DYNAMIC ANALYSIS OF A RCC BUILDING WITH CORE AND EDGE SHEAR WALL UNDER DIFFERENT EARTHQUAKE ZONES USING ETABS

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Abstract

The primary objective of earthquake engineers is to design and build a structure to such a degree that damage to the structure and its component during the earthquake is insignificant. This paper aims towards the dynamic analysis of multi storey building with shear walls under the Earthquake zones II, III, IV and V. For the analysis purpose, models of G +14 storey RCC building with core shear wall and another model of G+14 storey RCC building with edge shear walls are considered. The area of building considered is 36mX22.5m. The dynamic analysis of building is carried out with the FE based software ETABSv9.7.4 under different earthquake zones. Estimation of response such as; storey shear, storey drift and lateral storey displacement is carried out. For dynamic analysis time history method or response spectra method is used. In present paper, dynamic analysis is done by Response Spectrum method. ETABS (Extended Three dimensional Analysis of Building Systems) software is commonly used to analyze: Skyscrapers, low and high rise buildings, parking garages, steel & concrete structures and portal frame structures.

Keywords: Dynamic effect, storey shear, storey drift and lateral storey displacement.

1. INTRODUCTION

Various civil structures are primarily based on normative method of building codes and loads which follow up on the structure are very low and giving in elastic structural behavior. A structure can be subjected to the force greater than the elastic limit. The structural safety against earthquake related to the structural design of building for seismic loads. The earthquake loading behavior is different from wind loading and gravity loading which requires detail analysis to reach the acceptable elastic range in the structure. The mathematical model of a building in Dynamic Analysis strength is determined when mass, stiffness and inelastic properties are assigned. The analysis should be executed for symmetrical and unsymmetrical buildings also. The main objective is to create awareness about dynamic effect on the building with the help of ETABSv9.7.4 software and it also depicts good response of building under dynamic loading and minimizes the hazard to the life for all structures.

Structural design of buildings for seismic loads is mainly concerned with the structural safety during major ground motions. A complete conceptual view of structural performance under huge plastic deformations is essential for Earthquake loading. Building behavior under this loading is different from the wind loading or gravity loading. It demands more detailed analysis to ensure satisfactory seismic performance in outside the elastic range. When a structure experiences design ground motions, some structural damage can be expected, because in the structural systems almost all building codes permit inelastic energy dissipation. The primary step in dynamic analysis of building is to develop a mathematical model of the building, by means of which figures of strength, stiffness and inelastic member properties are assigned.

1.1 Dynamic analysis

Dynamic analysis is one of the types of analysis which includes structural behavior subjected to Dynamic loadings i.e. actions having high acceleration. Dynamic analysis is also related to resistance forces developed by the structure, when the structure is excited by sudden dynamic loads. Dynamic analysis of simple structures can be done manually, however for complex structures finite element analysis is used. ETABS is a FE (finite element) based software and it provides static and dynamic analysis for wide range of gravity and lateral loads.

This analysis mainly deals with the study of a rectangular plan of G+14 storey RCC building and is modeled using ETABS. The height of each storey of the building is taken as 3m, making total height of the structure as 45m above plinth level. Loads considered are taken according to the IS-875(Part1, Part2), IS-1893:2002 code and load combinations in accordance with IS-875(Part5).

1.2 Shear walls

It is a structural system composed of braced panels to oppose the effects of lateral loads acting on a structure. Shear wall is called as shear panels. Shear wall are designed to carry wind loads and earthquake loads. Shear walls opposes flat loads that are applied on its height.

Shear wall sections are classified as six sections

1. L-section
2. T-section
3. H-section
4. U-section
5. W-section and
6. Box section

In the present dynamic analysis L-type sections and box sections are used. For core shear wall box type section and for edge shear wall L type section shear walls are used.

Core shear wall: Shear walls are provided at the centre or core of the building.

Edge shear wall: Shear walls are provided at the corners or edges of the building.

1.3 Objectives:

- The principal objective of this project is to check and compare the dynamic response of G+14 building with core and edge shear walls under different seismic zones.
- Core shear wall building model and edge shear wall building will be modeled in ETABSv9.7.4 software and the results in terms of storey drifts, lateral storey displacements and storey shears are compared.
- Comparison is to be made between core and edge shear wall building models in all Earthquake Zones i.e. Zones II, III, IV and V.

2. METHODOLOGY

Various methods of seismic analysis are described as follows

- Equivalent Static Analysis (Linear Static)
- Pushover Analysis (Nonlinear Static)
- Response Spectrum Analysis (Linear Dynamic)
- Time History Analysis (Nonlinear Dynamic)

Response spectrum analysis is one of the dynamic methods of analysis. Minimum 3 response modes of the structure should be considered except in the cases where it can be shown qualitatively that either second or third mode produces least response. There are computational advantages in response spectrum method of seismic/earthquake analysis for anticipation of displacements and member forces in structural systems. The method includes the evaluation of only the highest values of the displacements and member forces in each mode of vibration using smooth design spectrum that are the mean of several earthquake motions.

