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PERFORMANCE OF MULTY OUTRIGGER STRUCTURAL SYSTEM IN GEOMETRICALLY IRREGULAR SHAPED HIGHRISE BUILDING

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Abstract – *The development of high-rise building has been continuously expanding worldwide and brings up 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. For high-rise buildings, particularly in seismic active zone or wind load dominant, this system can be chosen as an appropriate structure.*

In present paper an investigation has been focused on performance of multi outrigger structural system in geometrically irregular shaped building. Static and dynamic behavior of 60 storey irregular shaped building with different outrigger configurations was analyzed by using ETABS Software. Time history analysis for ground motion data of El Centro was carried out. The Parameters discussed in this paper include variation of Storey Displacement, Storey Drift, Base shear, Base moment, Time period and Torsion for static and dynamic behaviour of different outrigger configurations.

Key Words: Outrigger, Belt truss, Time history Analysis, Geometry irregularity, High-Rise Building.

1. 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

1.1 OUTRIGGER STRUCTURAL SYSTEM

The outrigger and belt truss system is one of the lateral loads resisting system in which the external columns are tied to the central core wall with very stiff outriggers and belt truss at one or more levels. The belt truss tied the peripheral column of building while the outriggers engage them with main or central shear wall. 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 structure.

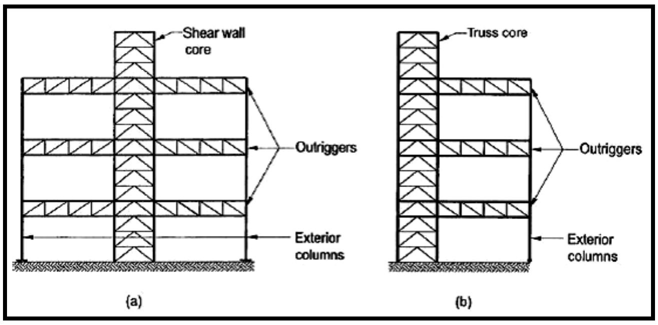

Fig -1: Outrigger Structural System

1.2 CONCEPT OF OUTRIGGER

The great sailing ships of the past and present use outriggers to help resist the wind forces in their sails. Like the ship, the core in the tall building can be related to the mast of the ship, the outrigger acting like the spreaders and the exterior columns like the stays or shroud of the ship.

The narrow boat will overturn when toss by unexpected wave but the small amount of flotation (i.e. upward resistance) or weight (i.e. downward resistance) acting through outrigger is sufficient to avoid overturning. In the same manner building outrigger are connected to perimeter columns capable of resisting upward and downward forces can greatly improve the building resistance.

Fig -2: Concept of Outrigger

1.3 BEHAVIOUR OF OUTRIGGER

The structural arrangement for this system consists of a main concrete core connected to exterior columns by relatively stiff horizontal members such as a one or two-storey deep walls commonly referred to as outriggers. The core may be centrally located with outriggers extending on both, or it may be located on one side of the building with outriggers extending to the building columns on one side.

The basic structural response of the system is quite simple. Because outrigger act as a stiff arm engaging outer columns, when central core tries to tilt its rotation at outrigger level induced a tension compression couple in outer columns and acting in opposite to that moment. The result is the Type of restoring moment acting on the core at that level. As a result, the effective depth of the structure for resisting bending is increased when the core bend as a vertical cantilever, by the development of tension in the windward columns, and by compression in the leeward columns.

In addition to those columns located at the ends of the outriggers, it is usual to also mobilize other peripheral columns to assist in restraining the rotation of outriggers. This is achieved by tying the exterior columns with a one- or two-storey deep wall commonly referred to as a “belt wall,” around the building

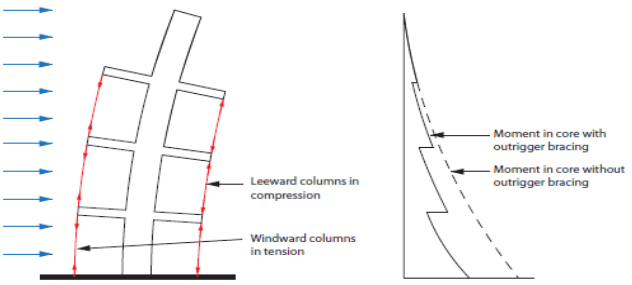

Fig -3: Behaviour of Outrigger

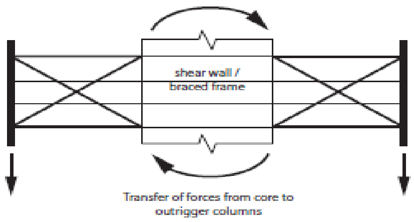

Fig -4: Behaviour of Outrigger

3. OBJECTIVES OF RESERCH

1. To develop Finite Element model of reinforced concrete multi-storeyed building prototypes with geometrically irregular and unsymmetrical L shaped plan layouts with different outrigger configurations.

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 time history method in which structure will be subjected to Time history load functions.

4. To determine the best possible location of possible 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.

4. MODELS CONSIDERED FOR ANALYSIS

In Present study a three dimensional 60 storey building with 53 m x56 m is considered.(Fig 5). The typical floor height is 3.5m giving a total height of 217m. The Beam, Column and shear wall are assumed as concrete structure and outrigger is assumed as steel structure. Column and beam size considered in the analysis are 750mmx750mm and 300x650mm respectively.

A total 10 Different outrigger configurations by varying the position and number of outrigger beam and belt truss has been modeled and analyzed.

M1	60-1	Without outrigger
M2	60-2	Outrigger at top
M3	60-3	Outrigger at 2/3 height
M4	60-4	Outrigger at mid-height
M5	60-5	Outrigger at top and mid-height
M6	60-6	Outrigger at top, mid-height and 2/3rd height
M7	60-7	Double outrigger at top
M8	60-8	Double outrigger at mid-height
M9	60-9	Double outrigger at 2/3 third height
M10	60-10	Double outrigger at top and mid-height

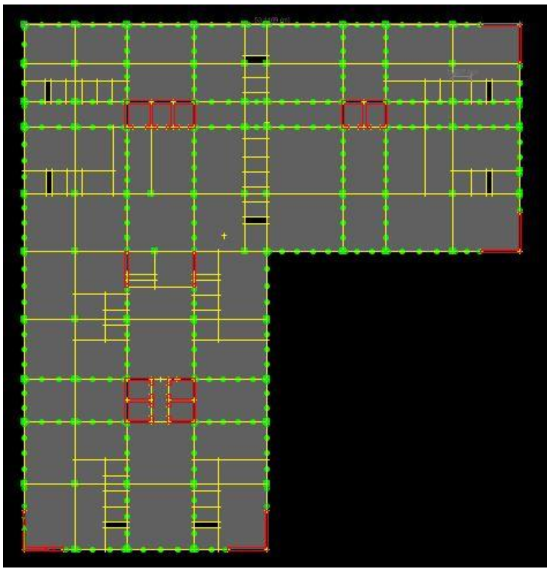

Fig -5: Typical Plan of Building

All wall piers are identical with uniform wall thickness of 300 mm is considered over the entire height of the building. The outrigger and belt truss beams are 300mm x 300mm structural steel box section is considered, M50 grade concrete is considered for beam and slab (Compressive strength 50 N/mm2) and M70 grade concrete is considered for columns and shear walls (Compressive strength 70 N/mm2) throughout the height of the building.

