A COMPARATIVE STUDY ON SEISMIC BEHAVIOUR OF MULTI-STOREYED RC BUILDING IN DIFFERENT ZONES CONSIDERING SHEAR WALL

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Abstract - *An earthquake is an abrupt expulsion of energy produced by crashing tectonic plates and volcanic explosions in earth's outer layer. Shear wall is orthogonally arranged wide beams along with slabs, beams and columns thereby, resisting the in-plane lateral loads which are induced due to wind and earthquake. In present study, the influence of shear wall in different zones on performance of G+13 storey RC building due to seismic forces is investigated using ETABS software (Version 2017). Two models were modelled and analysed for all the four zones of India and medium soil considering shear wall. The RC framed structure without shear wall was considered (i.e. M1). And for the same plan, RC framed structure considering shear wall was modelled (i.e. M2). The comparative study is done for both the models on the basis of storey shear, storey displacement & storey drift which are obtained by equivalent static analysis and response spectrum analysis. Seismic parameters such as story displacement, storey drift ratio, storey shear, base shear, time period for the 12th mode of vibration are found out using IS 1893-Part 1 (2002) code by Equivalent Static Analysis (ESA) and Response Spectrum Analysis (RSA) for zone II, zone III, zone IV and zone V. Among all the above models of the developed RC framed structure considered in the present study, the M2 having shear wall in the RC structure shows lesser storey displacement, storey drift and increases the base shear thereby making the structure to be safest against seismic forces.*

***Key Words*: ETABS, G+13, Zones, Shear wall, Equivalent Static Analysis, Response Spectrum Analysis.**

1. INTRODUCTION

1.1 GENERAL

The gigantic tectonic plate action that takes place in the earth's crust leads to the disfigurement of rocks. During this process, as the rock material is elastic in nature the elastic strain energy is deposited in them. The rock is very hard material and can be broken easily. The weaker region in rocks reach their strength, a sudden movement in earth crust causes a crack in the opposite sides of fault. It releases large amount of elastic strain energy deposited in the boundary of rocks causing ground shaking. Earthquake results in dislodgment of the earth's layer. Glancing at the past records of earthquake, earthquake resisting building with the shear wall systems have greater demands.

RC Multi-Storey Buildings sufficiently withstand the perpendicular and parallel load. In this sort of buildings, the beam and column sizes are overwhelming. At their junctions, clogging take place so it's problematic in laying the concrete and quiver at these joints. During earthquake, heavy forces are induced due to the deformation. Due to the lateral forces, deformation takes place in frames and wall behaves like a vertical cantilever with the primary winding distortions. Shear wall is widely used as it is economical and controls lateral deflection. If shear wall is well planned and built correctly, then it has good ability to resist the horizontal forces. It is firm erect diaphragm which transfers forces coming laterally to structural elements and then to the foundation. When tall buildings are exposed to wind and seismic forces, a special importance is given to shear wall.

Lateral load causes sway and high stress. It's very essential that structure have sufficient strength against gravity loads. Energy induced by horizontal load should be absorbed by deforming the structure without any collapse. The structures should be designed such that no harm is caused to them during the strong earthquake. When buildings are not damaged during strong seismic tremor, engineers do not make an effort to build earthquake proof buildings which is sturdy and also costly. The perspective of the seismic resistant design is to construct structure which performs elastically and exist without failure throughout the life of structure under major earthquakes. The structure ought to be more ductile to engross and dissolve energy by post-elastic deformation to evade collapse during ground shaking.

1.2 SEISMIC ZONES OF INDIA

In accordance with IS 1893-Part 1 (2002), it is divided into four zones which are distinguished below. The figure 1.1 shows seismic zone map of India. Where Z = zone factor,

a) Zone II: Here, Less damage occurs to structures. (Z = 0.1)
b) Zone III: The value of Z is 0.16 and average destruction of structures happens in this zone.
c) Zone IV: The critical Damage takes place here. (Z = 0.24)
d) Zone V: It is acquired by the areas which are suffering from very acute destruction. (Z = 0.36)

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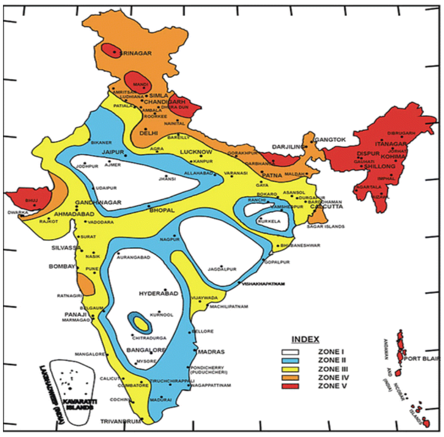


