Stability Enhancement of Optimum Outriggers and Belt Truss Structural System

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Abstract - *It has been observed from various analyses that the stability of the structure solely depends upon its structural members which are connected to each other and transfer their loads. But when the structure height is more along with it is under the influence of seismic loads with gravity loads, its stability decreases. In present work, shear core outrigger and belt supported system is used on G+10 multistory residential building located at seismic zone IV. General structure compared with both wall belt and truss belt supported system using optimum location suggested by Taranath method. Response spectrum method is used to evaluate nodal displacement, story drift time period with mass participation and beam stress values. Total seven cases has used and compared with each other in this work and most efficient case among all discussed in this article.*

Key Words: Earthquake forces, Efficient case, Story drift, Outrigger and Shear core, Staad Pro, Response spectrum method, Wall Belt system, Truss Belt system.

1. INTRODUCTION

The stability of tall structures requires some modifications into it since the scarcity of land generate need of the tall structures such as multistory building and skyscrapers. Since it has been observed that the competition is going on among the countries. Since the loads on the structure such as vertical and horizontal loads itself generate a huge combined load that has somehow generated by structure and that load has to be bear by structure itself. Since the earthquake generates oscillations from the ground which is connected to the structure and the most effective technique used to resist the structure by these combinations is the use of outriggers, belt supported system and outrigger and belt supported system.

Outriggers:

Outriggers are the members of beams or plates connected from the core to exterior columns in both the directions that hold the structure and act as frame connections. The core provided such as shear wall core holds the entire structure firmly that accepts the loads and transfer the loads equally to the exterior columns. This system provides more stiffness to the structure than conventional frame systems.

Belt supported system:

The most efficient system used in multistory building is the bracing system either it is wall belt or truss belt system. This system is the connection of the members to the nodes of the structure. It is called as belt supported system because the belt generally made up of trusses or shear wall, connects the periphery columns of the structure. The load moves from each member distributed to the connected structures evenly.

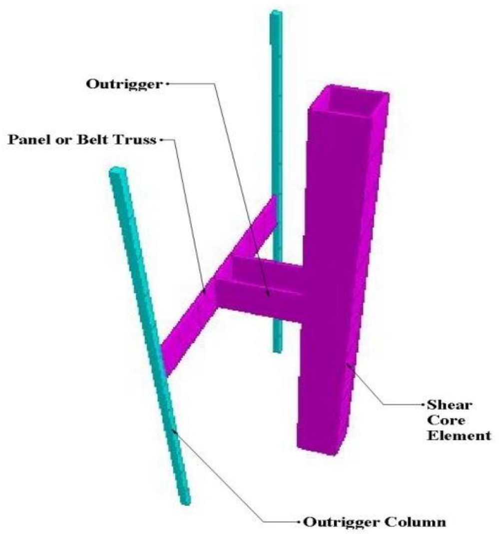


Fig -1: Typical Outrigger and Belt Supported System

To counteract the seismic forces and to maintain the rigidness of the structure, outriggers and belt supported system is used.

2. OBJECTIVE OF THE PRESENT STUDY

The objectives of this work are as follows:

- To analyze the maximum nodal displacement case in X direction with most efficient case which provide more stability.
- To obtain the maximum nodal displacement values in Z direction with most efficient case among all cases.
- To compare the story drift case in X direction with most efficient case which provide more stability.
- To evaluate story drift values in Z direction with most efficient case among all cases.

- To study and compare the time period and mass participation factor of the structure
- To investigate maximum compressive and tensile stresses values in members.
- To demonstrate the efficiency of truss belt or wall belt at optimum height.

3. PROCEDURE AND 3D MODELLING OF STRUCTURE

As per criteria for earthquake resistance design of structures, a residential 43.26 m eleven story building has taken for analysis. As mentioned above, a total of seven different cases have been chosen for parametric analysis. Various dimensions of structure and its loadings are shown in table 1 and table 2; seismic parameters taken have shown in table 3 respectively. After than seven building cases has described as case S1 to case S7. Figure 1 shows typical outrigger and belt supported system. From figure 2 to figure 9, plan and 3D views of different cases is described and after the result of various parameters are described in tabular form with its worst case and optimal case. With each parameter, a graph is provided to compare each parameter figuratively.