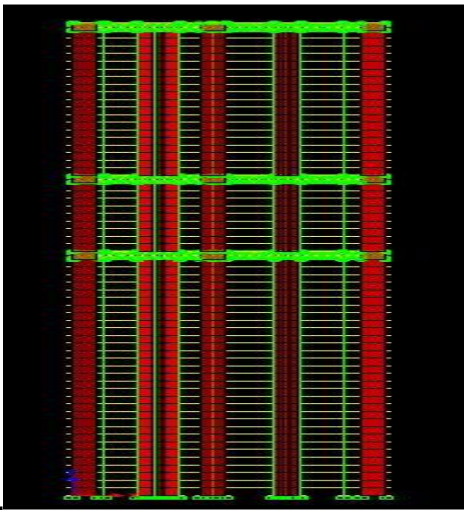

Fig -6 Elevation (Model No 6- OUTRIGGER AT Top, Mid & Two third Height)

The method of analysis of the above mentioned system is based up on the assumptions that the outriggers are rigidly attached to the core wall; The core is rigidly attached to the foundation; The section properties of the shear wall, beams and columns are uniform throughout the height of building; Material behaviour is in linear elastic range; The outrigger beams are flexurally rigid and induced only axial force in the column

5. LOAD CONSIDERATION & ANALYSIS OF THE BUILDING

For Static behaviour purpose equivalent static analysis is carried out. And For Dynamic behaviour purpose Response Spectrum Analysis and Time History Analysis is carried out . The acceleration Time Histories were obtained from records of past historical occurred in California Region.

By using ETABS Software dynamic analysis has been carried out. The Core wall and Slabs are modeled as a thin shell element with meshing as well as beam and columns are modeled as beam element.

For static behaviour purpose the dead load (Floor finish) of building is considered as 1.5 kN/m2 and live load as 4kN/m2 including self weight. Member load as U.D.L. of 6 kN/m is considered on all beams for the wall load considering the wall to be made of light weight bricks. Lateral Seismic load was considered confirming IS 1893 (PART-1) 2002. The following parameters has been considered for seismic analysis-

1. Seismic Zone = Zone IV (Z= 0.24)
2. Importance Factor = 1
3. Type of Soil = Medium Soil (Soil Type II)
4. Response Reduction Factor = IV
5. Damping Ratio = 5%
6. Time Period (Tx and Ty) = 4.24 Sec
7. Diaphragm = Semi Rigid

The structure is analyzed as per the loading combinations providing in IS: 456-2000.

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

6. RESULTS AND DISCUSSIONS

The following results of 60 storey building are studied,

The Parameters discussed include variation of Storey Displacement, Storey Drift, Base shear, Base moment, Time period and Torsion for static and dynamic behaviour of different outrigger configurations.

6.1 STOREY DISPLACEMENT

Chart 1 and 2 shows profile for variation of storey displacement in equivalent static analysis. As well as well as Chart 3,4,5 and 6 shows the variation of top storey displacement in different outrigger configurations for equivalent static analysis and response spectrum analysis. It is observed that top displacement in model 3 (OUTRIGGER AT Mid Height) is reduced up to 15%. And if we consider the multi outrigger system i.e. two or more outrigger storey then in model 10(Double outrigger at top and mid) it observed that top storey displacement reduced up to 32%.

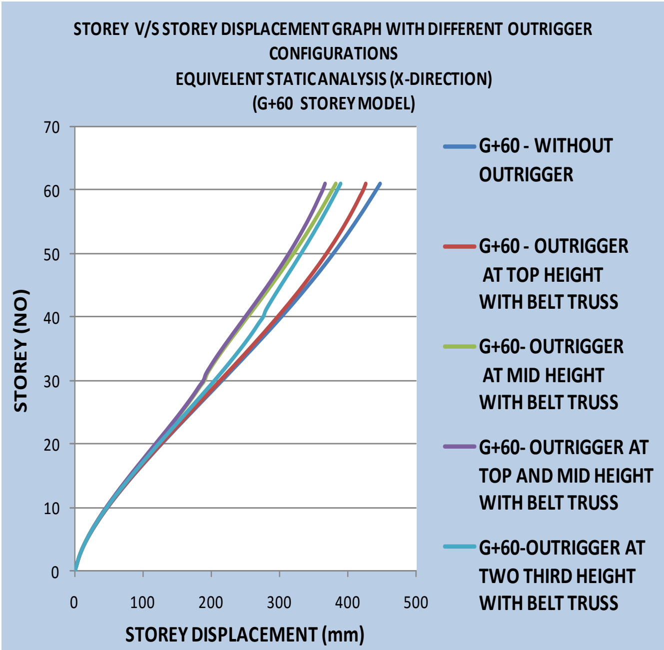

Chart -1: Equivalent Static Analysis (X Direction)

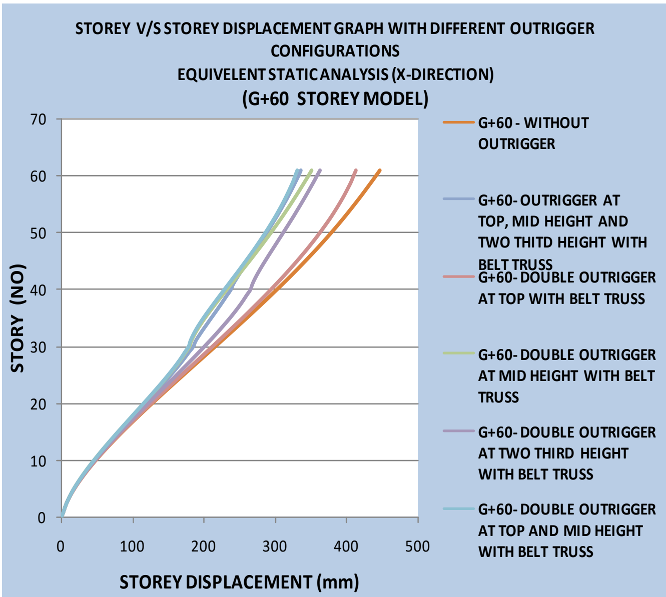

Chart -2: Equivalent Static Analysis (X Direction)

Table -1: Percentage Reduction In Top Displacement With Different Outrigger Configuration (Equivalent Static And Response Spectrum Analysis- X & Y Direction)

