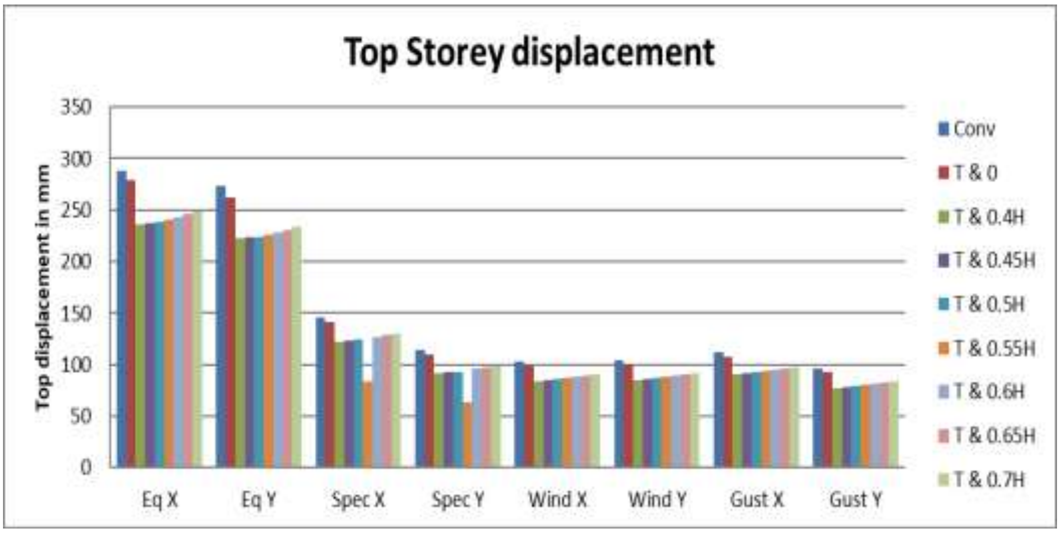
Graph 7. Gust Factor Analysis (X Direction)



Graph 8. Gust Factor Analysis (Y Direction)

Table -1: Percentage Reduction in Top Storey Displacement with Different Outrigger Configuration (Equivalent Static Analysis, Response Spectrum Analysis, Wind Analysis and Gust Factor Analysis in X and Y Direction)

Top Storey Displacement										
		Conv	T & 0	T & 0.4H	T & 0.45H	T & 0.5H	T & 0.55H	T & 0.6H	T & 0.65H	T & 0.7H
Eq X (mm)		288.5	278.76	236.2	237.078	238.257	240.454	242.544	245.901	248.86
Eq Y (mm)		273.334	262.4	222.879	223.239	224.094	225.939	227.811	230.915	233.69
Spec X (mm)		145.632	141.947	121.761	123.21	124.341	83.939	127.142	128.874	130.258
Spec Y (mm)		113.878	109.867	91.516	92.457	93.358	63.178	95.955	97.67	99.043
Wind X (mm)		103.007	99.898	83.885	84.92	85.833	87.176	88.253	89.755	90.917
Wind Y (mm)		104.271	100.564	85.391	86.188	86.952	88.133	89.113	90.508	91.604
Gust X (mm)		111.513	107.973	90.525	91.563	92.504	93.912	95.055	96.665	97.925
Gust Y (mm)		96.012	92.581	77.554	78.273	78.996	80.146	81.115	82.513	83.622
% Reduction in Top Storey Displacement	Eq X		3.38 %	18.13 %	17.82 %	17.42 %	16.65 %	15.93 %	14.77 %	13.74 %
	Eq Y		4 %	18.46 %	18.33 %	18.01 %	17.34 %	16.65 %	15.52 %	14.50 %
	Spec X		2.53 %	16.39 %	15.40 %	14.62 %	42.36 %	12.70 %	11.51 %	10.56 %
	Spec Y		3.52 %	19.64 %	18.81 %	18.02 %	44.52 %	15.74 %	14.23 %	13.03 %
	Wind X		3.02 %	18.56 %	17.56 %	16.67 %	15.37 %	14.32 %	12.87 %	11.74 %
	Wind Y		3.56 %	18.11 %	17.34 %	16.61 %	15.48 %	14.54 %	13.20 %	12.15 %
	Gust X		3.17 %	18.82 %	17.89 %	17.05 %	15.78 %	14.76 %	13.32 %	12.19 %
	Gust Y		3.57 %	19.22 %	18.48 %	17.72 %	16.53 %	15.52 %	14.06 %	12.90 %



