STATIC ANALYSIS OF MULTISTORIED RC FRAMED BUILDING USING ETABS

Abstract

In the present study modeling and analysis of G+3 storeys (4 storeys excluding headroom) RC building is done in ETABS Software. Totally thirteen 3D RC framed building models are considered for the seismic analysis having plan dimensions of 10.5m x13m with a storey height of 3.2m each and the depth of foundation is taken as 1.5 m (Total height of building including depth of foundation and headroom is 17.5 m). As per IS-1893: 2016, Part-1, the equivalent static lateral force method is considered for all thirteen buildings for all Zones (II, III, IV & V) and Soil conditions (Hard, Medium & Soft Soil) respectively. The response quantities are mode period, storey displacement, and base shear obtained from those models, and the results are tabulated. Further work has been carried out for the cost analysis of with and without earthquake building models. The concrete quantity and steel quantity has been estimated separately and tabulated for different zones and soil conditions. The estimated costs are compared for all building models (with and without earthquakes) and the results are tabulated. The displacement and base shear values are maximum in zone-V, and soil-3 when compared with all zones and soil conditions. The estimation cost is maximum in zone-V compared with all other models.

Keywords: Static analysis, ETABS, mode period, base shear, cost analysis

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I. INTRODUCTION

An earthquake is a sudden shaking of the ground caused by the movement of the earth's crust. In general, there are different types of seismic waves some are called surface and body waves. This tends to do is make the ground shake and make the structure fall. These waves combined are body waves and surface waves create a repel in the ground which ultimately results in additional forces on the building. These different waves will end up resulting in different kinds of ground movements; this could be very complex to very simple. All the ground movement or all the forces that are generated due to an earthquake can be simply broken down into three mutually perpendicular vectors. There will be some kind of force that will be generated in the x, y & z-directions, which will result in the movement of the building or ground itself in the x or y, or z-direction, and the combination of these three results in varying complexity of ground movements. When it comes to earthquakes the horizontal forces due to earthquakes are usually predominant. In this study IS 1893:2016, part-1 is used for the analysis of thirteen RC framed buildings to know the response of base shear, mode period, and storey displacements for equivalent static lateral force method by ETABS software.

II. METHODOLOGY

1. Static analysis is to be carried out for all Zones (II, III, IV &V) and Soil conditions (Hard, Medium & Soft) for G+3 RC framed building.
2. IS:456-2000 is adopted for the design of RC members such as beams, columns, and slabs.
3. IS 1893-2016 part-1 is adopted for earthquake analysis.
4. Individual quantities are taken from different building elements to know the variation of quantities and cost in different zones and soil conditions.

III. DESCRIPTION AND MODELING OF BUILDING

A 3D RC framed building having dimensions 10.5m x 13m x 16m (excluding the depth of foundation), has been considered for static analysis. Thirteen building models are considered for parametric studies, they are:

1. Model-1: Reinforced concrete building without earthquake analysis
2. Model-2: Reinforced concrete building with earthquake analysis for all zones and soil conditions.

The density for reinforced concrete, brick masonry, and cinders are taken as 25 kN/m^3, 19.2 kN/m^3, and 8.8 kN/m^3 as per IS 875-1987, part 1. The imposed loads for roof and floor slab are taken as 2 kN/m^2 and 0.75 kN/m^2 for headroom as per IS 875-1987, part 2. The floor finishes on the roof and floor slabs are taken as 1 kN/m^2 and 0.25 kN/m^2 for the headroom. Characteristic strength of concrete and steel are taken as 25 and 415 N/mm^2 respectively.

Note: Beams, columns, and slabs self-weight are taken by ETABS software. 25% of the imposed load to be considered for calculation of seismic weight.

The calculation of sunken load on slabs, staircase load, and wall loads on beams are shown below.

- Depth of sunken slab = overall depth of beam - depth of the slab
  = 450-125
  =325mm

- Sunken load = depth of sunken slab x density of cinders
  = 0.325 x 8.8
  = 2.86 kN/m^2

- Staircase load = waist slab thickness x (Stair length/2) x density of RCC
  = 0.15 x 1.5875 x 25
  = 11.9 kN/m

Wall load = wall thickness x (storey height – depth of beam) x density of the brick

- Main walls = 0.23 x (3.2-0.45) x 19.2 = 12.14 kN/m
- Partition walls = 0.10 x (3.2-0.45) x 19.2 = 5.28 kN/m

The parameters used for the equivalent static lateral force method as per IS 1893:2016, part-1 are shown below.