	M1	M2	M3	M4	M5
EQXD	447	426	382	367	390
SPECX	327	308	277	263	284
EQYD	396	382	343	332	349
SPECY	262	249	226	217	230
% Redu in Story Displacement	**EQXD**	5	15	21	16
	SPECX	6	15	20	13
	EQYD	4	14	16	12
	SPECY	5	14	17	12

		M6	M7	M8	M9	M10
EQXD		336	413	350	362	331
SPECX		240	293	247	258	228
EQYD		303	372	317	327	304
SPECY		199	239	204	211	195
% Redu in Story Displacement	**EQXD**	29	10	23	24	32
	SPECX	26	10	24	21	30
	EQYD	24	6	20	18	23
	SPECY	24	9	22	19	26

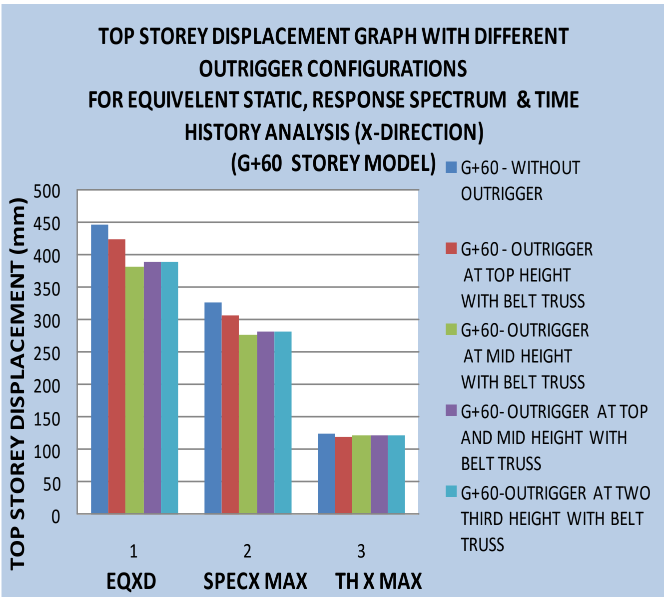

Chart -3: Top Displacement (X Direction)

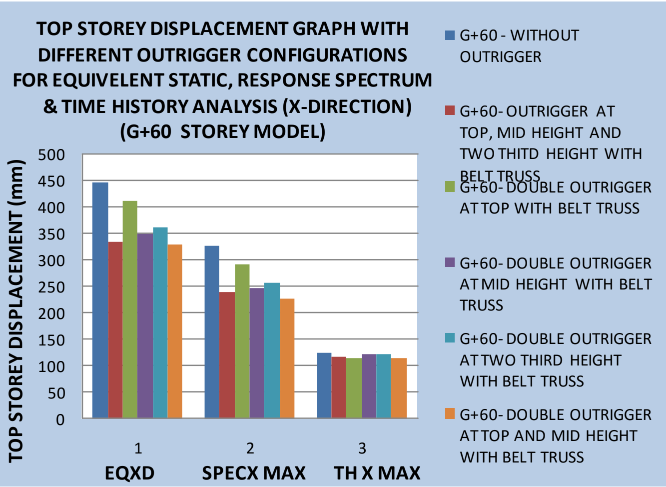

Chart -4: Top Displacement (X Direction)

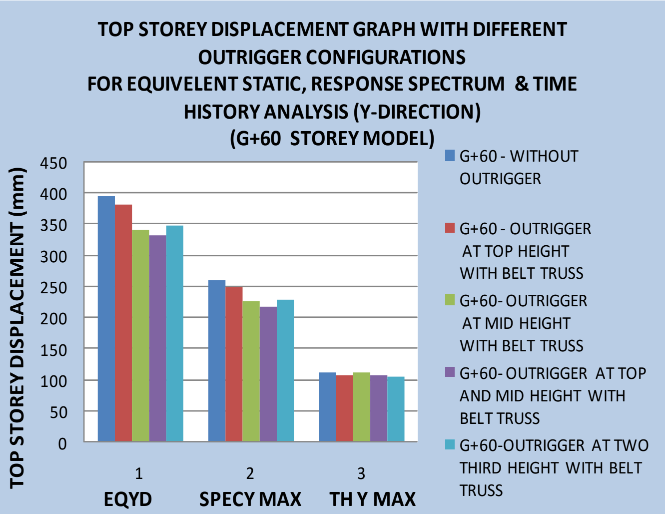

Chart -5: Top Displacement (Y Direction)

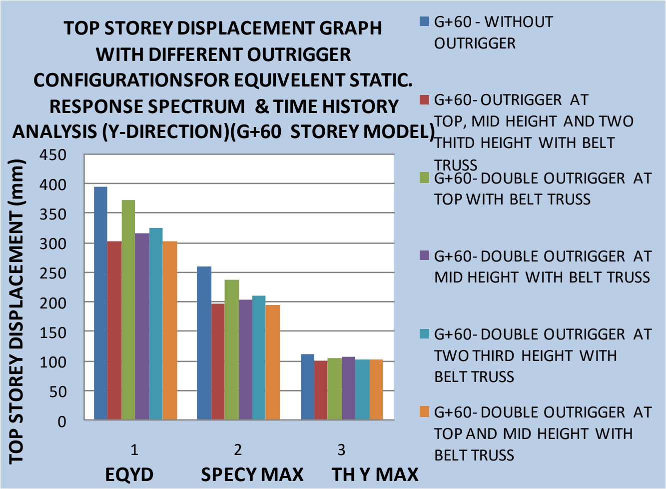

Chart -6: Top Displacement (Y Direction)

6.2 STOREY DRIFT

Chart 7,8 and table 2 shows profile for variation of storey drift in equivalent static analysis in x direction. Chart 9,10 and table 3 shows profile for variation of storey drift in response spectrum analysis in x direction and Chart 11,12 and table 4 shows profile for variation of storey drift in time history analysis in x direction

Similarly Table 5, 6 and 7 shows profile for variation f storey drift in different outrigger configurations for Equivalent static analysis, Response Spectrum analysis and Time History Analysis in (Y Direction)

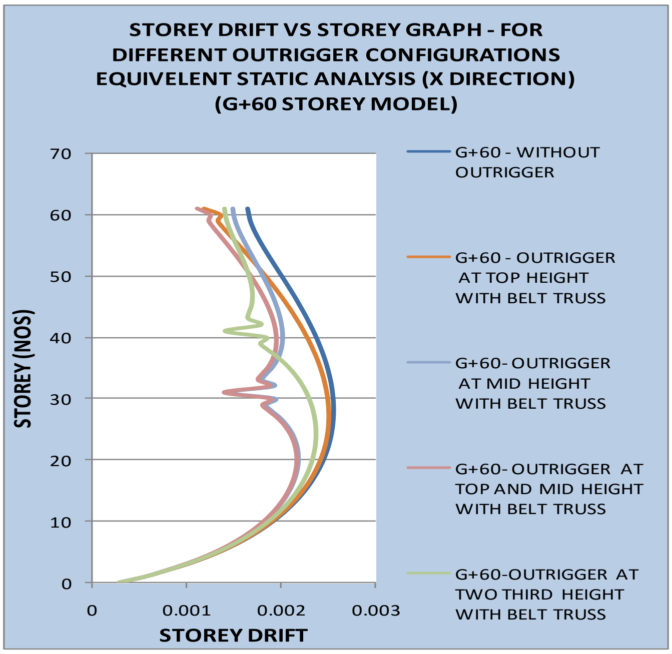

Chart -7: Equivalent Static Analysis (X Direction)