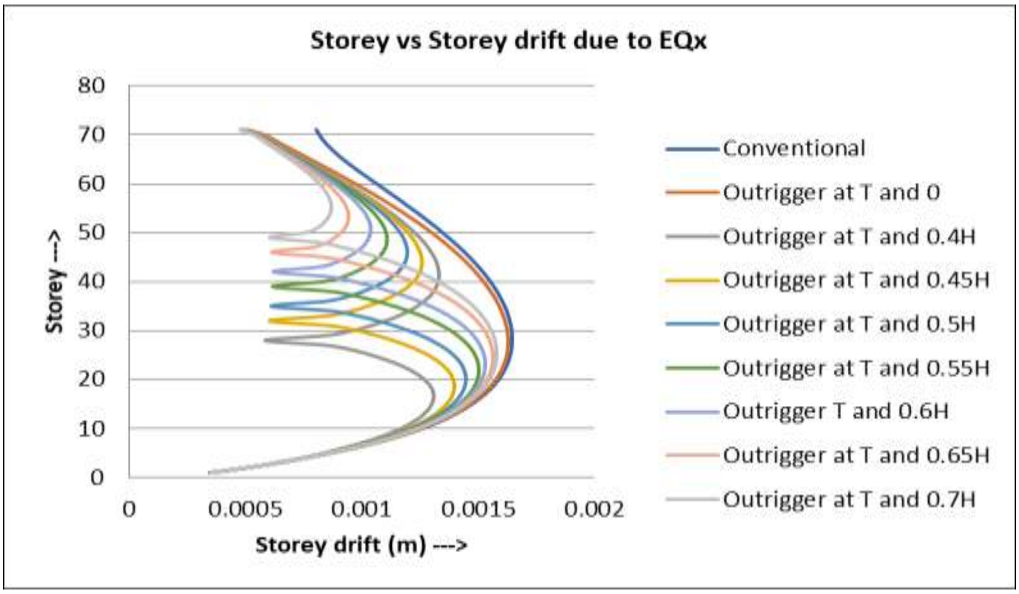
Graph 9. Top Storey Displacement

5.2. Storey Drift

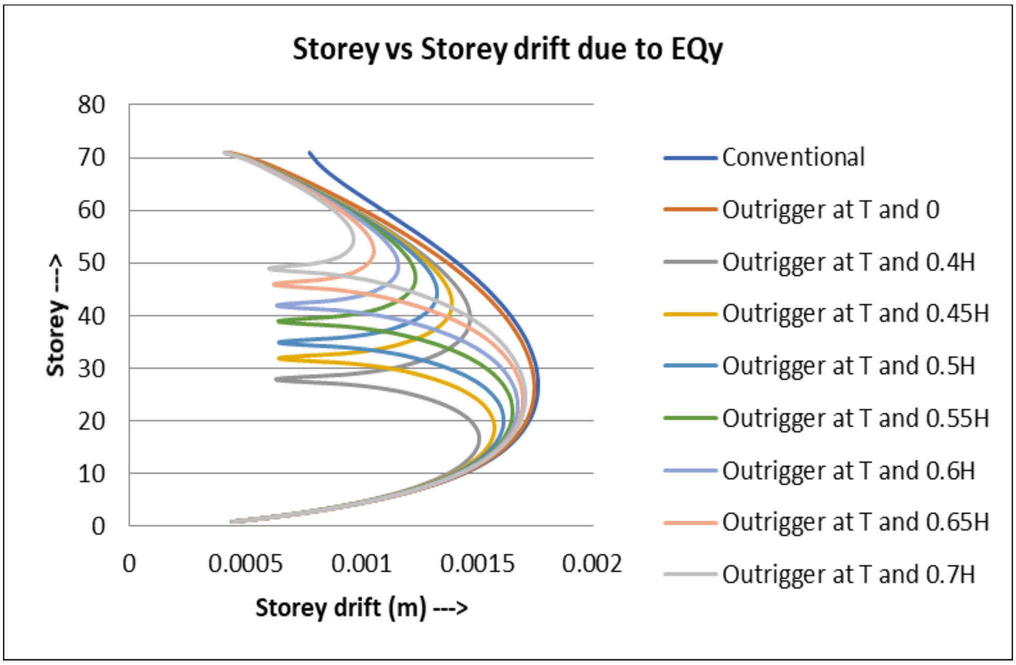
Graph 10 to 17 shows profiles for variation in storey drift as well as graph 18 shows variation of maximum storey drift in different outrigger configurations for equivalent static analysis, response spectrum analysis, wind analysis and gust factor analysis.It can be observed from graphs in chart 10to15, the sudden change or drop in story drift is due to high stiffness in wall at those outrigger stories due to presence of stiff trussed which restricts rotation of walls. From result obtained in Table no.2 maximum reduction in drift is observed for M3 model where outrigger is provided at top and 0.4H i.e. height of the building. The reduction in maximum storey drift observed is as follow

1. 18.86% in X-direction and 14.41% in Y-direction for Equivalent Static analysis.
2. 15.76% in X-direction and 9.82% in Y-direction for Response Spectrum analysis

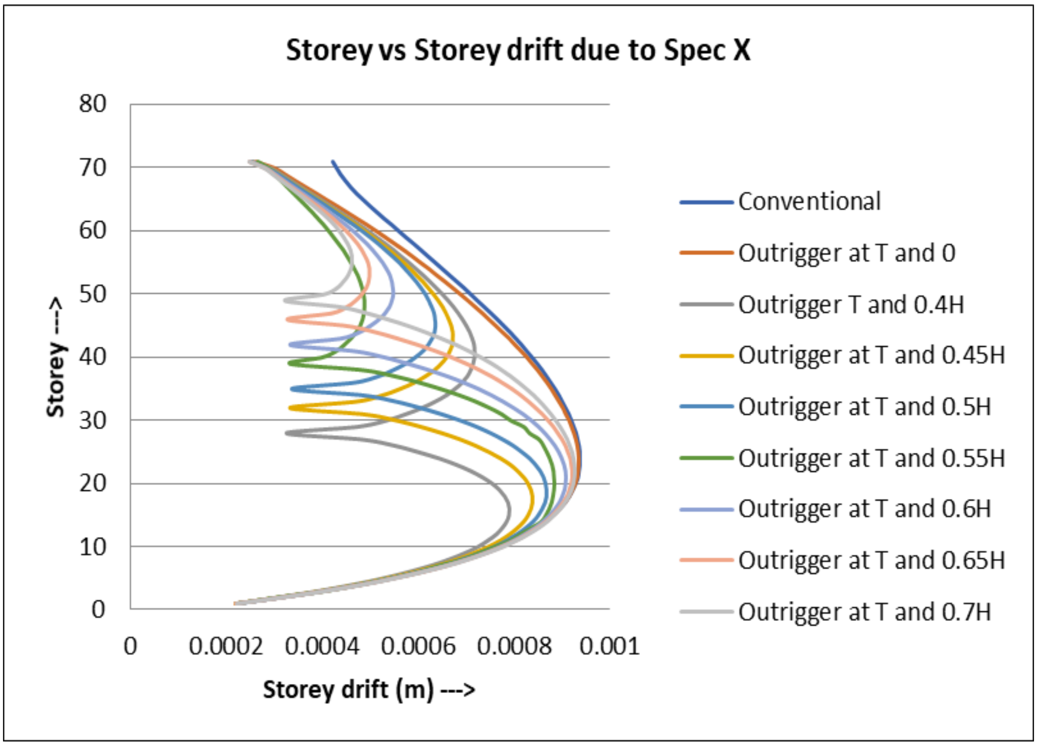
3. 12.01% in X-direction and 7.63% in Y-direction for Wind analysis
4. 11.78% in X-direction and 14.11% in Y-direction for Gust Factor analysis