Table -1: Dimensions of different components of building

Building Length	15m
Building Width	21 m
Height of each floor	3m
Depth of footing	3.66m
Beam dimensions	600 mm x 300 mm
Column dimensions	500 mm x 500 mm
Slab thickness	125 mm
Shear wall thickness	230 mm
Bracing dimensions	230 mm x 230 mm

Table -2: Loadings selected and used on the structure

Self weight	Applied to entire structure
Floor finish load	1 KN/m2
Terrace finish load	1 KN/m2
Water proofing load	2 KN/m2
Interior wall load	4.9 KN/m
Exterior wall load	17.934 KN/m
Parapet wall load with height	4.9 KN/m
Live load for intermediate floors	4 KN/m2
Live load for roof of building	1.5 KN/m2

Table -3: Seismic parameters on the structure

Importance factor I	1
fundamental natural period (Ta) for X direction	1.2978 seconds
fundamental natural period (Ta) for Z direction	0.8496 seconds
Response reduction factor R	5
Zone factor	0.24
Zone	IV
Soil type	Hard soil

Different building model cases has taken for analysis using Staad pro software

- Regular building on plane ground - Case S1.
- Regular building with shear core - Case S2.
- Building with shear core and wall outriggers - Case S3.
- Shear core outrigger and wall belt supported system - Case S4.
- Shear core outrigger and truss belt supported system - Case S5.
- Shear core outrigger and truss belt supported system optimum bracing T 1 - Case S6.
- Shear core outrigger and truss belt supported system optimum bracing T 2 - Case S7.