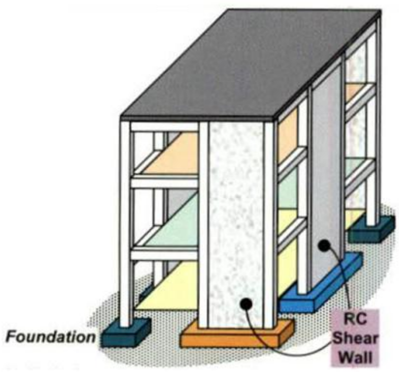
Fig. 1.1: **Seismic zoning map of India according to IS 1893-Part 1(2002)**

1.3 SHEAR WALL

Shear wall is orthogonally arranged wide beams along with slabs, beams and columns thereby, resisting the in-plane lateral loads which are induced due to wind and earthquake. Thickness varies from 150mm to 400 mm. They run from the footing to the altitude of the structure. Plane stiffness and lateral strength are high so it is strong enough to resist large horizontal loads. As shear wall offers the necessary lateral strength, the seismic forces are transmitted to the subsequent elements and then to the footing. Shear wall is sufficiently firm and prevents all frame members from dislocation. If shear wall is adequately firm, the structure will experience a reduced amount of non-structural damage. Figure 1.2 shows RC shear wall.

The chief functions are:

- For enhancing firmness of structure to withstand lateral load.
- Offering lateral strength and stiffness to structure.



. Fig. 1.2: RC shear wall in building

1.4 METHODS ADOPTED FOR SEISMIC ANALYSIS IN ACCORDANCE WITH IS 1893-PART 1(2002)

1) Equivalent Static Analysis:
Here, the influence of seismic motion at ground level is studied by distribution of forces on building. Based on appropriate fundamental natural period, specific ground acceleration, soil category, exposure condition and building type the total base shear evaluated.

2) Response Spectrum Analysis:
In every natural mode of vibration the response is evaluated and modal responses are combined for calculating the full reaction of the structure. The frequency of vibration for every structure varies.

2. LITERATURE REVIEW

Rajiv Banerjee, J.B. Srivastava (2019) :
Analysed G+15 storey irregular building (T shaped) with shear wall by RSA and time history analysis using ETABS v. 2016. For best location, the length is kept constant for shear wall. The data which recorded during EI Centro Earthquake at Array Recording station, USA was used for the analysis of the structure at time interval of 0.010 sec and with 5% damping. It was determined that shear wall configuration in model 3 has more influence in withstanding lateral load.

Shubham Borkar, Dr. G.D. Awchat (2019) :
Analysed G+6 storey RC commercial building considering all the four zones and three types of soils was analysed using ETABS by adopting Response spectrum analysis. The storey drift values for soil-I & for the load combination 1.5(DL+EQX-RS) is maximum and designed as an RCC framed structure with a reinforced concrete slab as per IS 456-2000.

Sylviya B, P. Eswaramoorthi (2019) :
Analysed G+4 storey RCC building with shear wall at various places by linear dynamic response spectrum analysis using ETABS 16.2.0. Shear wall was placed at periphery, intermediate walls and at core. Structural wall was most effective when placed on the periphery. All the seismic variables were increased in Seismic Zone V compared other.

Thae Su Mon and Min Zaw (2018) :
Analysed 20-Storeyed RC Building with five dissimilar locality of shear wall using ETABS by ESA and RSA. As per ACI code 318-99 all the members were designed. Loads which were used in analysis were in accordance with UBC-97. Totally six models were analysed with various vicinity of shear wall. Check for Structural stability were performed. P-delta effect was studied. Based on behaviour of structure, sixth model was found to be more effective than the other.

Narla Mohan, Vardhan A. Mounika (2017) :
Analysed G+20 storeyed RC building with four zones subjected to earthquake and wind load using ETABS 9.7 nonlinear version software by Response spectrum analysis. Four models were used for analysis with varying bay lengths.. It was concluded that displacement is increased by more than 50%, base shear is enhanced by 350% and storey drift. The storey-drift owing to wind load is maximum in 6th floor and gradually increases with wind pressure.