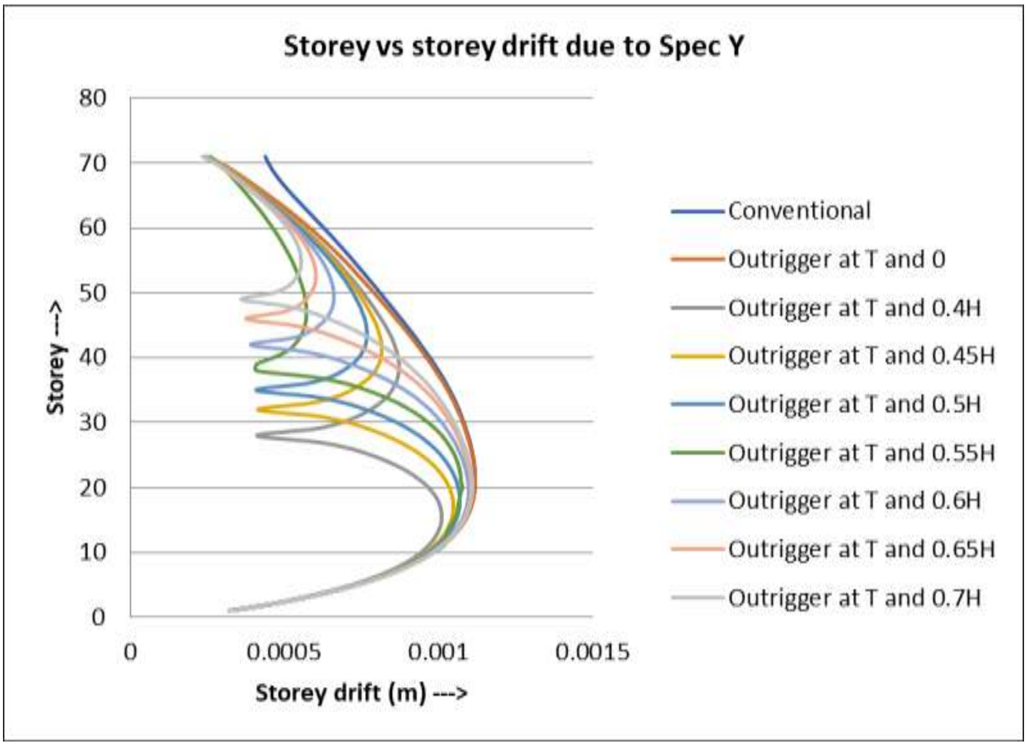
Graph 10. Equivalent Static Analysis (X Direction)



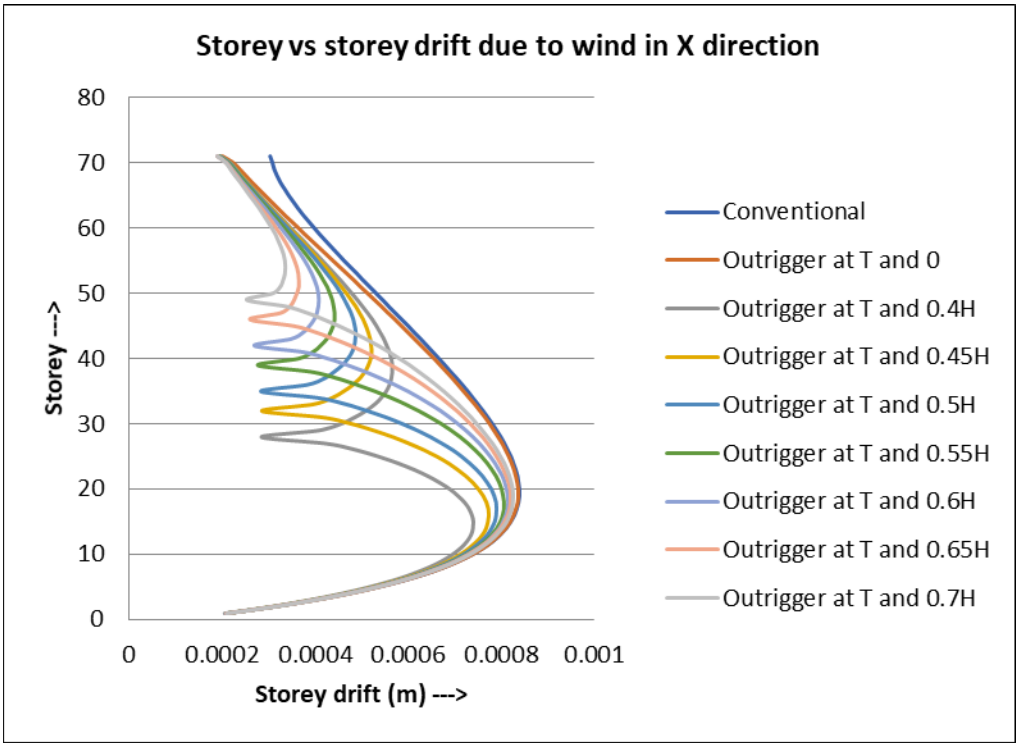
Graph 11. Equivalent Static Analysis (Y Direction)



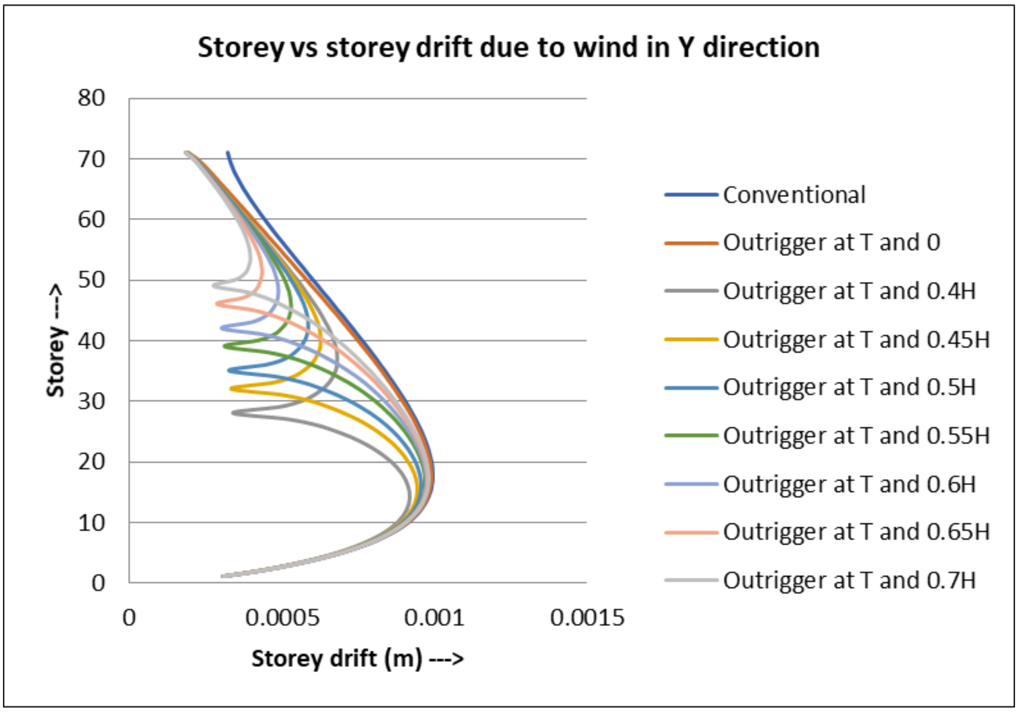
Graph 12. Response Spectrum Analysis (X Direction)