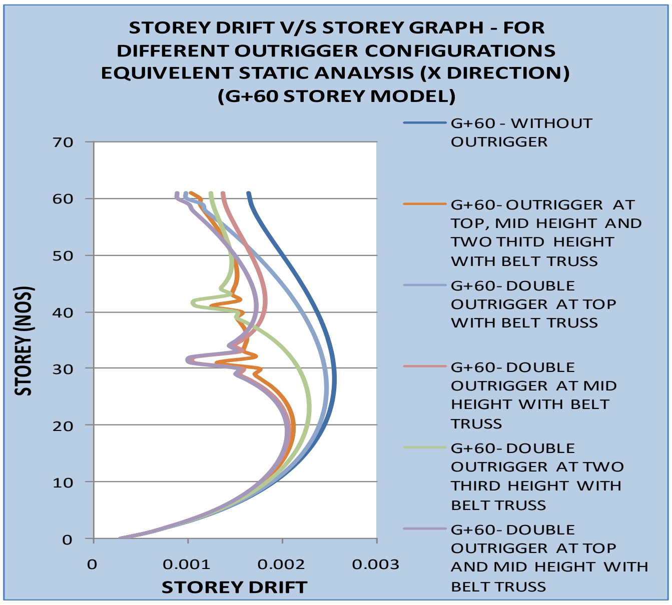

Chart -8: Equivalent Static Analysis (X Direction)

Table -2: Percentage Reduction In Storey Drift With Different Outrigger Configuration (Equivalent Static Analysis- X Direction)

PERCENTAGE REDUCTION IN STORY DRIFT FOR DIFFERENT OUTRIGGER CONFIGURATIONS EQUIVELENT STATIC ANALYSIS (X DIRECTION) (G+60 STORY MODEL)																	
M2		M3		M4		M5		M6		M7		M8		M9		M10	
TOP	28	MID	45	TOP	35	2/3 HT	41	TOP	40	TOP	44	MID	60	2/3 HT	56	TOP	50
								2/3 HT	49								
				MID	47			MID	51							MID	63

The variation of storey drift as indicated in Chart 7 and 8, it is observed that the storey drift is reduced by 28% by providing outrigger at top (Model 2) and it is reduced up to 45% by providing outrigger at Mid height (Model 3). Further it can be observed that in multi outrigger structural system storey drift is reduced up to 63% by providing double storey outrigger at top and mid height.

It can be observed from graphs in chart 7 and 8, that there is curvature change at the outrigger location this is due to the rotation of the wall which is partially restrained at these points by outrigger-column interaction.

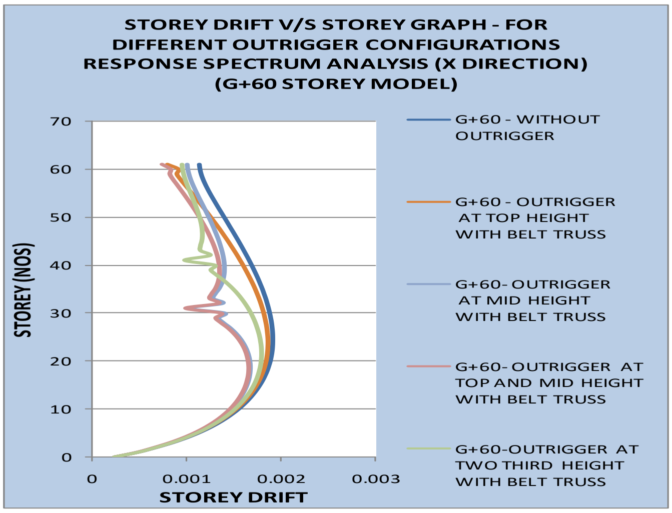

Chart -9: Response Spectrum Analysis (X Direction)

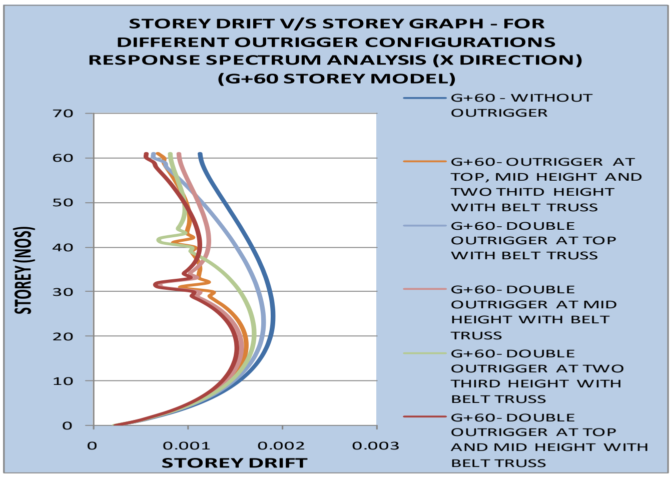

Chart -10: Response Spectrum Analysis (X Direction)

Table -3: Percentage Reduction in Storey Drift with Different Outrigger Configuration (Response Spectrum Analysis- X Direction)

PERCENTAGE REDUCTION IN STORY DRIFT FOR DIFFERENT OUTRIGGER CONFIGURATIONS RESPONSE SPECTRUM ANALYSIS (X DIRECTION) (G+60 STORY MODEL)								
M2	M3	M4	M5	M6	M7	M8	M9	M10
TOP 30	MID HEIGHT 45	TOP 35 MID 47	TWO THI 41	TOP 40 2/3 49 MID 51	TOP 44	MID HEI 60	TWO THI 56	TOP 50 MID 63