For the present dynamic analysis, response spectrum analysis method is used in the FE based software ETABS. This analysis is carried out according to IS: 1893 - 2002 (1) in which type of soil, seismic zone factor should be entered from IS: 1893 - 2002 (1).

2.1 Loads considered

Gravity loads

Gravity loads are the loads which act vertically on the structure. The weight of the structure, human occupancy and snow are all types of loads that need to have a complete load path to the ground.

Lateral loads:

Lateral loads are the horizontal forces that are act on a structure. Wind loads and earthquake loads are the main lateral loads act on structures.

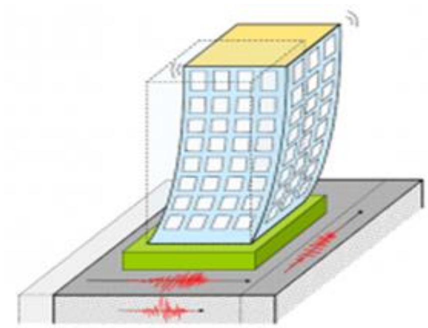

Fig 1: Behavior of building under Earthquake

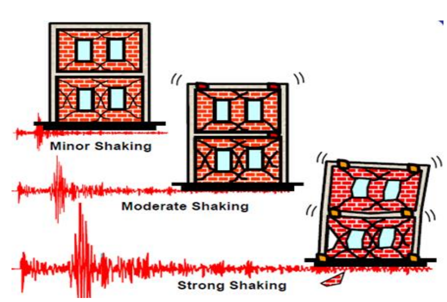

Fig 2: Performance under different intensities of Earthquake

3. ETABS

ETABS stands for Extended Three dimensional Analysis of Building Systems. And it is a structural analysis and design package.

Facilities:

- Various responses
- Object based modeling
- Automates templates
- Optimization of steel section.
- Design of composite beam

Models:
1. G+14 storey RCC building with edge shear wall (ESW model)
2. G+14 storey RCC building with core shear wall (CSW model)

3.1 Data required for modeling:

Table 1: Data for modeling of building

Geometric data	
Element	15 Storeys (including Ground storey)
Type of frame	OMRF (ordinary moment resisting frame)
Area of building	36mX22.5m
Number of bays in x-direction	6
Number of bays in y-direction	5
Spacing between frames in x– direction	6m
Spacing between frames in Y– direction	4.5m
Plinth height	1.5m
Storey height	3m
Material data	
Concrete:	
Grade of concrete	M25
Characteristic strength (f_{ck})	25 N/mm^2
Unit weight (γ_{ck})	24 kN/m^3
Steel:	
Steel – Fe500	Fe 500
Yield strength (f_y)	500 N/mm^2
Unit weight of steel (γ_y)	78.5 kN/m^3
Brick masonry:	
Unit weight of brick masonry	20 kN/m^3
Earthquake Data	
Earthquake zones	ZONE – II
	ZONE – III,
	ZONE – IV and
	ZONE – V.
Importance Factor (I)	1.5
Damping	5 Percent
Type of Soil	Medium (Type-2)
Seismic zone factor (z)	ZONE II – 0.10
	ZONE III – 0.16
	ZONE IV – 0.24
	ZONE V – 0.36
Loading Data	
Floor finish	1 kN/m^2
Live load	2 kN/m^2
Wall load	12 kN/m
Member sizes	
Size of Beam	230mm X 500mm
Size of Plinth beam	230mm X 300mm
Size of Column	300mm X 500mm
Depth of Slab	125mm
Thickness of Shear wall	230mm
Thickness of wall	230mm
Clear cover for beams	25mm
Clear cover for columns	40mm

Wind load is calculated from the wind speed and wind speed is considered as 50 m/sec for both the models in all Earthquake zones

4. MODELLING IN ETABS

Core shear wall is provided at the central portion of the building and edge shear wall is provided at the four corners of the building.