Khushboo K. Soni1, Dr. Prakash S. Pajgade (2015) :
Analysed three models by differing the number of floors i.e. 12th, 15th and 18th story building. Models were created by considering shear wall and lacking of shear wall. The method adopted was static analysis method. All models were analysed for zone III using ETABS (Version 9.7). In

accordance with analysis, the deflection was less at altered level in multi storied building with shear wall than that of other.

3. OBJECTIVES

Following are significant objectives of the existing study:

1. To create the RC structure models without shear wall.
2. To create the RC structure models with shear wall.
3. To investigate the seismic behaviour of RC structure and the seismic assessment of the structure should be carried out.
4. To carry out equivalent static analysis and response spectrum analysis as per IS 1893-Part 1 (2002) for RC structure models in different seismic zones.
5. To find various seismic factors viz. storey displacement, storey drift ratio, storey shear, time period and base shear for modelled RC framed structure by equivalent static analysis and response spectrum analysis.
6. To equate the results acquired from different analysis of RC structure for all zones using ETABS Software.
7. To compare the results found from the model 1 and model 2.
8. To check all the obtained parameters are within limitations according to IS codes.

4. METHODOLOGY

Here, the multi-storeyed RC framed structure with and with no shear wall are modelled by ESA and RSA in accordance with IS 1893-Part 1(2002) codal provisions using ETABS software (Version 2017). Firstly, the G+13 storeyed RC structure models without and with shear wall were created consisting of structural elements like beams, columns, slabs. The material and sectional properties are assigned for all elements of the RC structure. Then joint restraints are designated. The ESA and RSA are done by applying dead, live loads and dynamic loads. Load combination is taken according to Cl.19 IS 456(2000). The models are checked and analysed for all four zones. For the same plan, the RC framed structure models are created by providing shear wall of specified thickness and properties assigned at different locations. The obtained results are evaluated and charts are drawn for all developed models.

4.1 DESCRIPTION OF THE MODEL

Table 4.1 shows the considerations for creating RC framed structure models. IS 875-Part 1 (1987) and IS 875-Part 2 (1987) are referred for gravity loads. Seismic analysis is done according to IS 1893-Part 1 (2002). Size of columns and beams are chosen such that the RC structure model is safe for all load combinations as per Cl.19 of IS 456(2000).

Table 4.1: Specifications of evolved RC structure models

SL.NO.	PARTICULARS	REMARK
1	Structure category	Commercial
2	No. of floors	G+13
3	Total Height of Building	44.1m
4	Storey Height	3.3m
5	Ground floor height	1.2m
6	Plan dimension	38.252mx28.826m
7	Size of column	300mmx900mm
8	Size of beam	300mmx450mm
9	Slab thickness	150mm
10	Shear Wall Thickness	300mm
11	Column concrete grade	M30
12	Beam concrete grade	M25
13	Slab concrete grade	M25
14	Grade of steel	HYSD415
15	Density of concrete block	16.09 kN/cum
16	Concrete density	25 kN/cum
17	Mortar density	20.4 kN/cum
18	Plaster density	27 kN/cum
19	Earthquake load	As per IS 1893- Part 1(2002)
20	Moment Resisting Frame	SMRF
21	Soil type	TYPE II ,Medium
22	Importance factor	1
23	Response reduction factor	5
24	Zone factor	II,III,IV,V
25	Damping ratio	5%
26	Wall load	13.765 kN/m
27	Slab Live load	2 kN/m2
28	Roof slab Live load	1.5 kN/m2
29	Floor finishes on slab	1.15 kN/m2
30	Floor finishes on roof slab	2 kN/m2