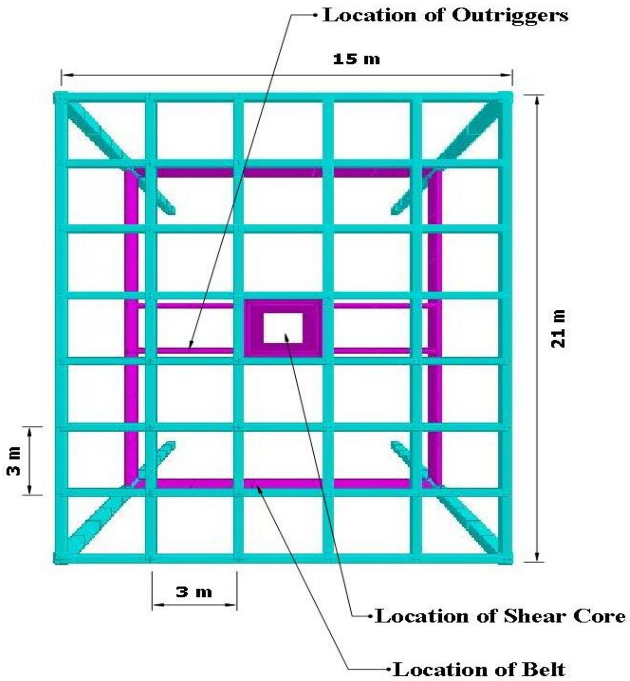


Fig -2: Typical floor plan

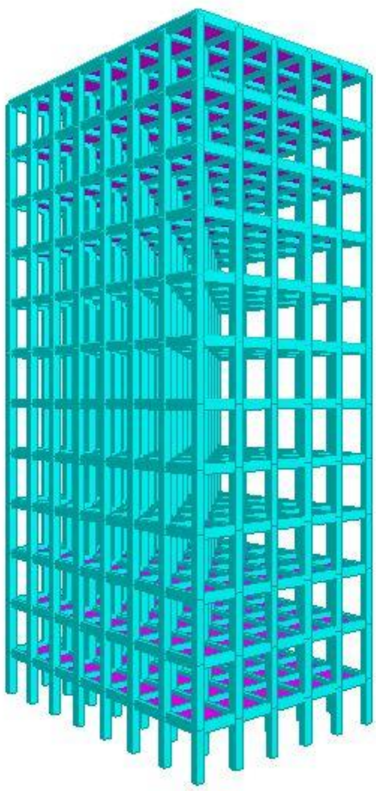


Fig -3: 3D view of case (S1) Regular building on plane ground

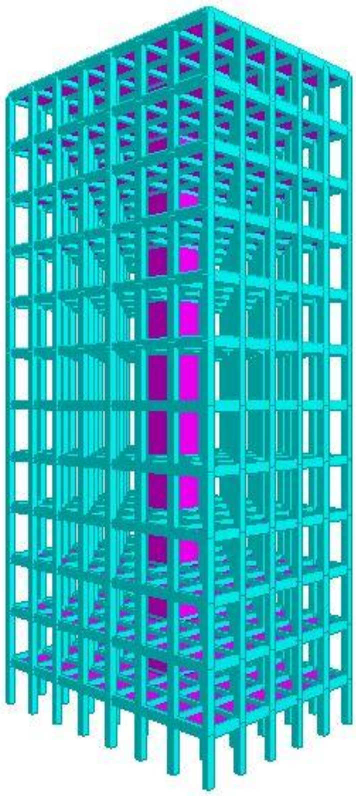


Fig -4: 3D view of case (S2) Regular building with shear core

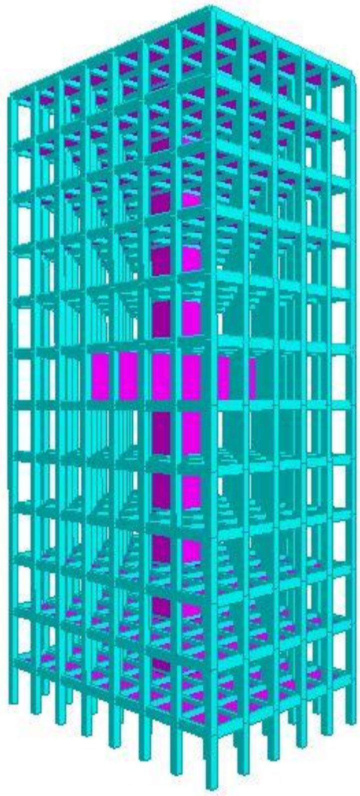


Fig -5: 3D view of case (S3) Building with shear core and wall outriggers

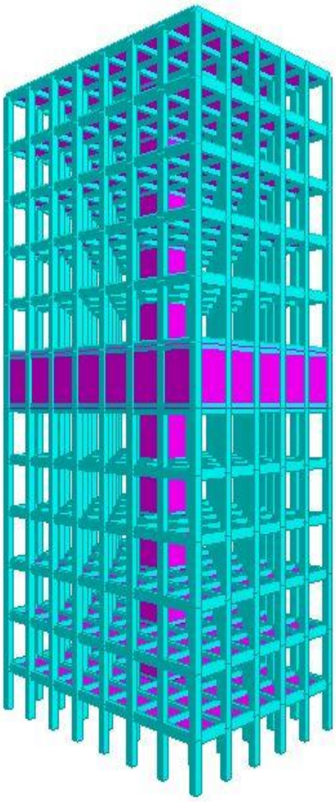


Fig -6: 3D view of case (S4) Shear core outrigger and wall belt supported system

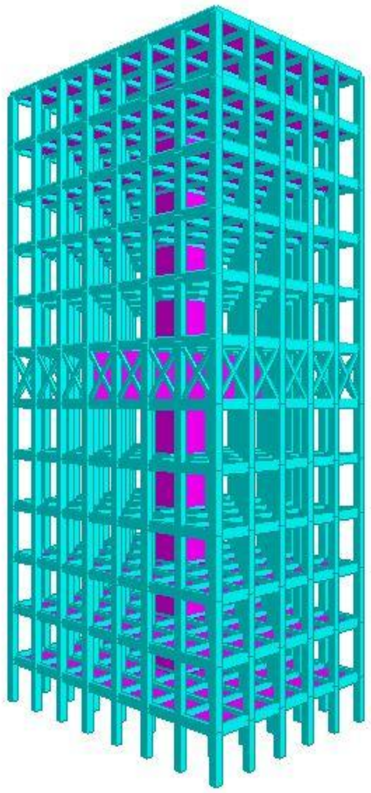


Fig -7: 3D view of case (S5) Shear core outrigger and truss belt supported system

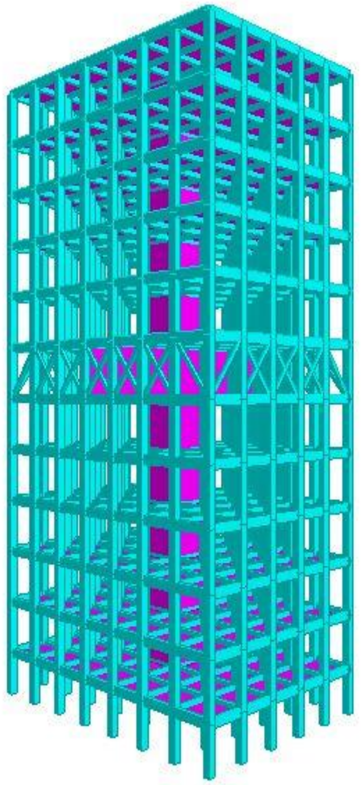


Fig -8: 3D view of case (S6) Shear core outrigger and truss belt supported system optimum bracing T 1