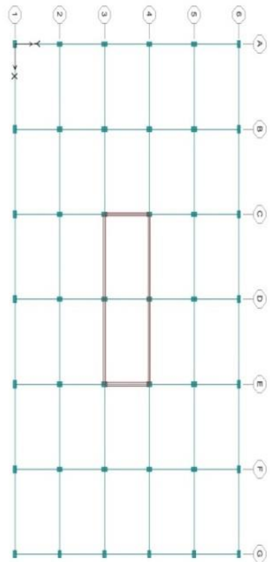

Fig 3: plan view of G+14 storey RCC building with CSW

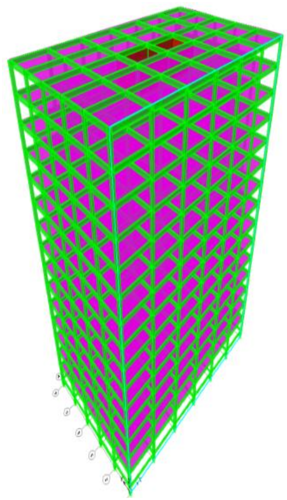

Fig 4: 3D elevation of G+14 storey RCC building with CSW

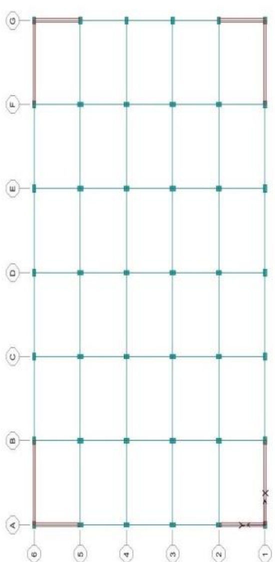

Fig 5: plan view of G+14 storey RCC building with ESW

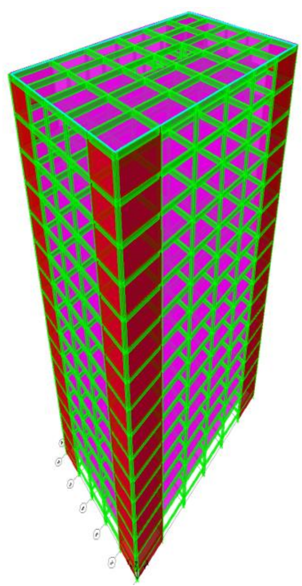

Fig 6: 3D elevation view of G+14 storey RCC building with ESW

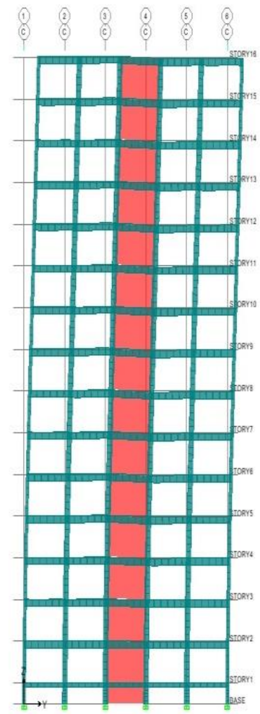

Fig 7: Deformed shape of G+14 storey CSW model in y-direction

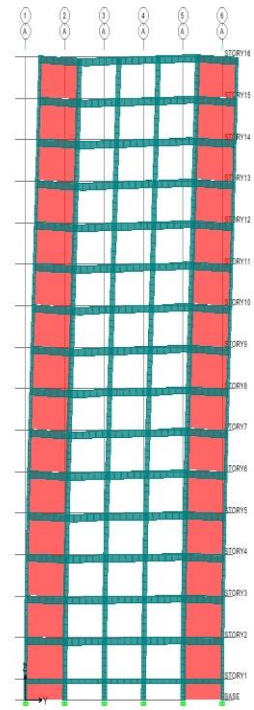

Fig 8: Deformed shape of G+14 storey ESW model in y-direction

5. RESULTS AND DISCUSSIONS

5.1 Analysis of Storey drifts

Storey drift is the displacement of the storey. It is the drift of one level of a multistory building relative to the level of below storey. The drift values are maximum in Y-direction because the load acting area is higher.

Table 2: Maximum storey drifts (meters) in ESW and CSW models in ZONE –II and ZONE - III

Storey. No	**Seismic Zone – II**		**Seismic Zone – III**	
	ESW	**CSW**	**ESW**	**CSW**
1	0.000177	0.000218	0.000252	0.00031
2	0.000281	0.00033	0.000447	0.00052
3	0.000435	0.000444	0.000695	0.00071
4	0.000579	0.000569	0.000924	0.00091
5	0.000696	0.00067	0.001111	0.001071
6	0.000789	0.000751	0.00126	0.001201
7	0.000861	0.000815	0.001377	0.001304
8	0.000915	0.000863	0.001463	0.001381
9	0.000952	0.000896	0.001522	0.001433
10	0.000973	0.000915	0.001556	0.001464
11	0.00098	0.000922	0.001567	0.001474

12	0.000977	0.000917	0.001561	0.001466
13	0.000963	0.000902	0.001539	0.001443
14	0.000942	0.000881	0.001505	0.001409
15	0.000929	0.000857	0.001477	0.001371
16	0.000944	0.000828	0.001481	0.00131

Table 3: Maximum storey drifts (meters) in ESW and CSW models in ZONE –IV and ZONE - V

St.. No	**Seismic Zone – IV**		**Seismic Zone – V**	
	ESW	**CSW**	**ESW**	**CSW**
1	0.000351	0.000431	0.000351	0.000431
2	0.000668	0.000774	0.000668	0.000774
3	0.001042	0.001064	0.001042	0.001064
4	0.001385	0.001365	0.001385	0.001365
5	0.001665	0.001607	0.001665	0.001607
6	0.001889	0.001802	0.001889	0.001802
7	0.002063	0.001955	0.002063	0.001955
8	0.002193	0.002071	0.002193	0.002071
9	0.002281	0.00215	0.002281	0.00215
10	0.002333	0.002196	0.002333	0.002196
11	0.00235	0.002211	0.00235	0.002211
12	0.00234	0.002199	0.00234	0.002199
13	0.002307	0.002164	0.002307	0.002164
14	0.002256	0.002112	0.002256	0.002112
15	0.002208	0.002056	0.002208	0.002056
16	0.002197	0.001958	0.003272	0.00293