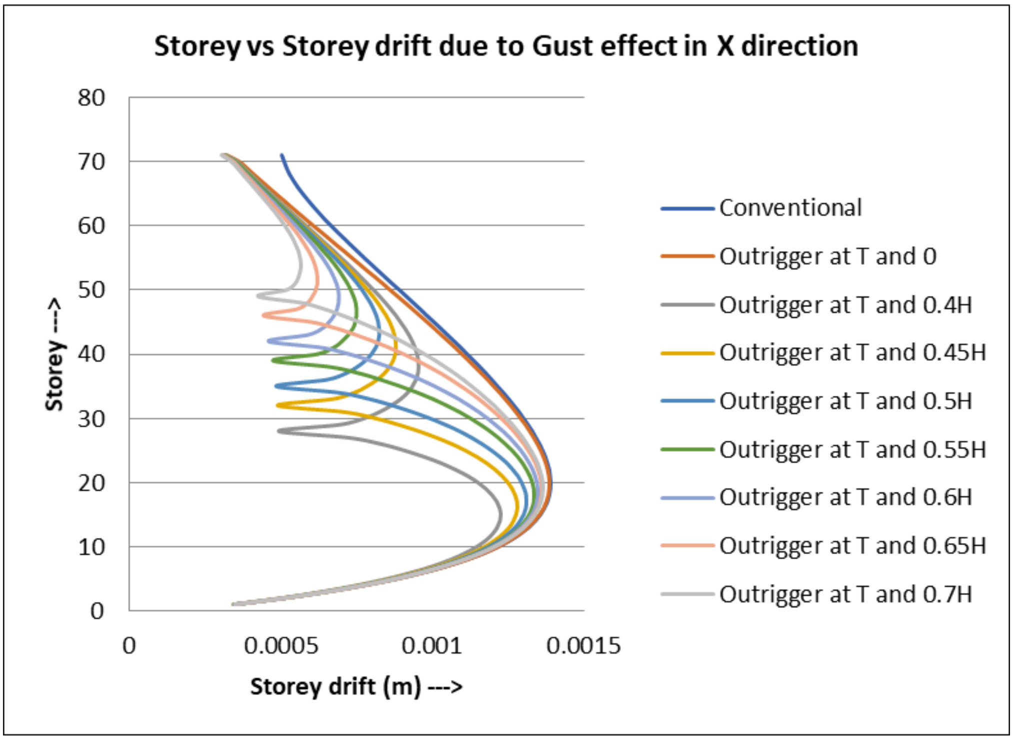
Graph 13. Response Spectrum Analysis (Y Direction)



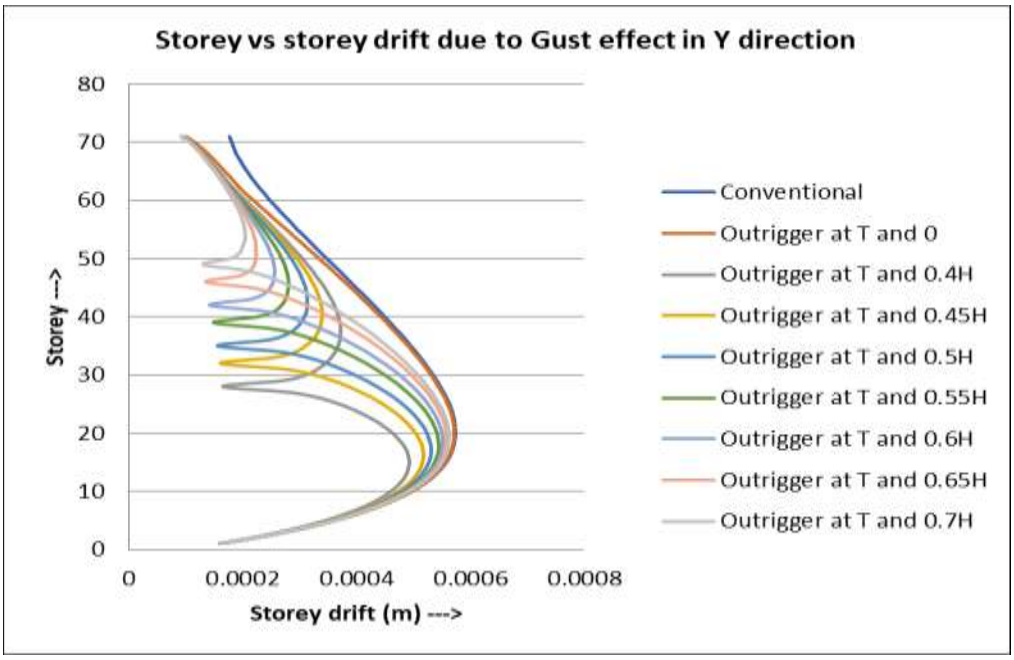
Graph 14. Wind Analysis (X Direction)



Graph 15. Wind Analysis (Y Direction)