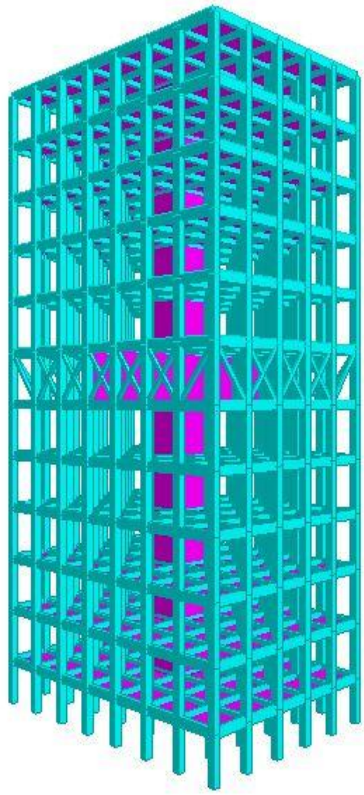


Fig -9: 3D view of case (S7) Shear core outrigger and truss belt supported system optimum bracing T 2

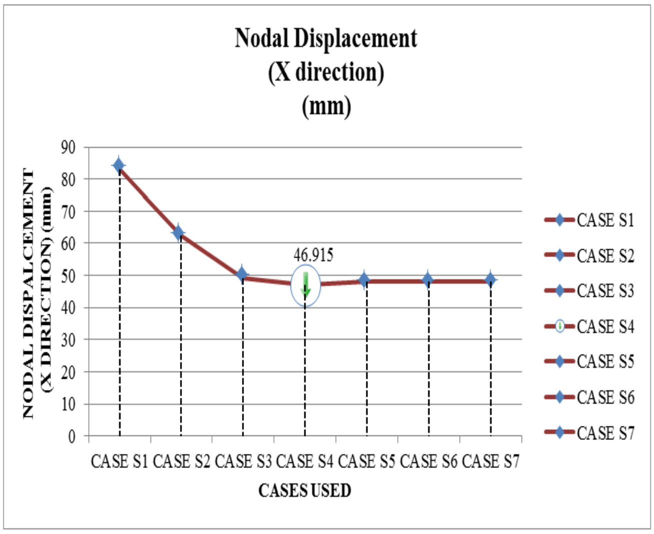
4. RESULTS ANALYSIS

For the stability of the structure, parameters such as the nodal displacement in both seismic directions, story drift in both seismic directions, beam stress values, time period and mass participation factors obtained by application of loads and their combinations on various cases of the multistory building. Tabular result of each parameters and its optimal case is discussed with its graphical form below:-

Table -4: Maximum nodal displacement (X direction) for all seven cases in Zone IV

S. No.	Building Cases	Nodal Displacement (X direction) (mm)	Worst Case
1	S1	83.163	Case S1
2	S2	62.301	
3	S3	49.290	
4	S4	46.915	
5	S5	48.215	
6	S6	48.203	
7	S7	48.256	

Optimal Case: When modifications to the regular building has implemented, Shear core outrigger and wall belt supported system shows the least value of nodal displacement parameter in X direction. Hence efficient case for this parameter will be S 4.

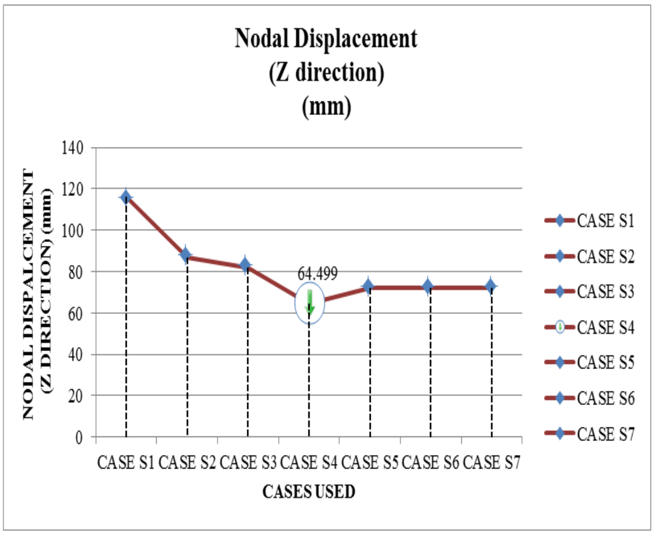


Graph-1: Comparison of maximum nodal displacement (in X direction) for all seven cases in Zone IV