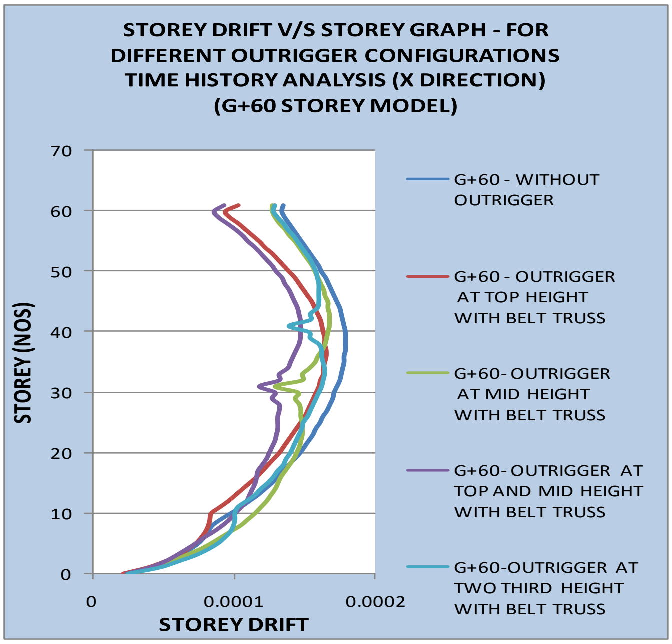

Chart -10: Time History Analysis (X Direction)

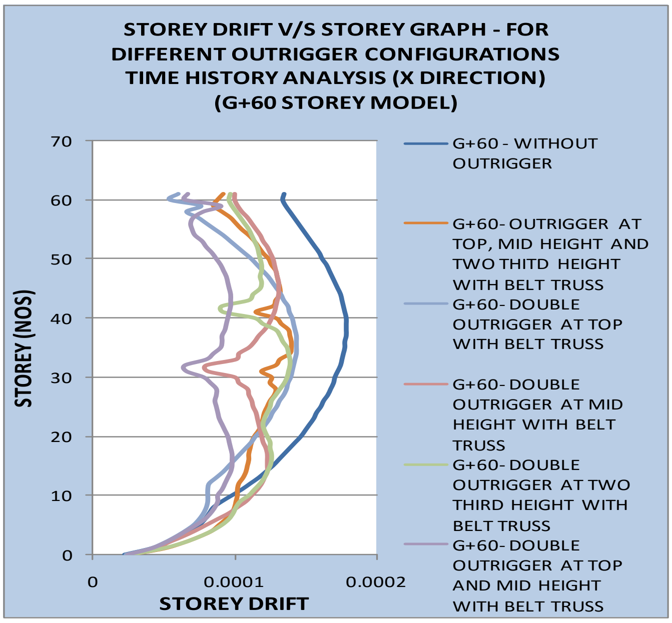

Chart -11: Time History Analysis (X Direction)

Table -4: Percentage Reduction in Storey Drift with Different Outrigger Configuration (Response Spectrum Analysis- X Direction)

PERCENTAGE REDUCTION IN STORY DRIFT FOR DIFFERENT OUTRIGGER CONFIGURATIONS TIME HISTORY ANALYSIS (X DIRECTION) (G+60 STORY MODEL)

M2		M3		M4		M5		M6		M7		M8		M9		M10	
				TOP	36			TOP	34							TOP	51
TOP	30	MID	36			2/3 HT	22	2/3	35	TOP	60	MID	54	2/3 HT	49		
				MID	32			MID	31							MID	63

Table -5: Percentage Reduction in Storey Drift with Different Outrigger Configuration (Equivalent Static Analysis- Y Direction)

PERCENTAGE REDUCTION IN STORY DRIFT FOR DIFFERENT OUTRIGGER CONFIGURATIONS EQUIVELENT STATIC ANALYSIS (Y DIRECTION) (G+60 STORY MODEL)

M2		M3		M4		M5		M6		M7		M8		M9		M10	
				TOP	27			TOP	34							TOP	42
TOP	20	MID	44			2/3 HT	40	2/3	48	TOP	32	MID	57	2/3 HT	53		
				MID	45			MID	49							MID	59

Table -6: Percentage Reduction in Storey Drift with Different Outrigger Configuration (Response Spectrum Analysis- Y Direction)

PERCENTAGE REDUCTION IN STORY DRIFT FOR DIFFERENT OUTRIGGER CONFIGURATIONS RESPONSE SPECTRUM ANALYSIS (Y DIRECTION) (G+60 STORY MODEL)

M2		M3		M4		M5		M6		M7		M8		M9		M10	
				TOP	28			TOP	36							TOP	45
TOP	21	MID	44			2/3 HT	40	2/3	49	TOP	34	MID	59	2/3 HT	54		
				MID	46			MID	50							MID	61

Table -7: Percentage Reduction in Storey Drift with Different Outrigger Configuration (Time History Analysis- Y Direction)

PERCENTAGE REDUCTION IN STORY DRIFT FOR DIFFERENT OUTRIGGER CONFIGURATIONS TIME HISTORY ANALYSIS (Y DIRECTION) (G+60 STORY MODEL)

M2		M3		M4		M5		M6		M7		M8		M9		M10	
				TOP	22			TOP	34							TOP	38
TOP	23	MID	36			2/3 HT	44	2/3	47	TOP	36	MID	48	2/3 HT	51		
				MID	37			MID	43							MID	51

6.3 BASE REACTIONS

Chart 12; table 8 shows graphs for variation of base reaction in different outrigger configurations for Equivalent static analysis, Response Spectrum analysis and Time History Analysis in (X Direction).

And similarly Chart 13, table 9 shows graphs for variation of base reaction in in different outrigger configurations for Equivalent static analysis, Response Spectrum analysis and Time History Analysis in (Y Direction).

And from Chart 12 and 13 it observed that there is no significant variation of base reaction values with provision of different outrigger configurations.

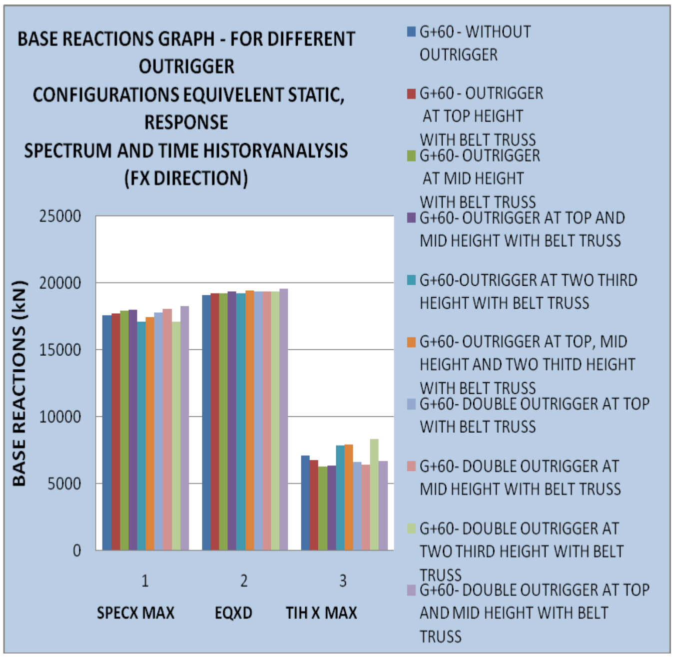

Chart -12: Base Reactions graph With Different Outrigger Configuration (Equivalent Static Analysis, Response Spectrum Analysis and Time History Analysis- X Direction)