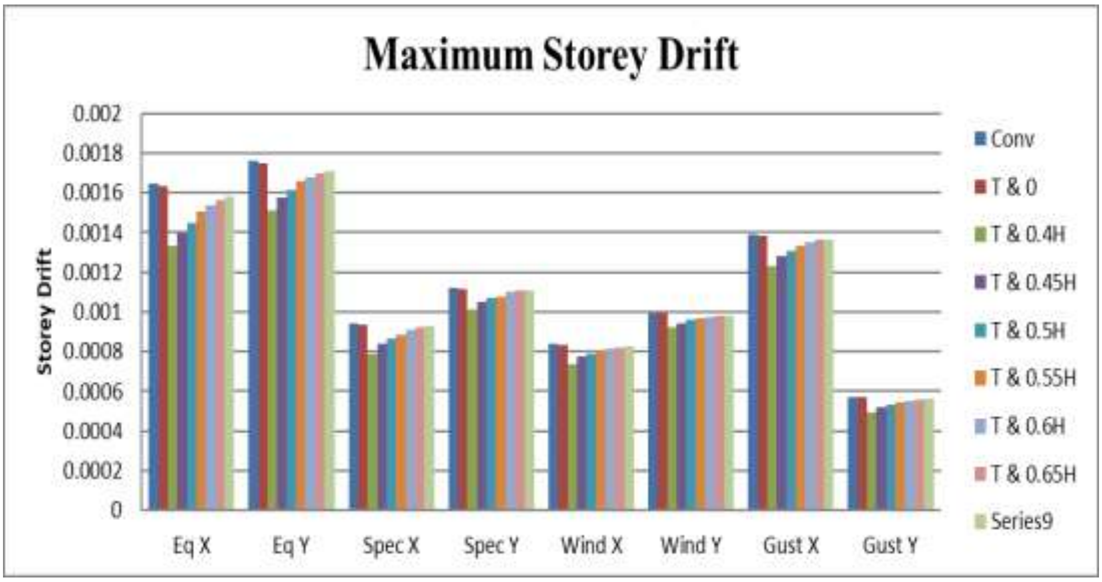
Graph 16. Gust Factor Analysis (X Direction)



Graph 17. Gust Factor Analysis (Y Direction)

Table -2: Percentage Reduction in maximum Storey Drift with Different Outrigger Configuration (Equivalent Static Analysis, Response Spectrum Analysis, Wind Analysis and Gust Factor Analysis in X and Y Direction)

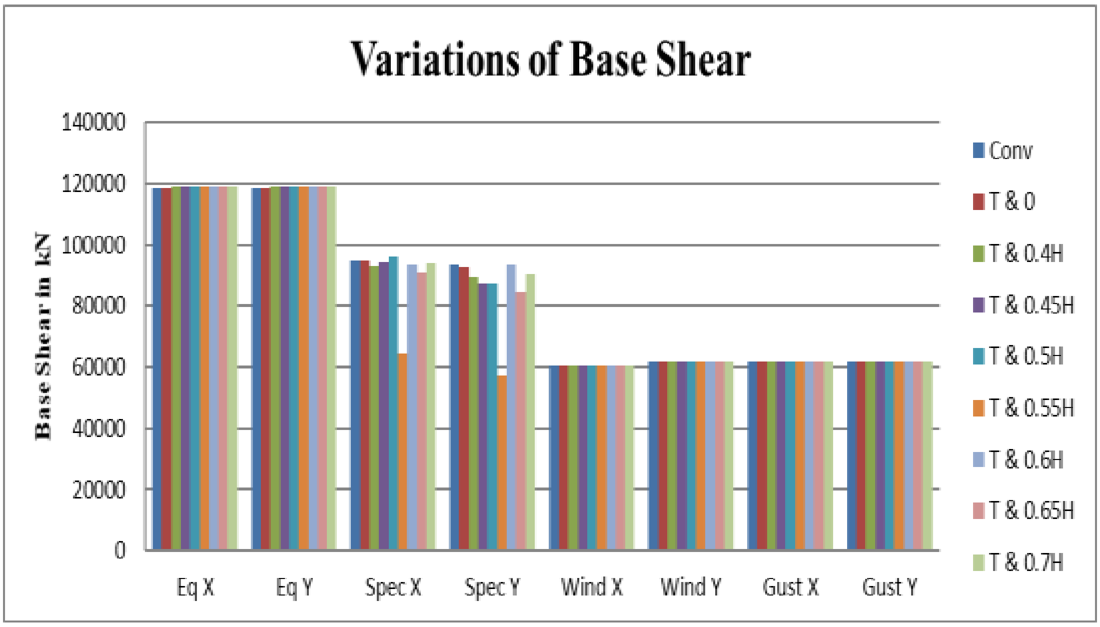
Maximum Storey Drift									
	Conv	T & 0	T & 0.4H	T & 0.45H	T & 0.5H	T & 0.55H	T & 0.6H	T & 0.65H	T & 0.7H
Eq X	0.001644	0.00163	0.001334	0.001398	0.00145	0.001503	0.001534	0.001564	0.001581
Eq Y	0.001763	0.001749	0.001509	0.001578	0.001616	0.001655	0.001676	0.001697	0.001708
Spec X	0.000939	0.000936	0.000791	0.000839	0.000867	0.000886	0.000909	0.000922	0.000928
Spec Y	0.00112	0.001117	0.00101	0.001049	0.00107	0.001075	0.001099	0.001107	0.001111
Wind X	0.000841	0.000836	0.00074	0.000773	0.00079	0.000806	0.000814	0.000821	0.000825
Wind Y	0.000996	0.000992	0.00092	0.000945	0.000958	0.000968	0.000974	0.000979	0.000982
Gust X	0.001392	0.001385	0.001228	0.001281	0.001309	0.001335	0.001348	0.001361	0.001367
Gust Y	0.000574	0.000571	0.000493	0.000517	0.000531	0.000544	0.000551	0.000558	0.000562
% Reduction in Maximum Storey Drift	Eq X	0.85 %	18.86 %	14.96 %	11.80 %	8.58 %	6.69 %	4.87 %	3.83 %
	Eq Y	0.79 %	14.41 %	10.49 %	8.34 %	6.13 %	4.93 %	3.74 %	3.12 %
	Spec X	0.32 %	15.76 %	10.65 %	7.67 %	5.64 %	3.19 %	1.81 %	1.17 %
	Spec Y	0.27 %	9.82 %	6.34 %	4.46 %	4.02 %	1.88 %	1.16 %	0.80 %
	Wind X	0.59 %	12.01 %	8.09 %	6.06 %	4.16 %	3.21 %	2.38 %	1.90 %
	Wind Y	0.40 %	7.63 %	5.12 %	3.82 %	2.81 %	2.21 %	1.71 %	1.41 %
	Gust X	0.50 %	11.78%	7.97 %	5.96 %	4.09 %	3.16 %	2.23 %	1.80 %
	Gust Y	0.52 %	14.11 %	9.93 %	7.49 %	5.23 %	4.01 %	2.79 %	2.09 %



Graph 18. Top Storey Drift

5.3 BaseShear

Graph 19 and tableNo.3 showsvariation of base shear in different outrigger configurations for Equivalent static analysis, Response Spectrum analysis,Windanalysis and Gust Factor analysis in X and Y Direction.And from Graph 19 it is observed that there is no significant variation of base shear values with provision of different outrigger configurations.