Zone = II, III, IV & V
Soil conditions = Hard soil, Medium soil, Soft soil
Response reduction factor =3 & 5 for ordinary and special moment resisting frames.
Important factor =1
Time period wall, $T_a = \frac{0.09h}{\sqrt{D}}$
X-direction, $T_a = \frac{0.09X16}{\sqrt{10.5}} = 0.455\ s$
Y-direction, $T_a = \frac{0.09X16}{\sqrt{13}} = 0.4\ s$

Table 1 shows the building sectional properties for the seismic analysis.
Figure 1 shows the plan and 3D view of RC framed building for the seismic analysis.

Table 1: Sectional properties of RC framed buildings

Members		Without earthquake	With earthquake
Beams		230mm x 380mm 230mm x 450mm	230mm x 450mm 230mm x 600mm
Columns		230mm x 450mm 230mm x 600mm	230mm x 450mm 230mm x 600mm 230mm x 750mm
Slabs		125mm	125mm
Walls	Main walls	230mm	230mm
	Partition walls	100mm	100mm

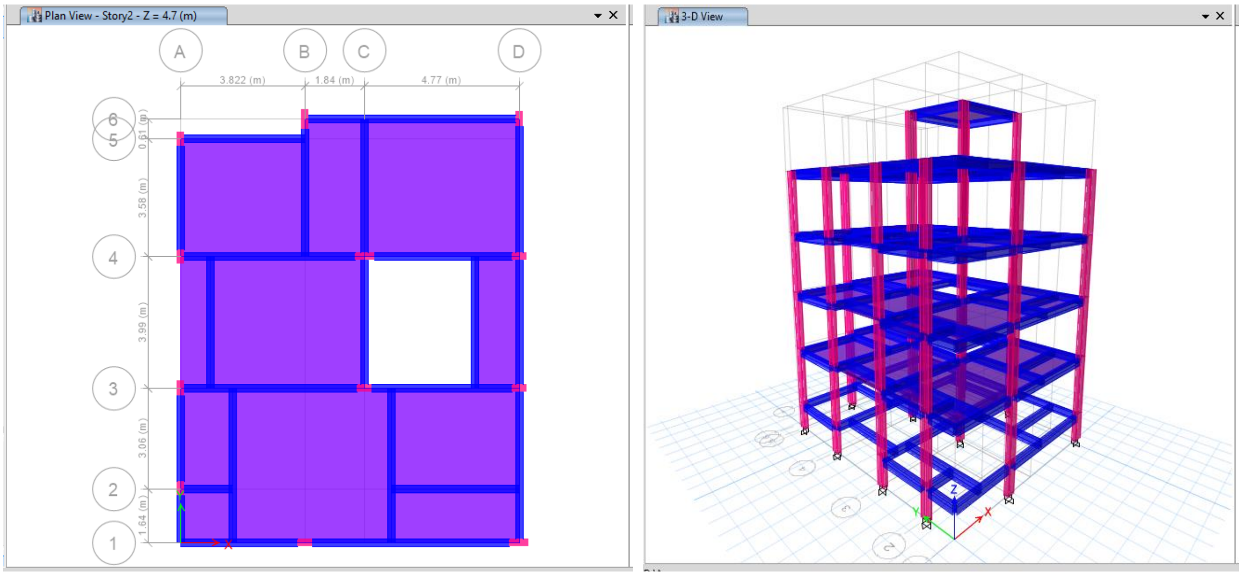


Figure 1: Plan and 3D view of RC building

IV. RESULTS AND DISCUSSIONS

Based on the seismic analysis of RC framed buildings, the response quantities such as mode period, base shear, and storey displacements have been taken for all zones and soil conditions. The cost analysis for all buildings is calculated and the results are tabulated.