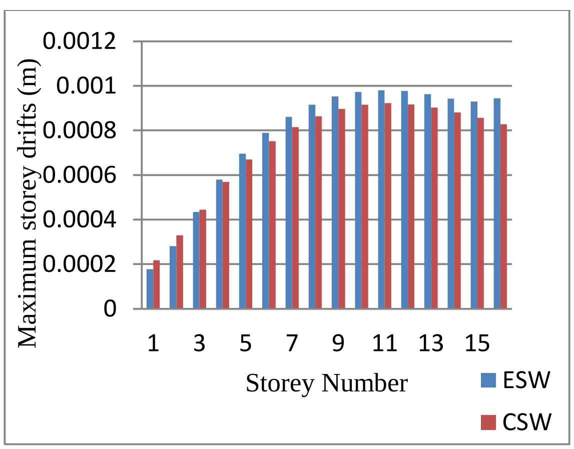

Fig 9: Maximum storey drift in Seismic ZONE – II

Fig 10: Maximum storey drift in Seismic ZONE – III

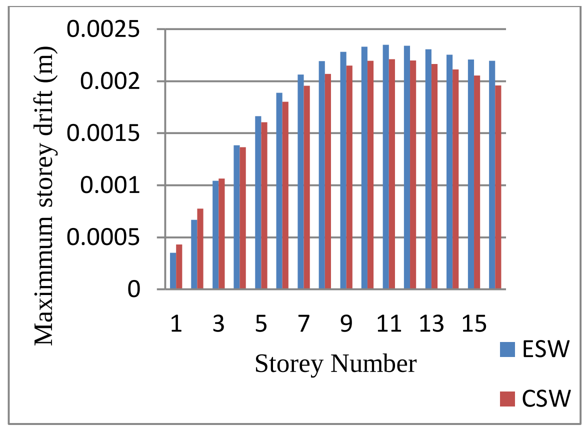

Fig 11: Maximum storey drift in Seismic ZONE – IV

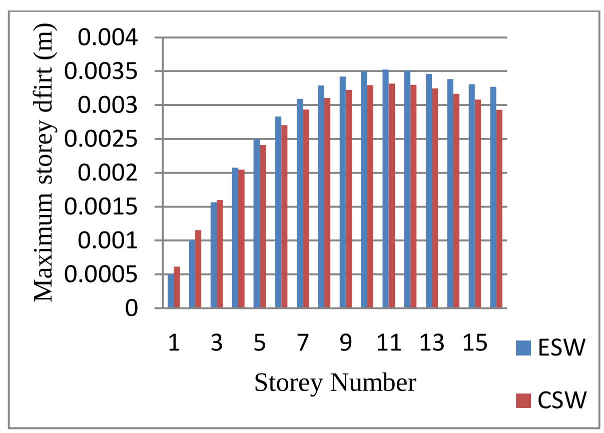

Fig 12: Maximum storey drift in Seismic ZONE – V

By the above graphs, In Zones II, III, IV and V in both the models the maximum storey drifts occur at storey 11.

The maximum permissible storey drift (IS 1893-2002) is 0.004 times the storey height.

Maximum permissible storey drift = 0.004 X 3 = 0.012 m

Table 4: Maximum storey drifts (meters) in ESW and CSW models in all Earthquake Zones

ZONE	ESW	CSW
ZONE-II	0.00098	0.000922
ZONE-III	0.001567	0.001474
ZONE-IV	0.00235	0.002211
ZONE-V	0.003524	0.003316

The storey drifts in Edge shear wall model are slightly greater than Core shear wall model which are not significant. The maximum storey drifts are within permissible limit, which are less than 0.012m.

Comparison graphs of storey drifts in edge and core shear wall under different earthquake zones:

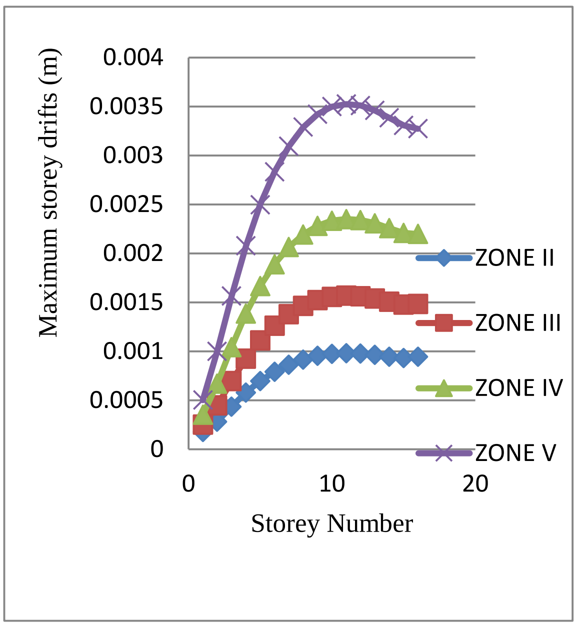

Fig 13: comparison of storey drifts (m) in all earthquake zones for Edge shear wall model