Table -5: Maximum nodal displacement (Z direction) for all seven cases in Zone IV

S. No.	Building CASES	Nodal Displacement (Z direction) (mm)	Worst Case
1	S1	115.894	
2	S2	86.682	
3	S3	81.649	
4	S4	64.499	Case S1
5	S5	71.893	
6	S6	72.173	
7	S7	72.340	

Optimal Case: When modifications to the regular building has implemented, Shear core outrigger and wall belt supported system shows the least value of nodal displacement parameter in Z direction. Hence efficient case for this parameter will be S 4.



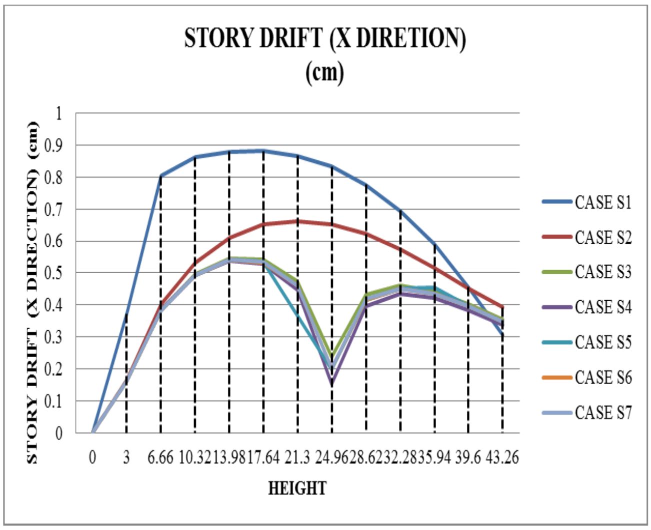
Graph-2: Comparison of maximum nodal displacement (in Z direction) for all seven cases in Zone IV

Table -6: Story drift (X direction) for all seven cases in Zone IV

S. No.	Height (m)	Storey Drift (cm) For X Direction				Worst Case
		CASE S1	CASE S2	CASE S3	CASE S4	
1	0	0	0	0	0	
2	3	0.3724	0.1652	0.1618	0.1633	
3	6.66	0.8024	0.4016	0.3848	0.3862	
4	10.32	0.8610	0.5310	0.4955	0.4946	
5	13.98	0.8793	0.6094	0.5453	0.5399	
6	17.64	0.8812	0.6505	0.5411	0.5283	
7	21.30	0.8660	0.6631	0.4733	0.4466	
8	24.96	0.8315	0.6523	0.2365	0.1537	
9	28.62	0.7753	0.6219	0.4313	0.3977	
10	32.28	0.6951	0.5750	0.4603	0.4361	
11	35.94	0.5891	0.5161	0.4429	0.4230	
12	39.60	0.4557	0.4523	0.4025	0.3849	
13	43.26	0.3072	0.3916	0.3536	0.3372	
S. No.	Height (m)	Storey Drift (cm)				Case S1
		For X Direction				
		CASE S5	CASE S6	CASE S7		
1	0	0	0	0		
2	3	0.1619	0.1618	0.1618		
3	6.66	0.3841	0.3839	0.3839		
4	10.32	0.4935	0.4932	0.4933		
5	13.98	0.5413	0.5410	0.5411		
6	17.64	0.5340	0.5337	0.5340		
7	21.30	0.3687	0.4608	0.4612		
8	24.96	0.2002	0.2010	0.2024		
9	28.62	0.4172	0.4172	0.4179		
10	32.28	0.4504	0.4502	0.4508		
11	35.94	0.4530	0.4348	0.4354		

12	39.60	0.3957	0.3955	0.3961		
13	43.26	0.3474	0.3472	0.3477		

Optimal Case: When modifications to the regular building has implemented, Shear core outrigger and wall belt supported system shows the least value of story drift parameter in X direction. Hence efficient case for this parameter will be S 4.