Mode Period

Table 2: Mode period for without earthquake analysis

Model	Mode Period (s)		
	Mode 1	Mode 2	Mode 3
Model-1	0.891	0.847	0.693

Table 2 shows that the mode period for G+3 stories buildings (without earthquake) is 0.891 sec along Y-direction, 0.847 sec along X-directions, and 0.693 sec in Torsion mode. The mode period is increased by 5% and 22% in mode-1 compared with mode-2 and mode-3.

Table 3: Mode period for with earthquake analysis

Model- 2	**Soil 1**			**Soil 2**			**Soil 3**		
Zones	**Mode 1**	**Mode 2**	**Mode 3**	**Mode 1**	**Mode 2**	**Mode 3**	**Mode 1**	**Mode 2**	**Mode 3**
Zone 2	1.182	1.037	0.976	1.164	1.046	0.871	1.158	1.073	0.84
Zone 3	1.109	0.968	0.83	1.105	0.97	0.83	1.094	0.95	0.83
Zone 4	1.093	1.014	0.832	1.105	0.97	0.819	1.094	0.95	0.816
Zone 5	0.972	0.855	0.728	0.99	0.848	0.717	0.956	0.82	0.733

Figure 2 shows that the mode period increases in mode-1 when compared with mode-2 and mode-3 for all zones and soil conditions respectively. As zone (II, III, IV, V) and soil

(Hard, Medium, Soft) increases with a decrease in mode period because mode period is inversely proportional to stiffness. The column and beam sections are increased with an increase in zones and soil depending on design criteria. As section increases with an increase in stiffness so mode period will slightly decrease with an increase in zones and soils. The mode period is around 5-15% and 20-30% increases in mode-1 compared with mode-2 and mode-3 for all zones and soil conditions respectively.