4.2 M1: RC FRAMED STRUCTURE MODEL WITHOUT SHEAR WALL

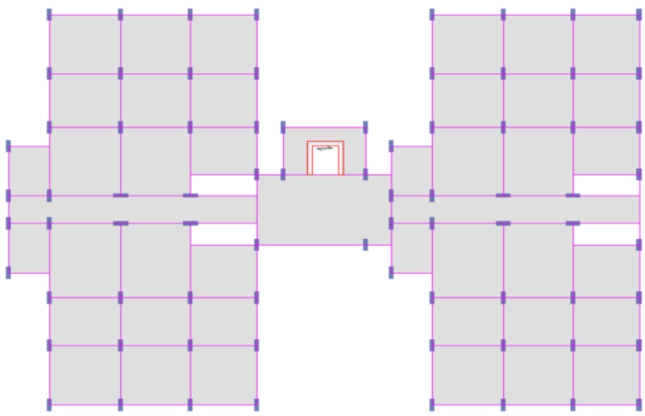


Fig. 4.2.1: Plan view of M1

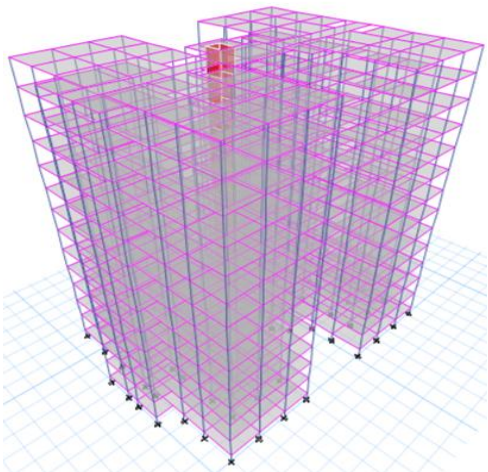


Fig. 4.2.2: 3D view of M1

4.3 M2: RC FRAMED STRUCTURE MODEL WITH SHEAR WALL

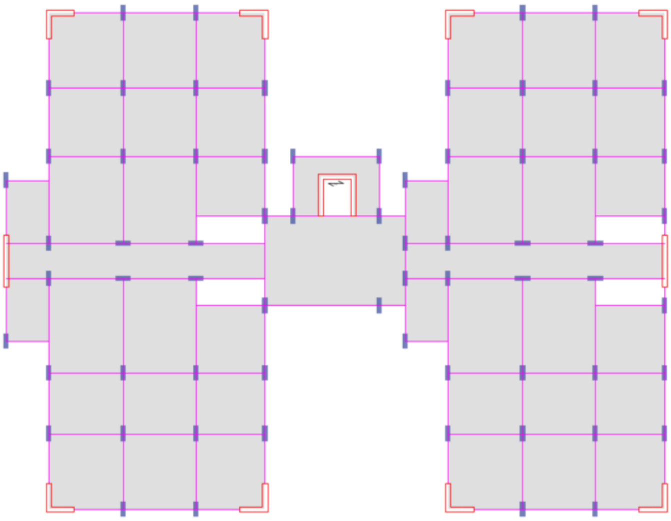


Fig. 4.3.1: Plan view of M2

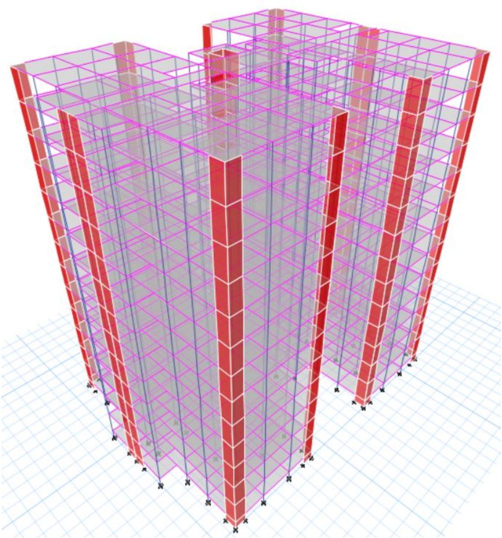


Fig. 4.3.2: 3D view of M2

5.0 RESULTS AND DISCUSSIONS

5.1 MAXIMUM STOREY DISPLACEMENT

It is acquired from developed RC structure are shown in table 5.1 to 5.4 and outlined in figs. 5.1 to 5.4.

Table 5.1: Maximum storey displacement in X-direction

MAXIMUM STOREY DISPLACEMENT (mm)				
	Z=0.10	Z=0.16	Z=0.24	Z=0.36
M1	16.91	27.04	40.57	60.85
M2	14.55	23.29	34.94	52.40

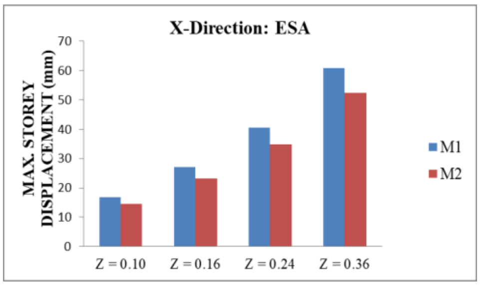


Fig. 5.1: Maximum storey displacement in X-direction by ESA

Table 5.2: Maximum storey displacement in X-direction by RSA

MAXIMUM STOREY DISPLACEMENT (mm)				
	Z=0.10	Z=0.16	Z=0.24	Z=0.36
M1	15.498	24.77	37.195	55.792
M2	12.759	21.26	30.623	47.834