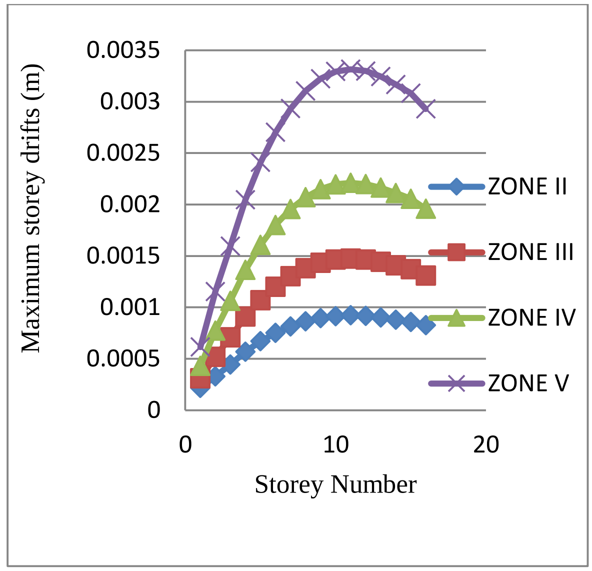

Fig 14: comparison of storey drifts (m) in all earthquake zones for Core shear wall model

The maximum storey drifts(y-direction) were observed In edge shear wall model are increased to 5.22%, 5.11%, 5.02% and 4.98% as compared to the Core Shear wall model in Zone II, III, IV and V respectively

The maximum storey drifts of Edge Shear wall in ZONE – III, compared to ZONE – II is increased by 59.25%. The maximum storey drifts of Core Shear wall in ZONE – IV, compared to ZONE – III is increased by 49.60%. The maximum storey drifts of Edge Shear wall in ZONE – V, compared to ZONE – IV is increased by 49.75%.

The maximum storey drifts of Core Shear wall in ZONE – III, compared to ZONE – II is increased by 59.42%. The maximum storey drifts of Core Shear wall in ZONE – IV, compared to ZONE – III is increased by 49.73%. The maximum storey drifts of Core Shear wall in ZONE – V, compared to ZONE – IV is increased by 49.81%.

5.2 Analysis of lateral storey displacements

Lateral displacements are produced by laterals loads that are acting on the structure. The considered lateral displacements are in y-direction.

Table 5: Maximum Lateral storey displacements (m) in ESW & CSW models in ZONES II & III

Storey.	**Seismic Zone – II**	**Seismic Zone – III**

No	ESW	CSW	ESW	CSW
1	0.0003	0.0003	0.0004	0.0004
2	0.001	0.0012	0.0016	0.0018
3	0.0023	0.0025	0.0036	0.0039
4	0.0041	0.0042	0.0064	0.0067
5	0.0061	0.0062	0.0097	0.0099
6	0.0085	0.0085	0.0135	0.0135
7	0.011	0.0109	0.0176	0.0174
8	0.0138	0.0135	0.022	0.0216
9	0.0166	0.0162	0.0265	0.0259
10	0.0195	0.0189	0.0312	0.0302
11	0.0224	0.0217	0.0359	0.0347
12	0.0254	0.0244	0.0406	0.0391
13	0.0282	0.0271	0.0452	0.0434
14	0.0311	0.0298	0.0497	0.0476
15	0.0338	0.0323	0.0541	0.0517
16	0.0366	0.0347	0.0585	0.0555

Table 6: Maximum Lateral storey displacements (m) in ESW & CSW models in ZONES IV & V

Storey. No	Seismic Zone – IV		Seismic Zone – V	
	ESW	CSW	ESW	CSW
1	0.0005	0.0006	0.0017	0.0008
2	0.0023	0.0027	0.0035	0.0041
3	0.0054	0.0059	0.0081	0.0089
4	0.0096	0.01	0.0143	0.015
5	0.0145	0.0148	0.0218	0.0222
6	0.0202	0.0203	0.0303	0.0304
7	0.0263	0.0261	0.0395	0.0392
8	0.033	0.0323	0.0494	0.0485
9	0.0398	0.0388	0.0596	0.0582
10	0.0468	0.0454	0.0701	0.0681
11	0.0538	0.052	0.0807	0.078
12	0.0608	0.0586	0.0912	0.0879
13	0.0677	0.0651	0.1016	0.0976
14	0.0745	0.0714	0.1117	0.1071
15	0.0811	0.0776	0.1216	0.1164
16	0.0876	0.0832	0.1314	0.1248