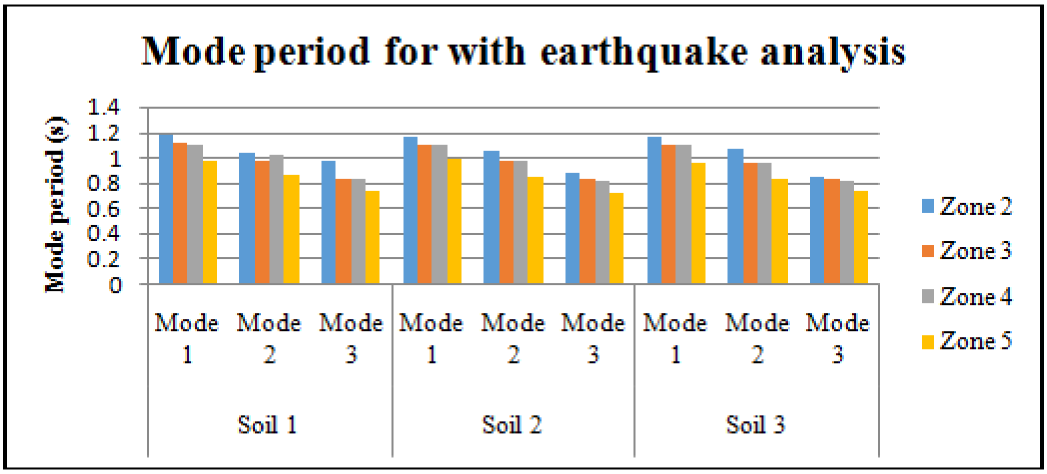


Figure 2: Mode period for with earthquake analysis

Mode Shapes

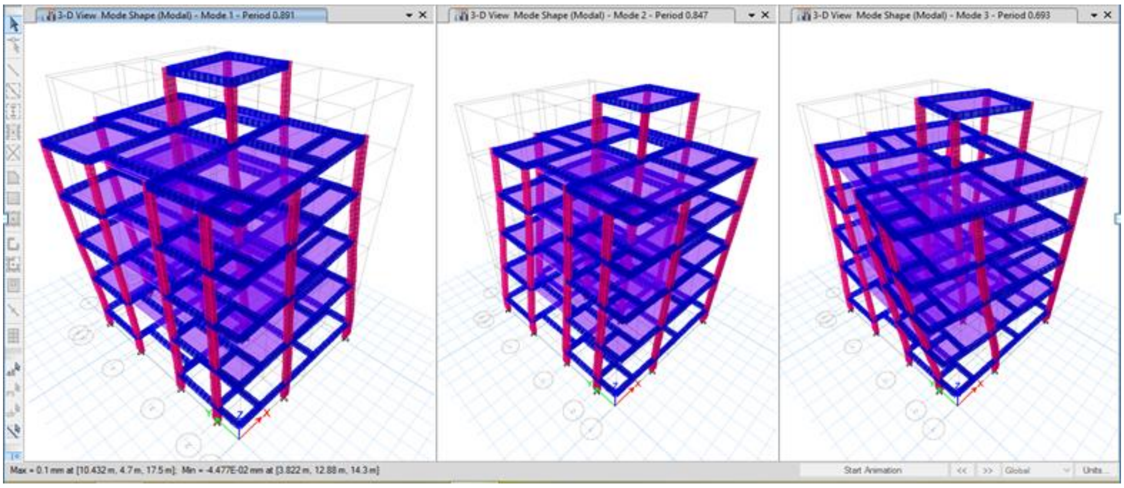


Figure 3: Mode shapes without earthquake analysis

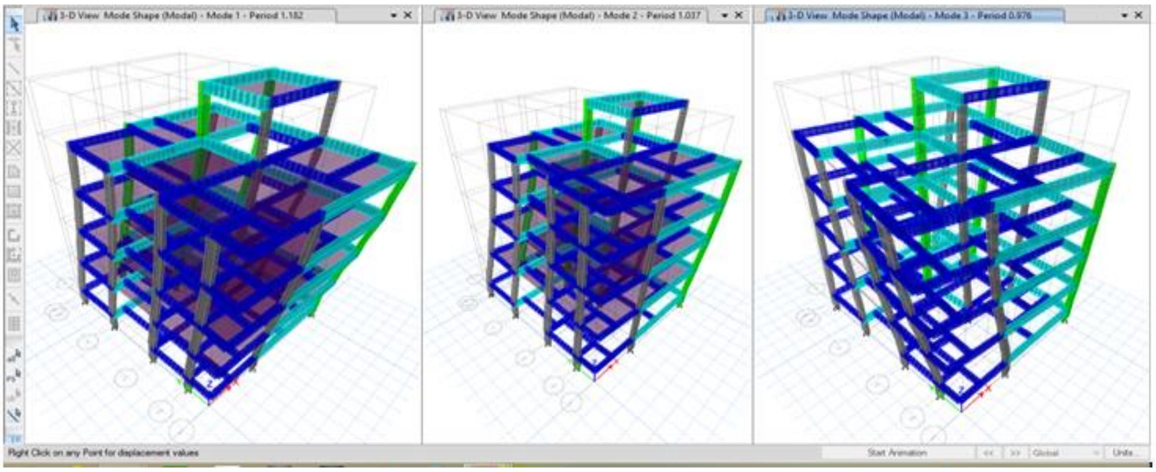


Figure 4: Mode shapes without earthquake analysis (Zone-2, Soil-1)

Base shear

Table 4: Base shear for different zones and soil conditions along X and Y direction

Models	Base shear (kN)					
	Soil 1		Soil 2		Soil 3	
	VX	VY	VX	VY	VX	VY
Zone 2	344.3903	383.1342	386.8024	386.8024	384.6083	384.6083
Zone 3	557.722	620.4657	623.5939	623.5939	624.9232	624.9232
Zone 4	503.5718	560.2237	567.0345	567.0345	567.167	567.167
Zone 5	782.8003	870.8653	869.9302	869.9302	873.7641	873.7641