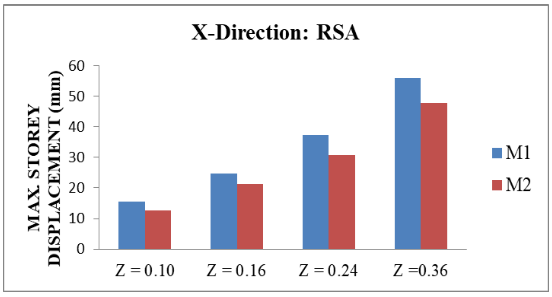


Fig. 5.2: Maximum storey displacement in X-direction by RSA

Table 5.3: Maximum storey displacement in Y-direction by ESA

MAXIMUM STOREY DISPLACEMENT (mm)				
	Z=0.10	Z=0.16	Z=0.24	Z=0.36
M1	13.23	21.16	31.75	47.63
M2	11.17	17.88	26.82	40.23

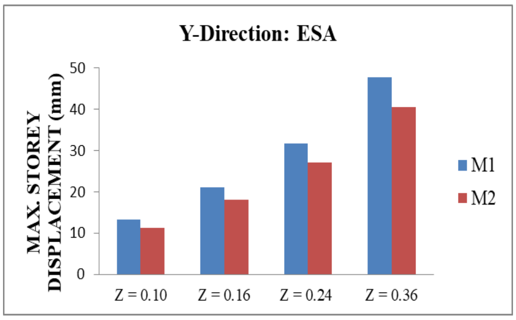


Fig. 5.3: Maximum storey displacement in Y-direction by RSA

Table 5.4: Maximum storey displacement in Y-direction by RSA

MAXIMUM STOREY DISPLACEMENT (mm)				
	Z=0.10	**Z=0.16**	**Z=0.24**	**Z=0.36**
M1	12.125	19.401	29.101	43.652
M2	11.502	15.87	27.604	35.706

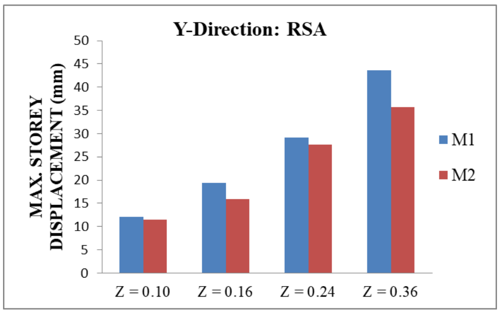


Fig. 5.4: Maximum storey displacement in Y-direction by RSA

5.2 MAXIMUM STOREY DRIFT

It is obtained from developed RC structure are shown in table 5.5 to 5.8 and outlined in figs. 5.5 to 5.8.

Table 5.5: Maximum storey drift in X-direction by ESA

MAXIMUM STOREY DRIFT				
	Z=0.10	**Z=0.16**	**Z=0.24**	**Z=0.36**
M1	0.000497	0.000795	0.00119	0.00178
M2	0.000425	0.000681	0.00102	0.00153

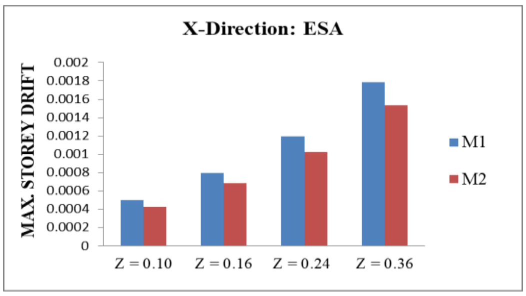


Fig. 5.5: Maximum storey drift in X-direction by ESA

Table 5.6: Maximum storey drift in X-direction by RSA

MAXIMUM STOREY DRIFT				
	Z=0.10	**Z=0.16**	**Z=0.24**	**Z=0.36**
M1	0.000489	0.000782	0.00117	0.00176
M2	0.000391	0.000626	0.00094	0.00140