Graph 19. Base Shear graph with Different Outrigger Configuration (Equivalent Static Analysis, Response Spectrum Analysis Wind Analysis and Gust Factor Analysis - X& Y Direction)

Table 3. Base Reactions (in kN) for Different Outrigger Configuration (Equivalent Static Analysis, Response Spectrum Analysis, Wind Analysis and Gust Factor Analysis- X &Y Direction)

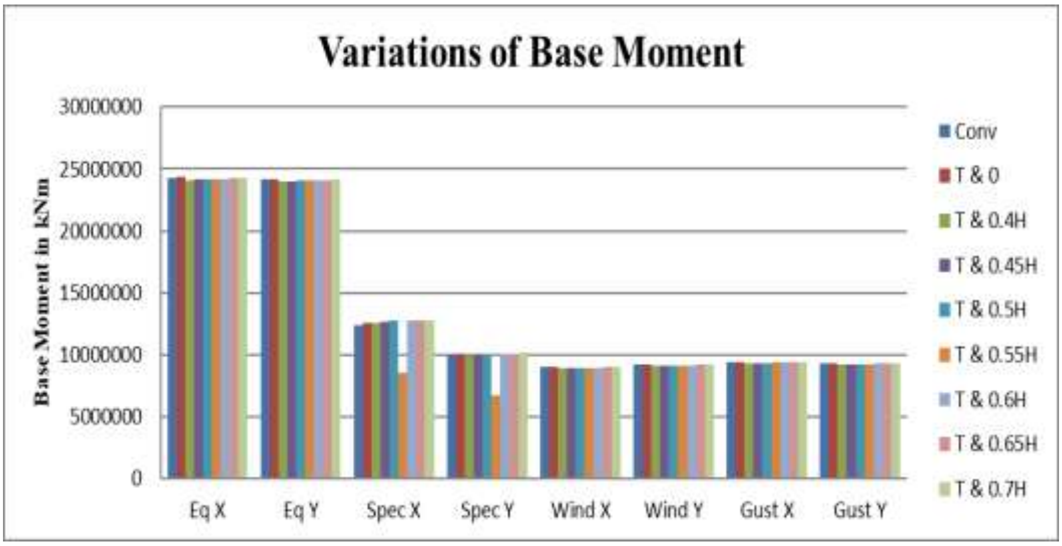
	Conv kN	T & 0 kN	T & 0.4H kN	T & 0.45H kN	T & 0.5H kN	T & 0.55H kN	T & 0.6H kN	T & 0.65H kN	T & 0.7H kN
Eq X	118433	118705	118977	118977	118977	118977	118977	118977	118987
Eq Y	118433	118705	118977	118977	118977	118977	118977	118977	118987
Spec X	95105	94689	93259	94332	96448	64330	93462	90882	94180
Spec Y	93682	92779	89329	87085	87497	57527	93462	34756	90227
Wind X	60480	60480	60480	60480	60480	60480	60480	60480	60480
Wind Y	61906	61906	61906	61906	61906	61906	61906	61906	61906
Gust X	61771	61771	61771	61771	61771	61771	61771	61771	61771
Gust Y	61771	61771	61771	61771	61771	61771	61771	61771	61771

Above graphs indicate that, there is no significant difference in base shear values among different models due to addition of outriggers. Reason behind that is, the outrigger doesn't significantly increase the seismic weight of the building and as per the codal philosophies the seismic inertial forces are directly proportional to the weight of the building. So, no increase in weight results in no increase in base shears.

However, in case of response spectrum results few variations could be observed but they are due to the random nature of ground motions and its variable effect on various frames and floor stiffness.

5.4 Base Moments

Graph 20 and table No.4 shows variation of base moments in different outrigger configurations for Equivalent static analysis, Response Spectrum analysis, Wind analysis and Gust Factor analysis in X and Y Direction. And from Graph 19 it is observed that there is no significant variation of base shear values with provision of different outrigger configurations



Graph 20. Base Moment graph with Different Outrigger Configuration (Equivalent Static Analysis, Response Spectrum Analysis Wind Analysis and Gust Factor Analysis - X & Y Direction)

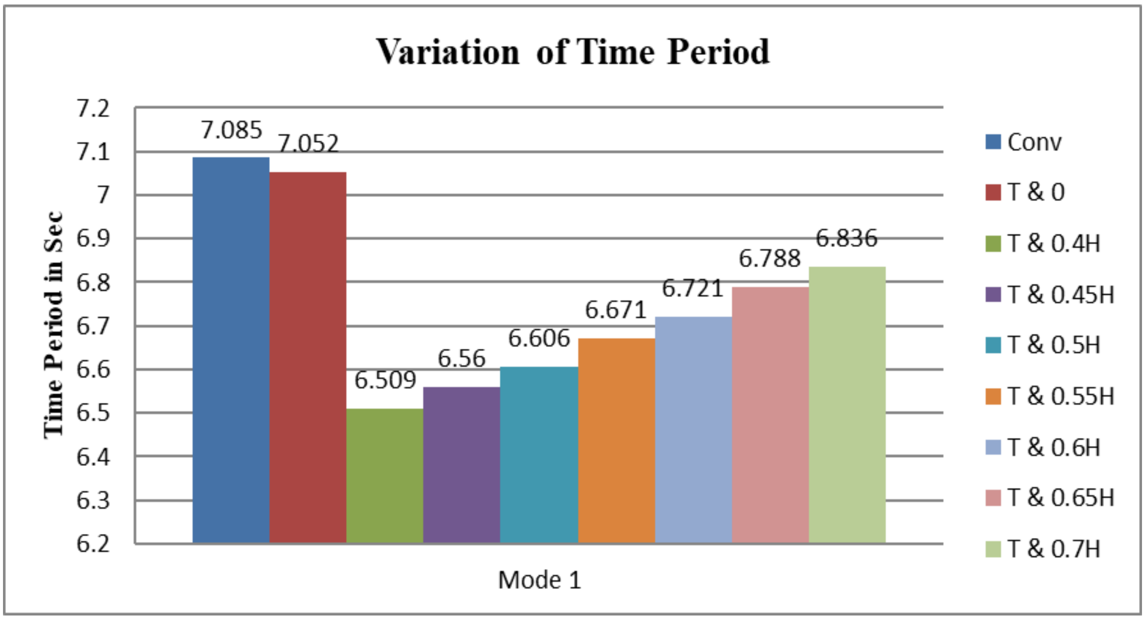
Table 4. Base Moment (in kN) for Different Outrigger Configuration (Equivalent Static Analysis, Response Spectrum Analysis, Wind Analysis and Gust Factor Analysis- X &Y Direction)