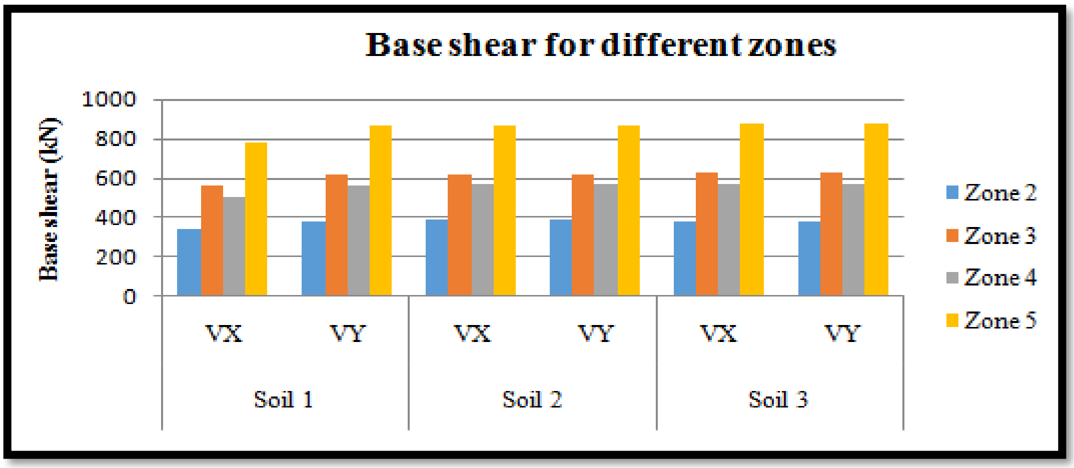


Figure 5: Base shear for different zones and soil conditions along X and Y direction

Figure 5 shows that the base shear decreases by 12% and 11% in soil-1 compared with soil-2 and soil-3 for zone-2 along X-direction. Similarly slight variations of base shear along the Y-direction. The increase in base shear in zone-5 was nearly 55%, 28%, and 35% compared to zone-2, zone-3, and zone-4 for soil-1 along the X and Y-direction respectively.

The base shear increases with an increase in zones and soil conditions along X and Y-directions.

Displacement

Table 5: Displacement (mm) for soil-1 along X-direction

No. of stories	Displacement (mm)			
	Zone 2	Zone 3	Zone 4	Zone 5
Storey 6	19.7	28.2	28.5	29.8
Storey 5	18.4	26	26.1	27.5
Storey 4	15.4	21.6	21.7	22.8
Storey 3	10.8	15.1	15.1	16
Storey 2	5.5	7.7	7.6	8.1
Storey 1 (ground level)	0.8	1.1	1	1.1

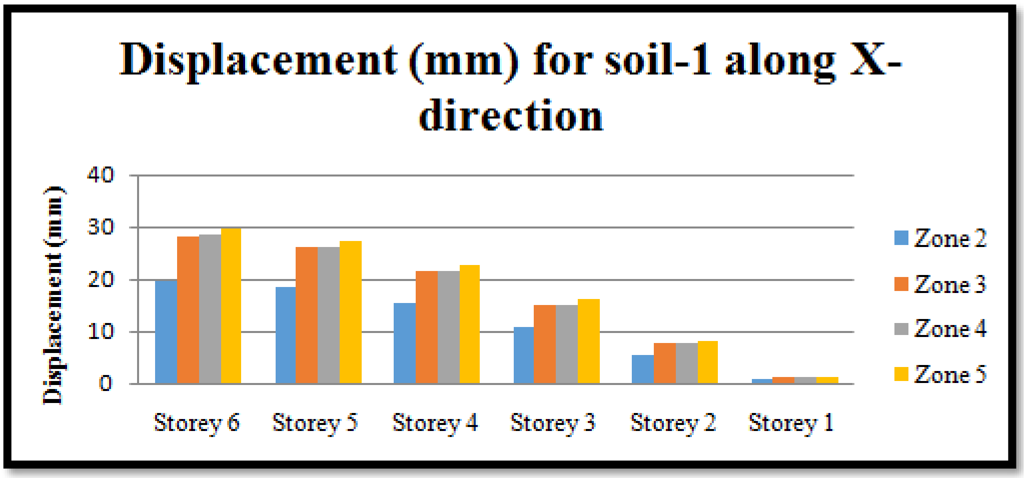


Figure 6: Displacement (mm) for soil-1 along X-direction

Figure 6 shows that the increase in displacement in storey-6 was around 95-96% in all zones compared to the bottom storey for soil-1 along the X-direction. The increase in displacement in zone-5 was nearly 33%, 5%, and 4% compared to zone-2, 3, and 4 for soil-1 along the X-direction at the top floor.