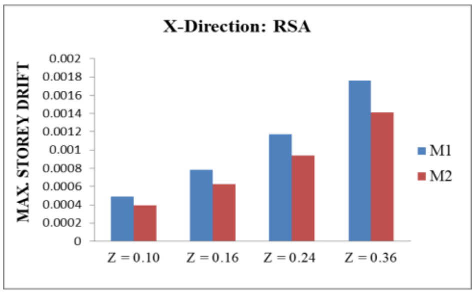


Fig. 5.6: Maximum storey drift in X-direction by RSA

Table 5.7: Maximum storey drift in Y-direction by ESA

MAXIMUM STOREY DRIFT				
	Z=0.10	**Z=0.16**	**Z=0.24**	**Z=0.36**
M1	0.000385	0.000616	0.00092	0.00138
M2	0.00033	0.000528	0.00079	0.00118

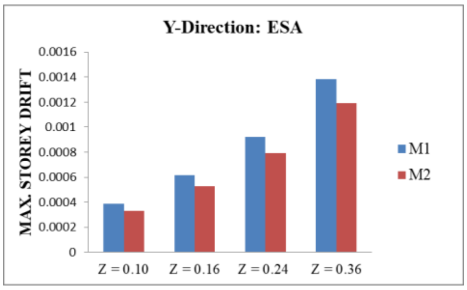


Fig. 5.7: Maximum storey drift in Y-direction by ESA

Table 5.8: Maximum storey drift in Y-direction by RSA

MAXIMUM STOREY DRIFT				
	Z=0.10	**Z=0.16**	**Z=0.24**	**Z=0.36**
M1	0.000369	0.000591	0.00088	0.00133
M2	0.000353	0.000565	0.00084	0.00127

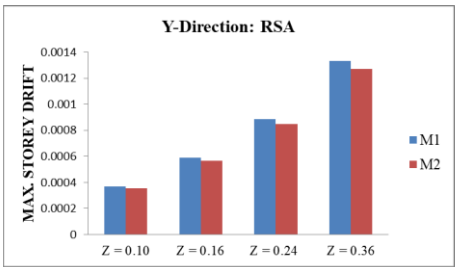


Fig. 5.8: Maximum storey drift in Y-direction by RSA

5.3 MAXIMUM STOREY SHEAR

Table 5.9: Maximum storey shear in X-direction

MAXIMUM STOREY SHEAR (kN) IN X-DIRECTION				
	Z=0.10	Z=0.16	Z=0.24	Z=0.36
M1	1052.57	1684.11	2526.1	3789.26
M2	1186.40	1898.23	2847.34	4271.02

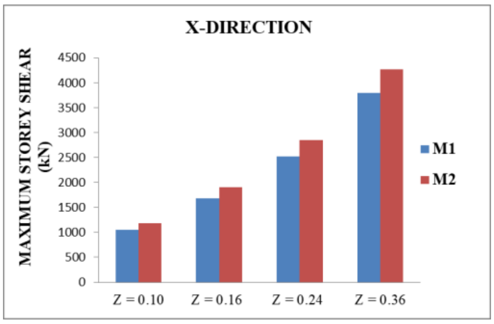


Fig. 5.9: Maximum storey shear in X-direction

Table 5.10: Maximum storey shear in Y-direction

MAXIMUM STOREY SHEAR (kN) IN Y-DIRECTION				
	Z=0.1	Z=0.16	Z=0.24	Z=0.36
M1	1411.98	2259.18	3388.7	5083.16
M2	1579.92	2527.88	3791.82	5687.74

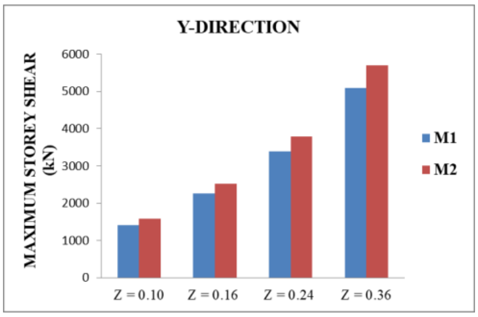


Fig. 5.10: Maximum storey shear in Y-direction

5.4 TIME PERIOD

Table 5.11: Time period for multi-storeyed RC structure

TIME PERIOD (sec)	
M1	M2
0.123	0.09

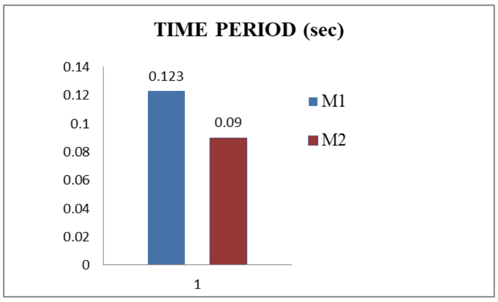


Fig. 5.11: Variation of time period (sec)