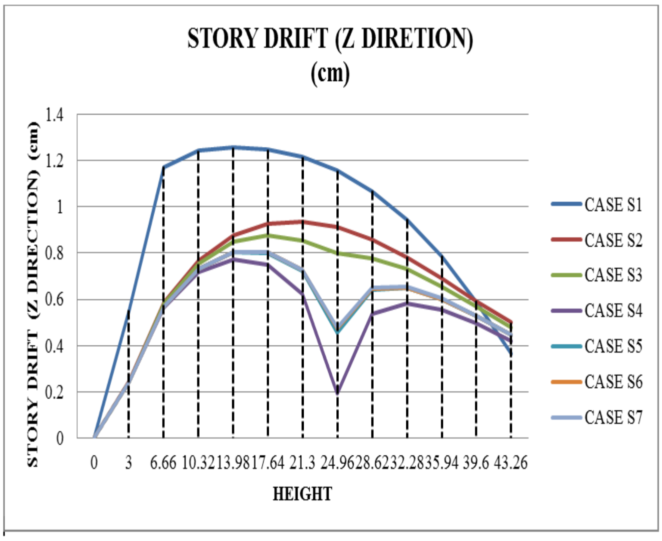


Graph-3: Comparison of story drift (X direction) for all seven cases in Zone IV

Table -7: Story drift (Z direction) for all seven cases in Zone IV

S. No.	Height (m)	Storey Drift (cm)				Worst Case
		For Z Direction				
		CASE S1	CASE S2	CASE S3	CASE S4	
1	0	0	0	0	0	Case S1
2	3	0.5520	0.2452	0.2444	0.2425	
3	6.66	1.1722	0.5880	0.5818	0.5653	
4	10.32	1.2415	0.7692	0.7547	0.7158	
5	13.98	1.2550	0.8746	0.8471	0.7734	
6	17.64	1.2466	0.9253	0.8769	0.7486	
7	21.30	1.2150	0.9347	0.8522	0.6233	
8	24.96	1.1568	0.9105	0.7980	0.1918	
9	28.62	1.0681	0.8580	0.7767	0.5373	
10	32.28	0.9456	0.7824	0.7307	0.5831	
11	35.94	0.7859	0.6900	0.6559	0.5557	
12	39.60	0.5865	0.5914	0.5672	0.4938	
13	43.26	0.3643	0.4988	0.4795	0.4194	
S. No.	Height (m)	Storey Drift (cm)				
		For Z Direction				
		CASE S5	CASE S6	CASE S7		
1	0	0	0	0		
2	3	0.2420	0.2419	0.2419		
3	6.66	0.5696	0.5695	0.5696		
4	10.32	0.7292	0.7293	0.7296		
5	13.98	0.8020	0.8027	0.8032		
6	17.64	0.8014	0.8033	0.8043		
7	21.30	0.7217	0.7263	0.7280		
8	24.96	0.4563	0.4719	0.4764		
9	28.62	0.6427	0.6472	0.6495		
10	32.28	0.6487	0.6504	0.6522		
11	35.94	0.6009	0.6013	0.6028		
12	39.60	0.5274	0.5270	0.5285		
13	43.26	0.4474	0.4466	0.4480		

Optimal Case: When modifications to the regular building has implemented, Shear core outrigger and wall belt supported system shows the least value of story drift parameter in Z direction. Hence efficient case for this parameter will be S 4.