Table 6: Displacement (mm) for soil-2 along X-direction

No. of stories	Displacement (mm)			
	Zone 2	Zone 3	Zone 4	Zone 5
Storey 6	22.6	24	31.5	33.4
Storey 5	20.9	22.1	29.1	30.8
Storey 4	17.5	18.4	24.2	25.6
Storey 3	12.3	12.9	16.9	17.9
Storey 2	6.3	6.5	8.6	9.1
Storey 1	0.9	0.9	1.2	1.3

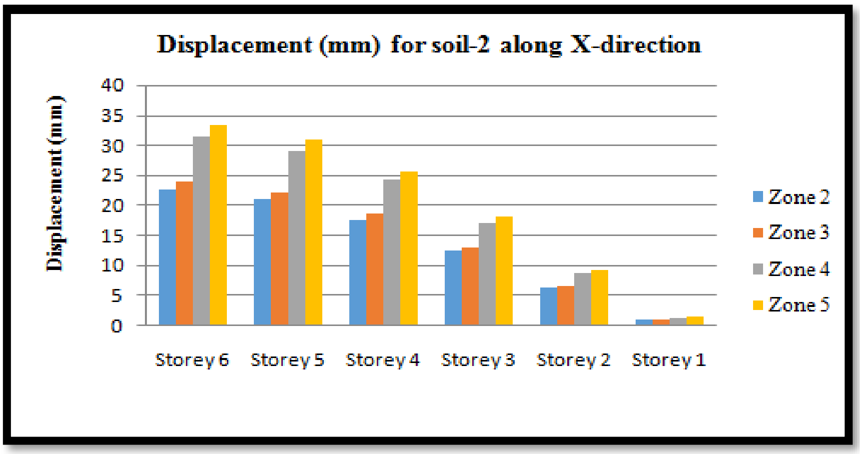


Figure 7: Displacement (mm) for soil-2 along X-direction

The increase in displacement in zone-5 was nearly 33%, 28%, and 5% compared to zone-2, 3, and 4 for soil-1 along the X-direction at the top floor.

Table 7: Displacement (mm) for soil-3 along X-direction

No. of stories	Displacement (mm)			
	Zone 2	Zone 3	Zone 4	Zone 5
Storey 6	25	25.8	29.9	31
Storey 5	23.1	23.8	27.7	28.6
Storey 4	19.2	19.8	23.1	23.7
Storey 3	13.5	13.9	16.2	16.6
Storey 2	6.8	7	8.2	8.4
Storey 1	0.9	1	1.1	1.2

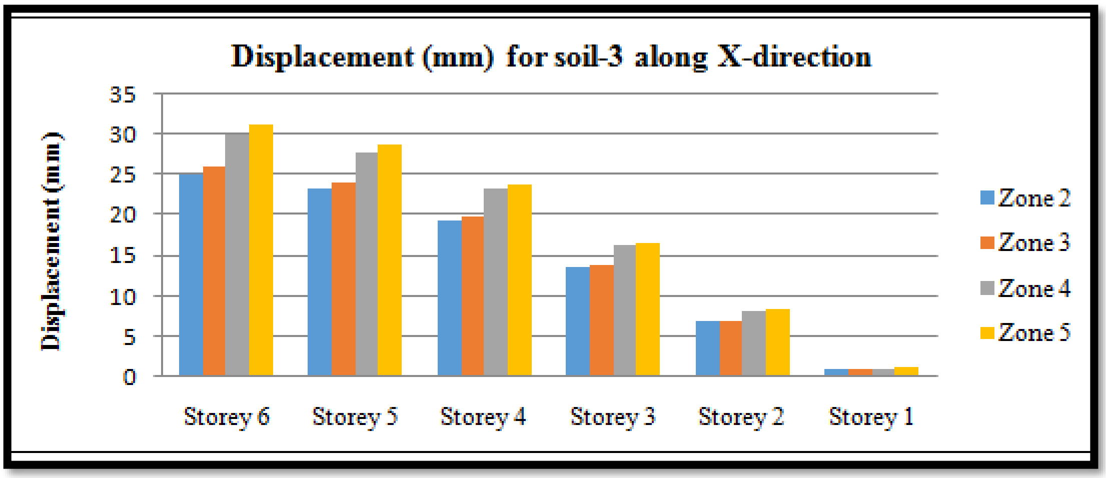


Figure 8: Displacement (mm) for soil-3 along X-direction

The increase in displacement in zone-5 was nearly 19%, 16%, and 3% compared to zone-2, 3, and 4 for soil-1 along the X-direction at the top floor.