	Conv kNm	T & 0 kNm	T & 0.4H kNm	T & 0.45H kNm	T & 0.5H kNm	T & 0.55H kNm	T & 0.6H kNm	T & 0.65H kNm	T & 0.7H kNm
Eq X	24269135	24356308	24095959	24126730	24152703	24189765	24218631	24257618	24288838
Eq Y	24133706	24218650	23986955	24010700	24032173	24064172	24089851	24125277	24154238
Spec X	12422067	12528108	12602746	12694849	12736155	8506154	12759007	12744076	12728007
Spec Y	10050449	10106415	9867716	9948690	10000115	6702562	10084555	10117643	10137451
Wind X	9033470	9028318	8914657	8931244	8943678	8959607	8970783	8984377	8993549
Wind Y	9218004	9212400	9108554	9122190	9132791	9146754	9156774	9169189	9177706
Gust X	9448136	9441722	9316389	9334020	9347403	9364713	9376955	9391954	9402137
Gust Y	9332339	9326906	9223161	9236273	9246674	9260556	9270614	9283167	9291825

The above graph is clearly indicating that there is no significant difference in base moment values for equivalent static analysis, wind analysis and gust factor analysis. But for Response spectrum analysis base moment value considerably decreases due to variable mass at different floors and Equivalent static analysis and Wind analysis methods fails to catch the same.

5.4 Time Period

Graph 21 and table No.5 shows graph for variation of time period in different outrigger configuration for modal analysis and it is found that there is maximum reduction in time period when outriggers are placed at top and 0.4H i.e. height of the structure.



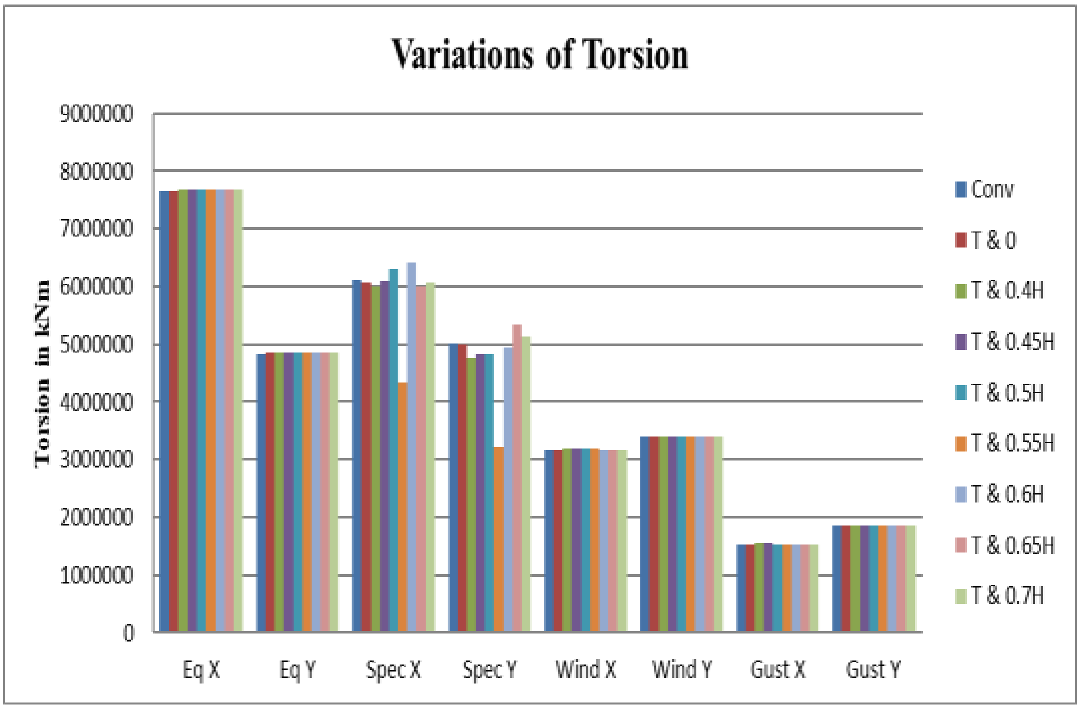
Graph 21. Time Period with Different Outrigger Configuration (Modal Analysis)

Table 5. Percentage Reduction in Time Period with Different Outrigger Configurations (Modal Analysis)

Time Period in Sec									
	Conv	T & 0	T & 0.4H	T & 0.45H	T & 0.5H	T & 0.55H	T & 0.6H	T & 0.65H	T & 0.7H
Mode 1	7.085	7.052	6.509	6.56	6.606	6.671	6.721	6.788	6.836
% Reduction in time period	Mode 1	0.47	8.13	7.41	6.76	5.84	5.14	4.19	3.51

6.5 TORSION

Graph 22 and table No.6shows variation of base moments in different outrigger configurations for Equivalent static analysis, Response Spectrum analysis, Wind analysis and Gust Factor analysis in X and Y Direction. And from Graph 19 it is observed that there is no significant variation in torsion values with provision of different outrigger configurations



Graph 20. Torsion graph with Different Outrigger Configuration (Equivalent Static Analysis, Response Spectrum Analysis Wind Analysis and Gust Factor Analysis - X & Y Direction)

Table 6. Torsion (in kNm) for Different Outrigger Configuration (Equivalent Static Analysis, Response Spectrum Analysis, Wind Analysis and Gust Factor Analysis- X &Y Direction)

	Conv kNm	T & 0 kNm	T & 0.4H kNm	T & 0.45H kNm	T & 0.5H kNm	T & 0.55H kNm	T & 0.6H kNm	T & 0.65H kNm	T & 0.7H kNm
Eq X	7650699	7668098	7689218	7688848	7688514	7688040	7687683	7687230	7687594
Eq Y	4833174	4844263	4853882	4854230	4854393	4854522	4854577	4854618	4854916
Spec X	6109219	6071322	6009926	6100682	6310938	4331613	6426309	5998507	6060583
Spec Y	5024678	5001356	4758462	4836402	4840033	3224896	4940467	5347357	5125371
Wind X	3179787	3179038	3183244	3182405	3181804	3181076	3180598	3180060	3179727
Wind Y	3401373	3402669	3398769	3399737	3400368	3401085	3401534	3402023	3402321
Gust X	1538839	1536288	1547596	1545185	1543489	1541463	1540146	1538676	1537772
Gust Y	1858709	1858428	1860648	1860231	1859904	1859490	1859212	1858899	1858710

VI. CONCLUSION

The focus of current study is seismic response of geometrically irregular shaped (in plan) structures and study of various parameters which include Storey displacement, Storey drift, Base reactions, Base moments, Time Period and Torsion by introducing outrigger structural system. For minimizing the twisting effect in tall irregular shaped building optimum location of outrigger play vital role, increases stiffness and performance of structure under lateral load.