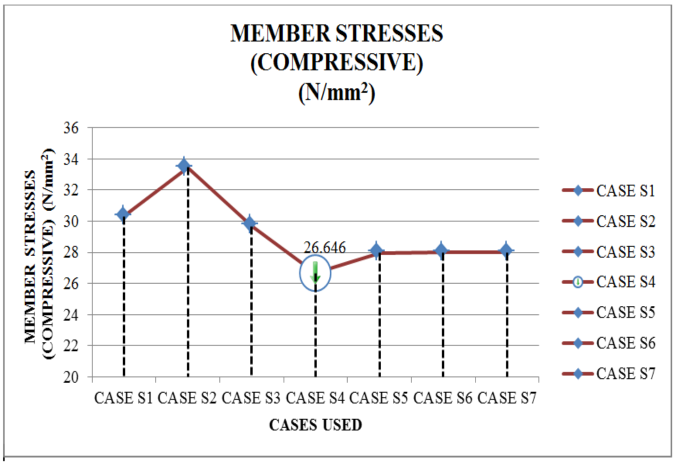


Graph-4: Comparison of story drift (Z direction) for all seven cases in Zone IV

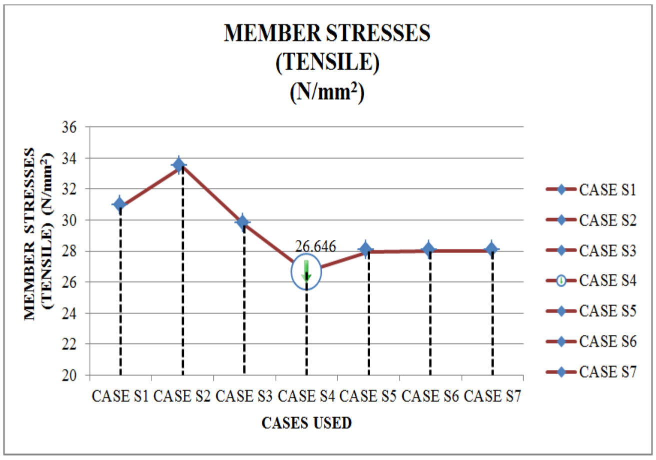
Table -8: Member stresses for all seven cases in Zone IV

S. No.	Building Cases	Member Stresses (N/mm^2)		Worst Case
		Compressive Stresses	Tensile Stresses	
1	S1	30.293	30.831	Case S1
2	S2	33.457	33.457	
3	S3	29.653	29.653	
4	S4	26.646	26.646	
5	S5	27.953	27.953	
6	S6	27.987	27.987	
7	S7	27.999	27.999	

Optimal Case: When modifications to the regular building has implemented, Shear core outrigger and wall belt supported system again shows the least value of member stress parameters. Hence efficient case for this parameter will be S 4.



Graph-5: Comparison of member compressive stresses for all seven cases in Zone IV



Graph-6: Comparison of member tensile stresses for all seven cases in Zone IV

Table -9: time period with participation factor in X and Z direction for case S1 in Zone IV

Mode No.	Time Period (Seconds)	Participation X (%)	Participation Z (%)
	CASE S1		
1	1.816	78.501	0
2	1.75	0	79.24
3	1.603	0	0
4	0.593	11.167	0
5	0.575	0	10.544
6	0.529	0	0

Table -10: Time period with participation factor in X and Z direction for case S2 in Zone IV

Mode No.	Time Period (Seconds)	Participation X (%)	Participation Z (%)
	CASE S2		
1	1.499	73.194	0
2	1.443	0	74.039
3	1.394	0	0
4	0.462	0	0
5	0.44	13.62	0
6	0.429	0	12.872

Table -11: Time period with participation factor in X and Z direction for case S3 in Zone IV

Mode No.	Time Period (Seconds)	Participation X (%)	Participation Z (%)
	CASE S3		
1	1.404	0	74.902
2	1.387	0	0
3	1.341	76.342	0
4	0.459	0	0
5	0.427	10.745	0
6	0.426	0	12.142

Table -12: Time period with participation factor in X and Z direction for case S4 in Zone IV

Mode No.	Time Period (Seconds)	Participation X (%)	Participation Z (%)
	CASE S4		
1	1.331	0	0
2	1.316	77.589	0
3	1.264	0	78.727
4	0.435	0	0
5	0.424	9.6	0
6	0.411	0	8.447

Table -13: Time period with participation factor in X and Z direction for case S5 in Zone IV

Mode No.	Time Period (Seconds)	Participation X (%)	Participation Z (%)
	CASE S5		
1	1.334	0	0
2	1.329	76.773	0
3	1.324	0	76.777
4	0.439	0	0
5	0.425	10.332	0
6	0.418	0	10.278

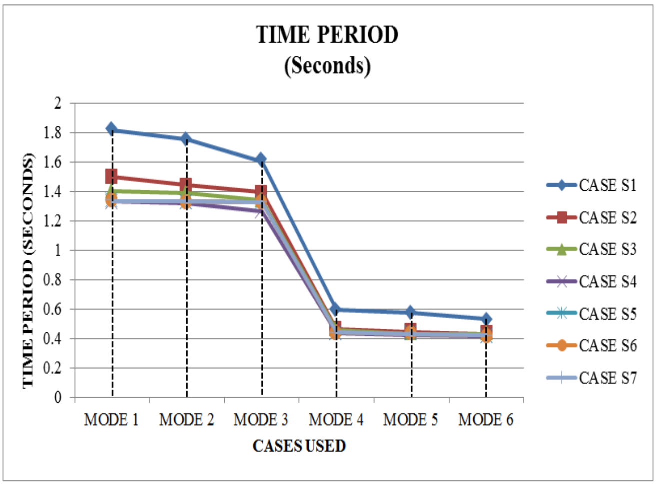
Table -14: Time period with participation factor in X and Z direction for case S6 in Zone IV