Fig 15: Lateral storey displacement in Seismic ZONE – II

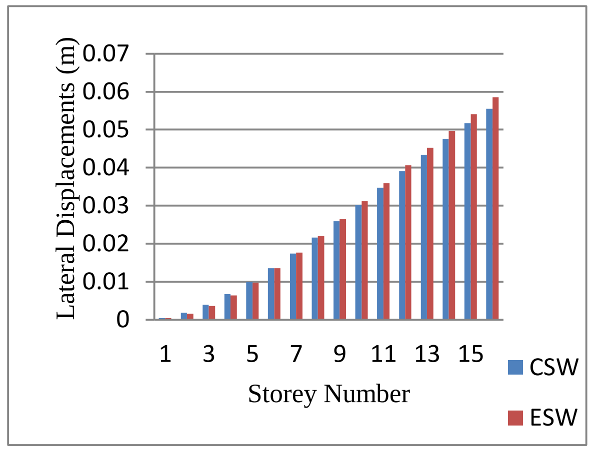

Fig 16: Lateral storey displacement in Seismic ZONE – III

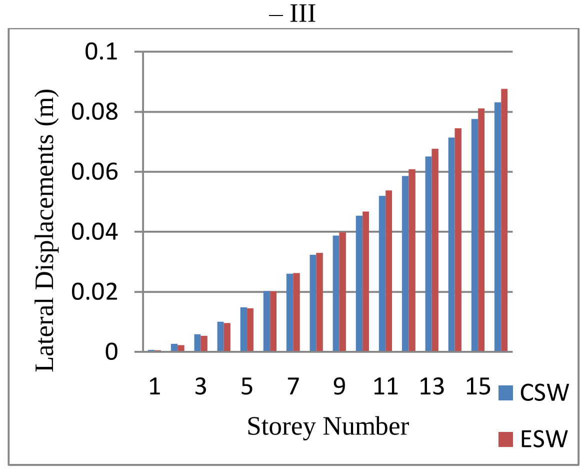

Fig 17: Lateral storey displacement in Seismic ZONE – IV

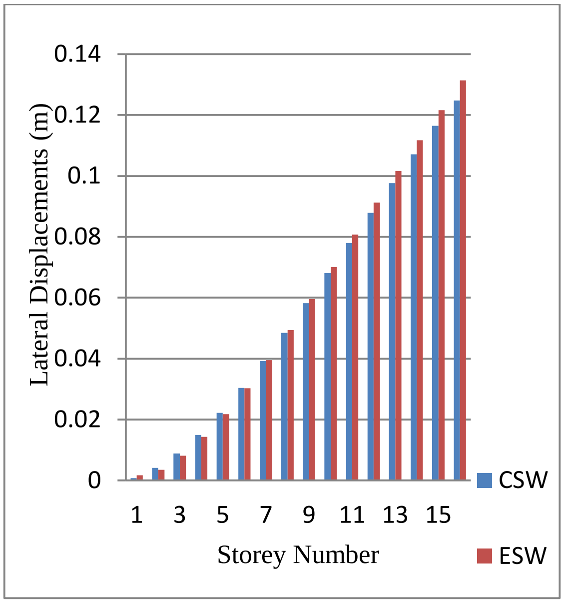

Fig 18: Lateral storey displacement in Seismic ZONE – V

Comparison graphs of lateral storey displacements in edge and core shear wall models under different earthquake zones:

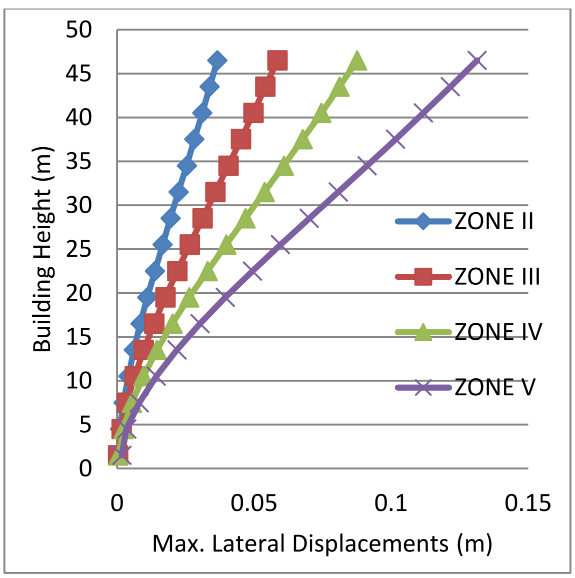

Fig 19: distribution of lateral storey displacements (m) along the height of building in all earthquake zones for ESW model

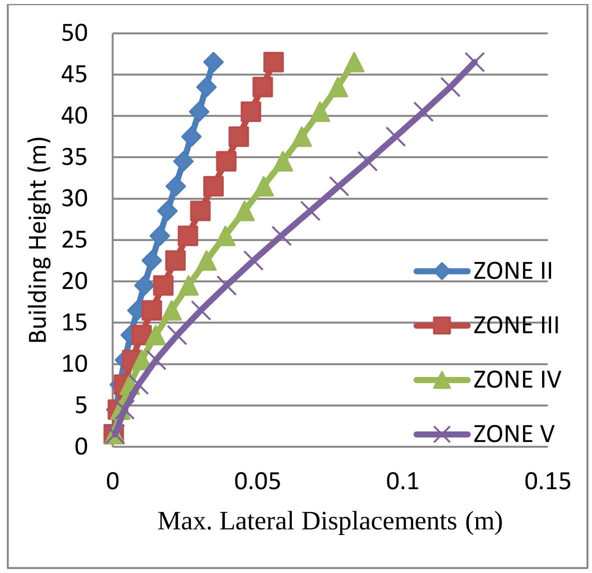

Fig 20: distribution of lateral storey displacements (m) along the height of building in all earthquake zones for CSW model

From the above graphs it is observed that the lateral storey displacements of core shear wall model are reduced to some extent compared to other model in both X and Y directions, while the maximum displacements are limited by providing shear wall.