5.6 BASE SHEAR

Table 5.12: Base shear in X-direction

BASE SHEAR (kN) IN X-DIRECTION				
	Z=0.10	Z=0.16	Z=0.24	Z=0.36
M1	1052.57	1684.11	2526.1	3789.26
M2	1186.40	1898.23	2847.34	4271.02

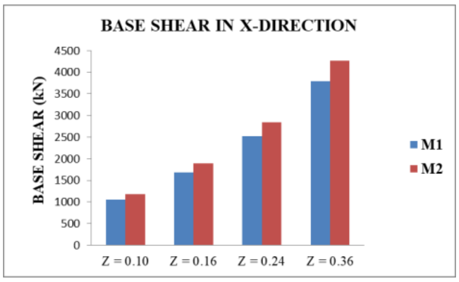


Fig. 5.12: Base shear in X-direction

Table 4.27: Base shear in Y-direction

BASE SHEAR (kN) IN Y-DIRECTION				
	Z=0.10	Z=0.16	Z=0.24	Z=0.36
M1	1411.98	2259.18	3388.7	5083.16
M2	1579.92	2527.88	3791.82	5687.74

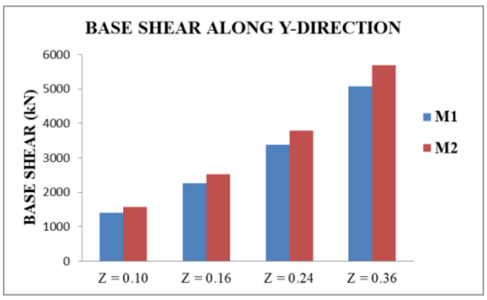


Fig. 4.27: Base shear in Y-direction

6. CONCLUSIONS

The main conclusions from this thesis are described below in view of the results found from ESA and RSA.

1. The storey displacement is reduced by 13-14% in M2 comparative to M1 in all zones. The percentage

increase in storey displacement from zone II to zone V is 260.14% in both models.

2. The storey drift ratio acquired from both analyses are within the allowable limit as per cl 7.11.1.1 of IS 1893-Part 1 (2002) and it is greater in storey 5, storey 6 and storey 7 in RSA and ESA for M2 than M1. In ESA, the storey drift is reduced by 14-15% for M2 relative to M1 in all zones at 6th storey. In RSA, the storey drift is reduced by 20-21% for M2 relative to M1 in all zones at 5th and 6th storey. The percentage increase in storey drift from zone II to zone V is 260.47%.
3. Similar deviations of storey shear values are obtained along the number of storeys in ESA and RSA for the developed RC structure models. The storey shear is more at zone V for M2 and it is enhanced by 12.7% for M2 relative to M1 in all zones. The percentage increase is 259.9% from zone II to zone V in both models.
4. The base shear is enhanced by 12.7% for M2 relative to M1 in all zones. The percentage increase in base shear from zone II to zone V is 259.9% in both models.
5. The time period for M1 is 0.123sec and it is decreased by 26.82% in M2 for the 12th mode of vibration. Since it depends on plan dimensions of building. It is not affected by seismic zones.
6. The values of seismic parameters got from ESA are observed to be more than RSA.

Concluding Remarks: Among all the above models of the developed RC framed structure considered in the study, the model M2 shows lesser storey displacement, storey drift and increases the base shear. Thus, the performance of model M2 is better and safest against lateral forces as compared to the other.

7. SCOPE FOR THE UPCOMING WORK

1. Time history analysis and pushover analysis can be carried out.
2. Effect of plan, mass and vertical irregularities.
3. Deriving fundamental natural period of the structures
4. Impact of different locality of shear wall.
5. Consequence of soil-structure interaction.
6. Influence of base isolation on the structure.
7. Seismic behaviour of steel and composite structures.
8. Further, the number of stories can be increased.

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