Table -8: Base Reactions (in kN) for Different Outrigger Configuration (Equivalent Static Analysis, Response Spectrum Analysis and Time History Analysis- X Direction)

		M1	M2	M3	M4	M5
	EQXD	17625	17724	17968	18038	17154
	SPECX	19113	19230	19229	19351	19231
FX	**TH-X**	7133	6773	6281	6385	7856

		M6	M7	M8	M9	M10
	EQXD	17465	17837	18104	17107	18270
	SPECX	19468	19353	19352	19351	19587
FX	**TH-X**	7940	6676	6405	8345	6683

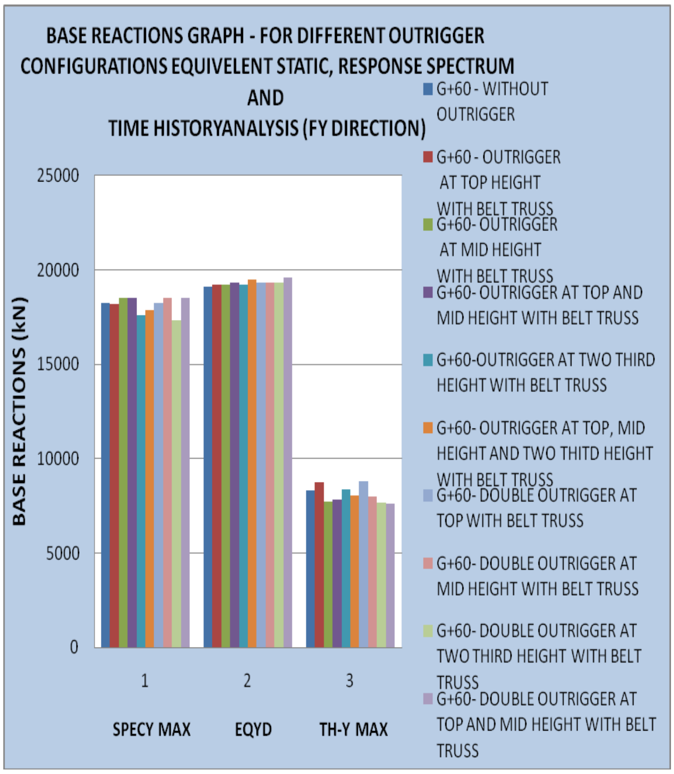

Chart -13: Base Reactions graph With Different Outrigger Configuration (Equivalent Static Analysis, Response Spectrum Analysis and Time History Analysis- Y Direction)

Table -9: Base Reactions (in kN) for Different Outrigger Configuration (Equivalent Static Analysis, Response Spectrum Analysis and Time History Analysis- Y Direction)

		M1	**M2**	**M3**	**M4**	**M5**
	EQYD	18226	18220	18515	18494	17612
	SPECY	19113	19230	19231	19353	19231
FY	**TH-Y**	8308	8760	7719	7847	8393

		M6	**M7**	**M8**	**M9**	**M10**
	EQYD	17855	18236	18522	17351	18545
	SPECY	19477	19353	19354	19353	19599
FY	**TH-Y**	8029	8822	7977	7688	7630

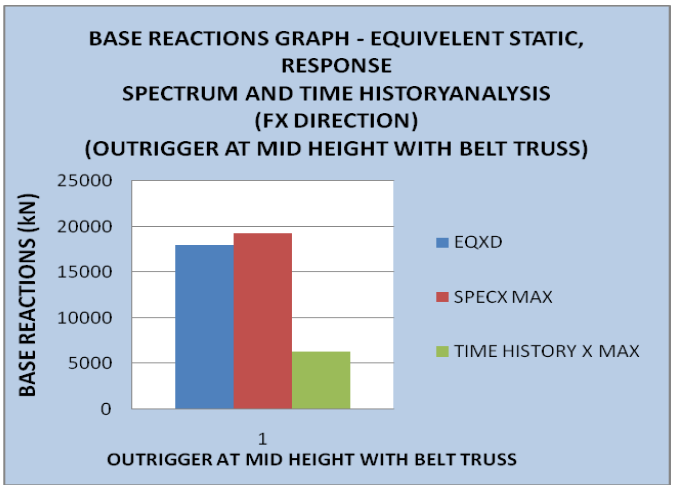

Chart -14: Base Reaction graph With Different methods of analysis (Equivalent Static Analysis, Response Spectrum Analysis and Time History Analysis- (FX Direction) (Outrigger at Mid Height with Belt Truss)

Chart 14 and Chart 15 shows graphs for variation of base reaction for Equivalent static analysis, Response Spectrum analysis and Time History Analysis in X Direction and Y direction respectively for (Modal- 3 - Outrigger at Mid Height with Belt Truss)

The above graphs are clearly indicate that there is no significant difference in base shear values for equivalent static analysis and response spectrum analysis. But for Time history analysis base reaction value considerably decrease up to 60 % in X direction and 58% in Y direction. The main reason for this change being due to variable mass at different floors and Equivalent static analysis and response spectrum methods fails to catch the same.

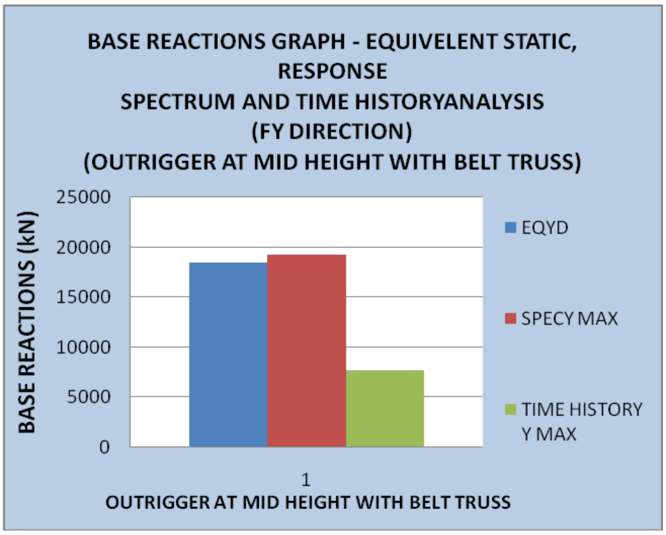

Chart -15: Base Reaction graph With Different methods of analysis (Equivalent Static Analysis, Response Spectrum Analysis and Time History Analysis- (FY Direction) (Outrigger at Mid Height with Belt Truss)

6.4 BASE MOMENTS

Chart 16; table 10 shows graphs for variation of base Moments in different outrigger configurations for Equivalent static analysis, Response Spectrum analysis and Time History Analysis in (X Direction)

And similarly Chart 17, table 11 shows graphs for variation of base moments in different outrigger configurations for Equivalent static analysis, Response Spectrum analysis and Time History Analysis in (Y Direction)

And from Chart 16 and 17 it observed that there is no significant variation of base moment values with provision of different outrigger configurations.