Mode No.	Time Period (Seconds)	Participation X (%)	Participation Z (%)
	CASE S6		
1	1.334	0	0
2	1.329	76.758	0
3	1.327	0	76.696
4	0.439	0	0
5	0.425	10.343	0
6	0.418	0	10.353

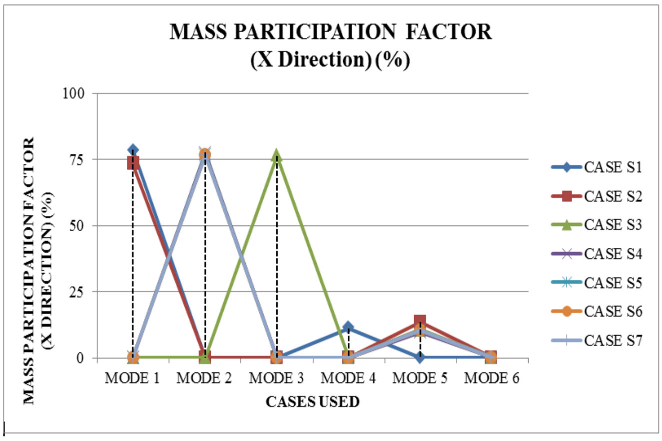
Table -15: Time period with participation factor in X and Z direction for case S7 in Zone IV

Mode No.	Time Period (Seconds)	Participation X (%)	Participation Z (%)
	CASE S7		
1	1.334	0	0
2	1.329	76.736	0
3	1.328	0	76.656
4	0.439	0	0
5	0.425	10.368	0
6	0.418	0	10.398

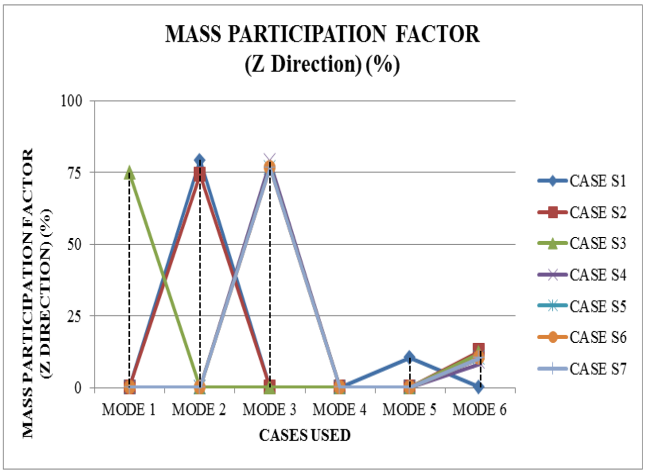
Optimal Case: Since when there will be more members in structure, the mass participation will increase. But the main criteria is to stable the structure from movement shown by each mode. The shear core outrigger and wall belt supported system in this parameter shows the least values results the reduction in time period. Hence efficient case for this parameter will be S 4.



Graph-7: Comparison of time period for all seven cases in Zone IV



Graph 8: Comparison of mass participation factor (in X direction) for all seven cases in Zone IV



Graph-9: Comparison of mass participation factor (in Z direction) for all seven cases in Zone IV

5. CONCLUSIONS

Conclusions evolved by analyzing the result data of various parameters are as follows:-

- Under the effect of earthquake forces, the wall belt will hold the entire building for stability and the forces transferred through the outriggers to the ground.
- Nodal displacement in X direction and Z direction shows least value when shear core outrigger and wall belt supported system will be used.
- For all cases in X and Z directions, story drift at height 24.96 m from foundation level, seems to be the lowest. This is because; the belt is at 24.96 m height holds the entire structure. Case S4 again shows least values among all.
- Compressive and tensile stresses in members seem to be the lowest in shear core outrigger and wall belt

supported system. Again stresses transfer from outer to the center of the structure.

- Time period for case S4 is least of all the cases taken for analysis. After modal analysis, Mode no. 1, 2 and 3 shows greater mass participation factors in X and Z directions.

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