Based on the above results obtained analyzing following conclusions are made:

1. In static and dynamic behaviour when we consider the storey displacement and storey drift parameters then the optimum location of outrigger is at top and 0.4H i.e. height of the building.

2. In parameter study of Storey Displacement it is reduced by 18.13% in X-direction and 18.46% in Y-direction for Equivalent Static analysis,16.39% in X-direction and 19.64% in Y-direction for Response Spectrum analysis, 18.56% in X-direction and 18.11% in Y-direction for Wind analysis, 18.82% in X-direction and 19.22% in Y-direction for Gust Factor analysis by providing outrigger at top and 0.4H i.e. height of the building
3. In parameter study of Storey Drift it is reduced by 18.86% in X-direction and 14.41% in Y-direction for Equivalent Static analysis, 15.76% in X-direction and 9.82% in Y-direction for Response Spectrum analysis, 12.01% in X-direction and 7.63% in Y-direction for Wind analysis, 11.78% in X-direction and 14.11% in Y-direction for Gust Factor analysis by providing outrigger at top and 0.4H i.e. height of the building.
4. In parametric study of base shear there is no significant difference in base shear values for equivalent static analysis, wind analysis and Gust Factor analysis. But for Response Spectrum analysis base shear value considerably decreasesdue to variable mass at different floors and Equivalent static analysis wind analysis and Gust Factor analysis fails to catch the same.
5. By introducing outrigger structural system, the time period can be controlled considerably. In parametric study there is maximum reduction in time period when outriggers are placed at top and 0.4H i.e. height of the building.
6. In parametric study of Base moments and Torsion there is no significant difference in valuesof base moments and torsion for equivalent static analysis, wind analysis and Gust Factor analysis. But for Response Spectrum analysis base moment and torsion value considerably decreases.
7. For different outrigger configurations, base shear does not affect to great extent.
8. When buildings are in geometrically irregular shape we cannot just rely on equivalent static analysis and hence it is essential to perform dynamic analysis due to non linear distribution of forces.
9. Thus conclusion is drawn that optimum location of outriggers is top and 0.4H i.e. height of the building.

Acknowledgements

I would like to thank my guide, Head of department, Principal, friends, family, and all others who have helped me in the completion of this Project.

REFERENCES

[1]. Shruti Badami and M.R. Suresh: "A Study on Behavior of Structural Systems for Tall Buildings Subjected to Lateral Loads", International Journal of Engineering Research & Technology (IJERT) Vol. 3 Issue 7, (July 2014).
[2]. Thejaswini R.M. And Rashmi A.R.: "Analysis and Comparison of different Lateral load resisting structural Forms" International Journal of Engineering Research & Technology (IJERT) Vol. 4 Issue 7, (July 2015).
[3]. Po Seng Kian, Frits Torang Siahaan: "The use of outrigger and belt truss system for high-rise concrete buildings"
[4]. N. Herath, N. Haritos, T. Ngo & P. Mendis: "Behaviour of Outrigger Beams in High rise Buildings under Earthquake Loads", Australian Earthquake Engineering Society (2009).
[5]. Kiran Kamath, N. Divya, Asha U Rao: "A Study on Static and Dynamic Behavior of Outrigger Structural System for Tall Buildings", Bonfiring International Journal of Industrial Engineering and Management Science, Vol2, No 4, (December 2012).
[6]. Alpana L. Gawate J.P. Bhusari: "Behaviour of outrigger structural system for high-rise building",International Journal of Modern Trends in Engineering & Research, e-ISSN No.:2349-9745, (July 2015).
[7]. Vijaya Kumari Gowda M R and Manohar B C: "A Study on Dynamic Analysis of Tall Structure with Belt Truss Systems for Different Seismic Zones", International Journal of Engineering Research & Technology (IJERT) Vol. 4 Issue 8, (August 2015).
[8]. Kiran Kamath, Shashikumar Rao and Shruthi: "Optimum Positioning of Outriggers to Reduce Differential Column Shortening Due to Long Term Effects in Tall Buildings", International Journal of Advanced Research in Science and Technology, Volume 4, Issue 3, (2015), pp.353-357.
[9]. Abbas Haghollahi, Mohsen Besharat Ferdous and Mehdi Kasiri: "Optimization of outrigger locations in steel tall buildings subjected to earthquake loads",15th world conference of earthquake engineering (2012).
[10]. Prateek N. Biradar, Mallikarjun S. Bhandiwad:"A performance-based study on static and dynamic behaviour of outrigger structural system for tall buildings", International Research Journal of Engineering and Technology (IRJET), Volume: 02 Issue: 05 | (Aug-2015).
[11]. Shivacharan K, Chandrakala S, Karthik N M: "Optimum Position of Outrigger System for Tall Vertical Irregularity Structures", IOSR Journal of Mechanical and Civil Engineering, Volume 12, Issue 2 Ver. II (Mar - Apr. 2015), PP 54-63.
[12]. Abdul Karim Mulla and Shrinivas B.N: "A Study on Outrigger System in a Tall R.C. Structure with Steel Bracing", International Journal of Engineering Research & Technology (IJERT) Vol. 4 Issue 7, (July 2015).
[13]. Dr. S. A. Halkude, Mr. C. G. Konapure and Ms. C. A. Madgundi: "Effect of Seismicity on Irregular Shape Structure" International Journal of Engineering Research & Technology (IJERT) Vol. 3 Issue 6, (June 2014).
[14]. Mr. Gururaj B. Katti and Dr. Basavraj Baapgol: "Seismic Analysis of Multistoried RCC Buildings Due to Mass Irregularity by Time History Analysis", International Journal of Engineering Research & Technology (IJERT) Vol. 3 Issue 6, (June 2014).

N.G. Gore" Performance of Dual-Outrigger Structural System in Geometrically Irregular Shaped High-Rise Building ' International Journal of Engineering Science Invention (IJESI), Vol. 08, No. 05, 2019, PP 16-35