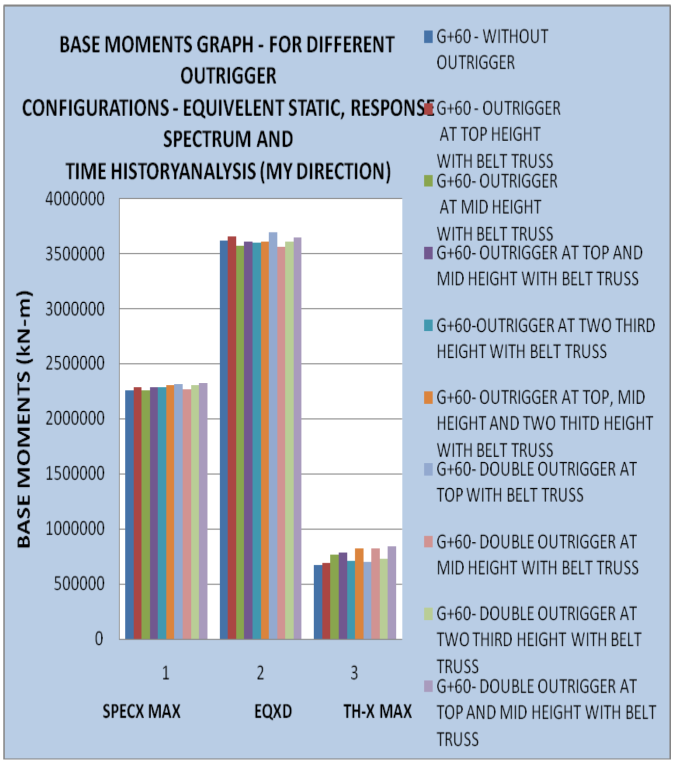

Chart -16: Base Moments graph With Different Outrigger Configuration (Equivalent Static Analysis, Response Spectrum Analysis and Time History Analysis- My Direction)

Table -10: Base Moments (in kN-m) for Different Outrigger Configuration (Equivalent Static Analysis, Response Spectrum Analysis and Time History Analysis- My Direction)

		M1	**M2**	**M3**	**M4**	**M5**
	EQXD	2260805	2288345	2263031	2290824	2284453
	SPECX	3623337	3658680	3575380	3615247	3602493
MY	**TH-X**	670712	686856	768472	781043	709131

		M6	**M7**	**M8**	**M9**	**M10**
	EQXD	2311339	2315349	2271881	2302657	2322090
	SPECX	3612209	3698024	3568283	3608174	3648446
MY	**TH-X**	818281	695572	820133	731484	839898

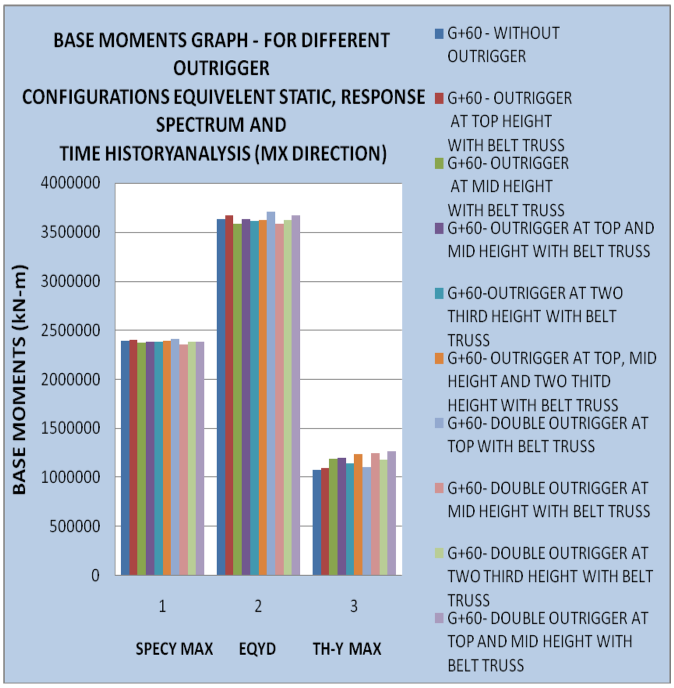

Chart -17: Base Moments graph With Different Outrigger Configuration (Equivalent Static Analysis, Response Spectrum Analysis and Time History Analysis- Mx Direction)

Chart 18 and Chart 19 shows graphs for variation of base Moments for Equivalent static analysis, Response Spectrum analysis and Time History Analysis in X Direction and Y direction respectively for (Modal- 3 - Outrigger at Mid Height with Belt Truss)

The above graphs are clearly indicate that there is no significant difference in base shear values for equivalent static analysis and response spectrum analysis. But for Time history analysis base reaction value considerably decrease up to 60 % in X direction and 58% in Y direction. The main reason for this change being due to variable mass at different floors and Equivalent static analysis and response spectrum methods fails to catch the same.

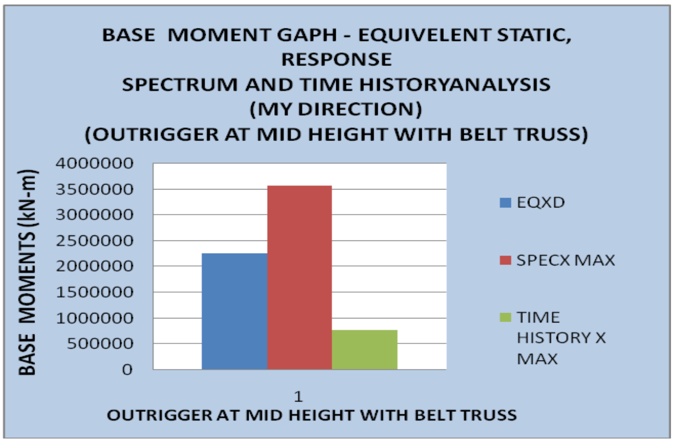

Chart -18: Base Moments graph With Different methods of analysis (Equivalent Static Analysis, Response Spectrum Analysis and Time History Analysis- MY Direction) (Outrigger at Mid Height with Belt Truss)

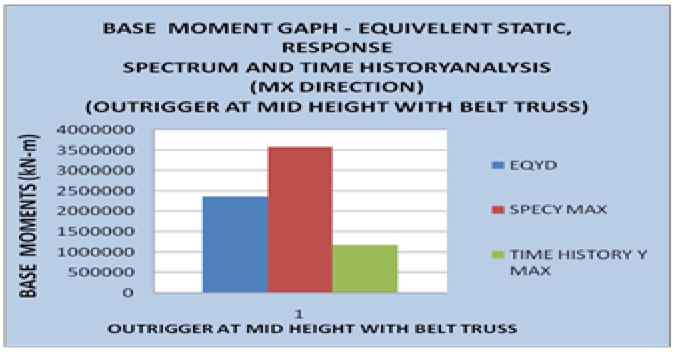

Chart -19: Base Moments graph With Different methods of analysis (Equivalent Static Analysis, Response Spectrum Analysis and Time History Analysis- MX Direction) (Outrigger at Mid Height with Belt Truss)