The lateral displacements were observed In edge shear wall model are increased to 3.28%, 3.27%, 3.15% and 3.23% as compared to the core Shear wall model in Zone II, III, IV and V respectively.

Comparing with Zone II, lateral displacements are increased to 37.5%, 58% and 72% in Zones III, IV and V respectively in both the models.

5.3 Analysis of Storey Shear:

The maximum storey shears in both the models in X & Y directions are equal under worst load combination

Table 7: Maximum Storey shears (kN) in ESW & CSW models in ZONES II & III

Storey Number	Seismic Zone – II		Seismic Zone – III	
	ESW	CSW	ESW	CSW
BASE	0	0	0	0
1	2593.37	2646.02	4149.4	4233.63
2	2593.37	2646.02	4149.4	4233.63
3	2591.26	2643.82	4146.02	4230.19
4	2582.82	2635.26	4132.51	4216.42
5	2563.82	2615.9	4102.11	4185.44
6	2530.04	2581.48	4048.07	4130.36
7	2477.27	2527.69	3963.62	4044.30
8	2401.27	2450.23	3842.03	3920.37

9	2297.82	2344.81	3676.52	3751.59
10	2162.72	2207.11	3460.35	3531.37
11	1991.72	2032.83	3186.75	3252.53
12	1780.61	1817.68	2848.98	2908.29
13	1525.18	1557.34	2440.28	2491.75
14	1221.18	1247.52	1953.89	1996.04
15	864.41	883.91	1383.06	1414.26
16	450.65	462.21	721.03	739.54

Table 8: Maximum Storey shears (kN) in ESW & CSW models in ZONES IV & V

Storey Number	ZONE - IV		ZONE - V	
	ESW	CSW	ESW	CSW
BASE	0	0	0	0
1	6224.1	6350.45	9336.14	9525.68
2	6224.1	6350.45	9336.14	9525.68
3	6219.03	6345.29	9328.15	9517.93
4	6198.76	6324.63	9298.15	9486.95
5	6153.16	6278.16	9229.75	9417.24
6	6072.1	6195.54	9108.15	9293.31
7	5945.44	6066.45	8918.15	9099.67
8	5763.04	5880.56	8644.25	8820.83
9	5514.78	5627.54	8272.15	8441.3
10	5190.52	5297.06	7785.78	7945.59
11	4780.13	4878.8	7170.2	7318.20
12	4273.48	4362.43	6410.21	6543.65
13	3660.42	3737.6	5490.63	5606.44
14	2930.84	2994.06	4936.26	4491.08
15	2074.59	2121.39	3111.89	3182.09
16	1081.55	1109.31	1622.23	1663.97

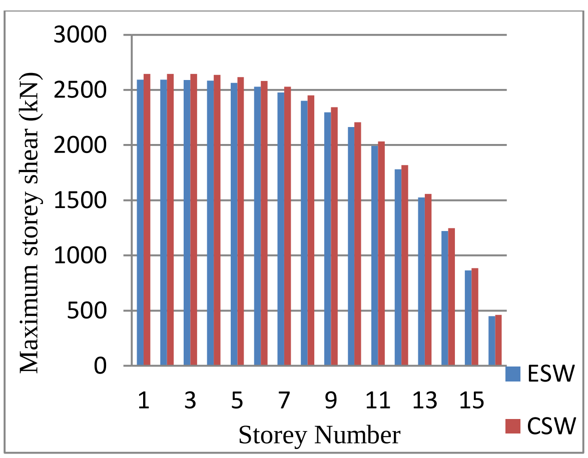

Fig 21: Maximum storey shear graph in Seismic ZONE – II

Fig 22: Maximum storey shear graph in Seismic ZONE – III

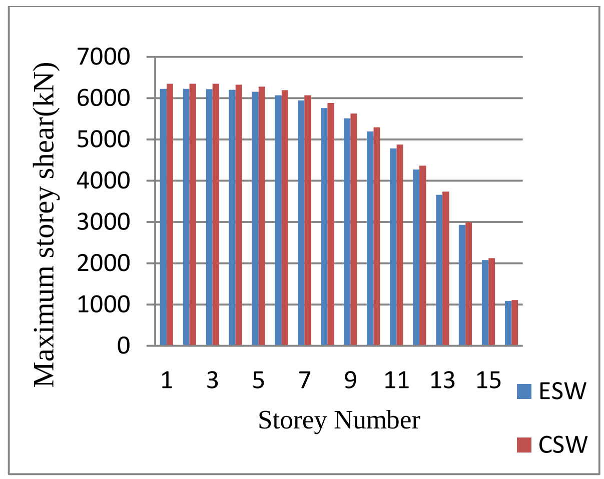

Fig 23: Maximum storey shear graph in Seismic ZONE – IV

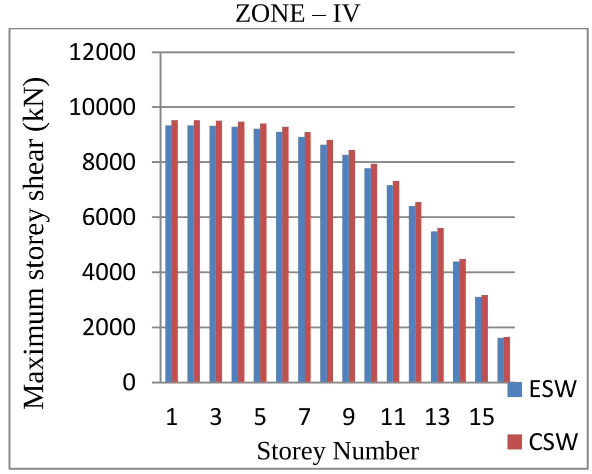

Fig 24: Maximum storey shear graph in Seismic ZONE – V

In all Earthquake zones II, III, IV and V in both the models the maximum storey shears are occurred at storey 1.