Table -11: Base Moments (in kN-m) for Different Outrigger Configuration (Equivalent Static Analysis, Response Spectrum Analysis and Time History Analysis- Mx Direction)

		M1	M2	M3	M4	M5
	EQYD	2388493	2399322	2370842	2384830	2387597
	SPECY	3634198	3671362	3587681	3628839	3614960
MX	**TH-Y**	1076425	1092263	1191509	1204290	1143470

		M6	M7	M8	M9	M10
	EQYD	2393526	2408425	2352600	2379712	2383565
	SPECY	3626175	3711419	3581841	3622178	3665506
MX	**TH-Y**	1236077	1103195	1243709	1182213	1264578

6.4 TIME PERIOD

Chart 20 and table 11 shows graphs 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 mid height of the structure.

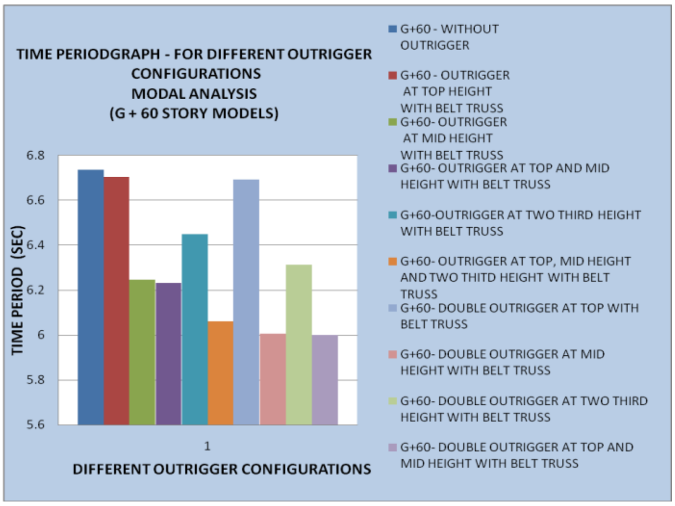

Chart -20: Time Period With Different Outrigger Configuration (Modal Analysis)

Table 12: Percentage Reduction in Time Period with Different Outrigger Configurations (Modal Analysis)

PERCENTAGE REDUCTION IN TIME PERIOD FOR DIFFERENT OUTRIGGER CONFIGURATIONS									
	M2	M3	M4	M5	M6	M7	M8	M9	M10
% Reduction in Time Period	0.4	7.2	7.4	4.2	9.9	0.6	10.8	6.2	10.9

6.5 TORSION

Chart 16 and table no 12 shows profile for variation of torsion in modal analysis for different outrigger configurations. It is observed that torsion in model 3 (OUTRIGGER AT Mid Height) is reduced up to 45%. And if we consider the multi outrigger system i.e. two or more outrigger storey then in model 10(Double outrigger at top and mid) then it observed that torsion reduced up to 60%.

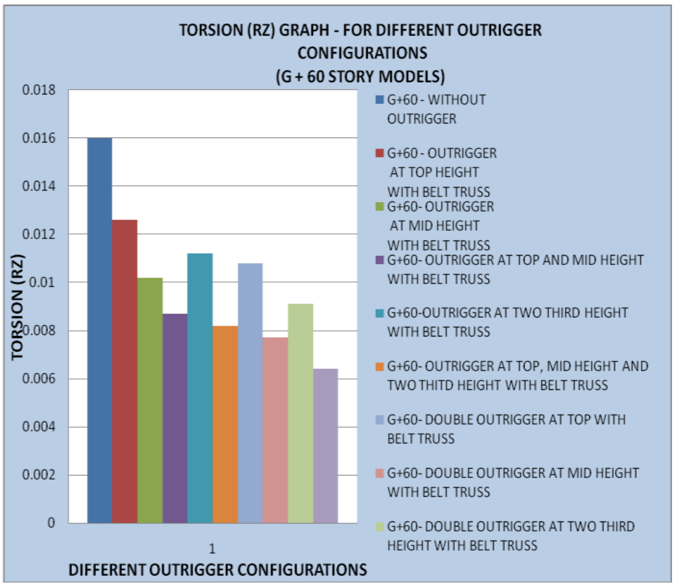

Chart -21: Torsion With Different Outrigger Configurations (Modal Analysis)

Table 13: Percentage Reduction in Torsion with Different Outrigger Configurations (Modal Analysis)

PERCENTAGE REDUCTION IN TIME PERIOD FOR DIFFERENT OUTRIGGER CONFIGURATIONS									
	M2	M3	M4	M5	M6	M7	M8	M9	M10
% Red in Time Period	21.2	36.2	45.6	30	48.7	32.5	51.8	43.1	60

7. CONCLUSIONS

The present work is clearly focused on the study of 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 irregular shaped buildings which are vulnerable to twisting, the use of outrigger at proper location minimizes twisting effect and the use of outrigger structural system in high rise building increases stiffness and makes the structural form efficient under lateral load.

Based on the analysis results obtained 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 mid height.
2. In parameter study of Storey Drift it is reduced by 28% by providing outrigger at top (Model 2) and it is reduced up to 45% by providing outrigger at Mid height (Model 3). Further it can be observed that in multi outrigger structural system storey drift is reduced up to 63% by providing double storey outrigger at top and Mid height.
3. In parametric study of base shear there is no significant difference in base shear values for equivalent static analysis and response spectrum analysis. But for Time history analysis base reaction value considerably decrease up to 60 % in X direction and 58% in Y direction. The main reason for this change being due to variable mass at different floors and Equivalent static analysis and response spectrum methods fails to catch the same.
4. 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 mid height of the building.
5. In geometrically irregular structure it is very challenging task to control the torsion. Therefore As per parametric study of different outrigger configurations it is observed that torsion in model 3 (OUTRIGGER AT Mid Height) is reduced up to 45%. And if we consider the multi outrigger system i.e. two or more outrigger storey then in model 10(Double outrigger at top and Mid) then it reduced up to 60%.
6. For different outrigger configurations, base shear does not alter to great extent.
7. Provision of shear wall near re-entrant corner and at the end of projections which are parallel to the direction of lateral load is very effective in resisting seismic effect.
8. From the graphs of storey displacement it is observed that the displacement obtained by Equivalent static analysis is higher than Dynamic analysis such as Response spectrum and Time history analysis.
9. Equivalent static analysis is not sufficient when buildings are in geometrically irregular shape and it is essential to perform dynamic analysis due to non linear distribution of forces.
10. It can be concluded that optimum location of outrigger is at mid height of the building.

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