Comparison graphs of storey shears in edge and core shear wall under different earthquake zones:

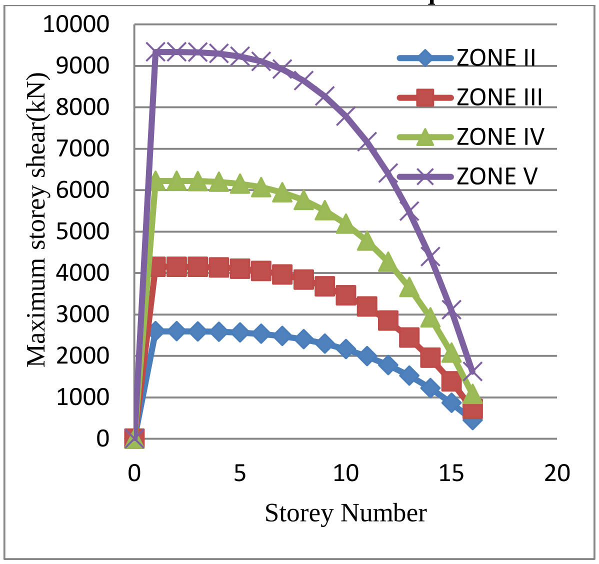

Fig 25: Comparison of storey shear (kN) in all earthquake zones for edge shear wall

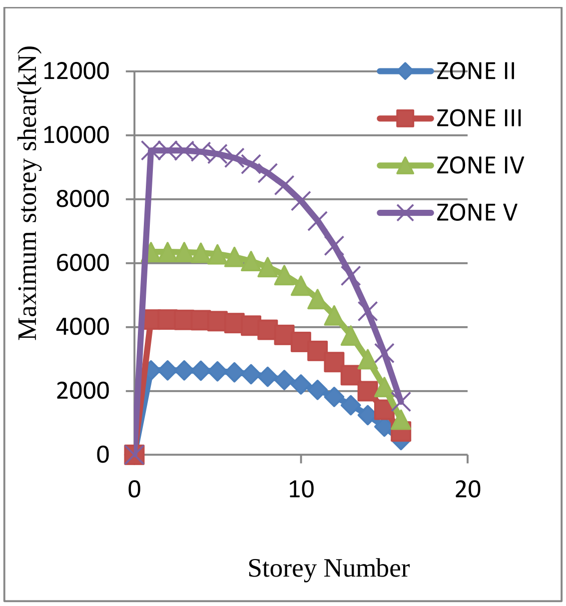

Fig 26: comparison of storey shear (kN) in all earthquake zones for edge shear wall

According to the above two graphs it is clear that storey shear values are increasing with increasing earthquake zone number in both the models.

The storey shears in building with core shear wall are greater than, when compared to the building with edge shear walls in all Earthquake Zones. The maximum storey shears are reduced in edge shear wall model as 2% in all seismic zones compared to core shear wall model.

While comparing with zone II, storey shears are increased to 37.5%, 59% and 72% in Zones III, IV and V respectively in both the models.

In all earthquake zones under consideration, the maximum storey shears are higher in the building model with core shear wall compared to the maximum storey shears in the building model with edge shear walls which are provided at the four edges/corners of the building.

6. CONCLUSION

1. The dynamic analysis of building with core shear wall and building with edge shear walls are done and compared at earthquake zones II, III, IV and V using ETABSv9.7.4.
2. Among all the load combinations, the load combination of 1.5DL±1.5EQy is found to be more critical combination for the both models.
3. In all Earthquake zones, storey drifts in both the models are found to be within the permissible limits as specified by IS 1893-2002, part1.
4. The storey drift is highly affected by provision and location of shear wall in the building. In the Earthquake Zones II, III, IV&V the Edge shear wall building model has higher storey drifts compared to Core shear wall building model. In which, the storey drifts in Y-direction are greater than those in X – direction.
5. The lateral displacements of the building in different Storeys for all Earthquake zones are found to be reduced in core shear wall model compared to edge shear wall model.
6. It is observed that in all Storeys at all earthquake zones the storey shear in Core shear wall building model is comparatively higher than Edge shear wall building model.
7. In the building model, where shear wall is provided at core resulting in lower drifts and higher storey shear hence vulnerable to Earthquake.
8. In the building model, where shear wall is provided at corners (edge) resulting in higher drifts and lower storey shear hence less vulnerable to Earthquake.

7. REFERENCES

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