Table 8: Displacement (mm) for soil-1 along Y-direction

No. of Stories	Displacement (mm)			
	Zone 2	Zone 3	Zone 4	Zone 5
Storey 6	28.1	32.7	38	39.4
Storey 5	26.5	30.7	35.6	36.9
Storey 4	21.9	25.4	29.3	30.2
Storey 3	15.3	17.7	20.5	20.9
Storey 2	7.7	9	10.4	10.4
Storey 1	0.9	1.1	1.2	1.2

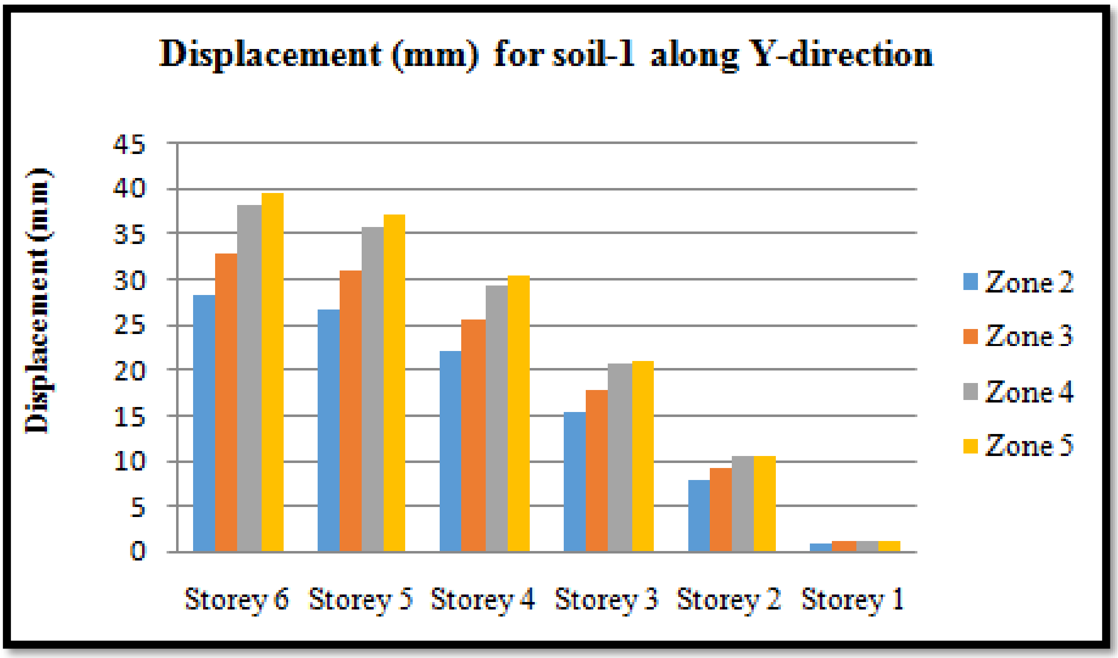


Figure 9: Displacement (mm) for soil-1 along Y-direction

Figure 9 shows that the increase in displacement in storey-6 was around 95-96% in all zones compared to the bottom storey for soil-1 along Y-direction. The increase in displacement in zone-5 was nearly 28%, 17%, and 3% compared to zone-2, 3, and 4 for soil-1 along Y-direction at the top floor.

Table 9: Displacement (mm) for soil-2 along Y-direction

No. of stories	Displacement (mm)			
	Zone 2	Zone 3	Zone 4	Zone 5
Storey 6	26.7	33.8	37.5	40.5
Storey 5	25.1	31.9	35.3	38
Storey 4	20.7	26.2	29.1	31.2
Storey 3	14.4	18	20.3	21.7
Storey 2	7.2	9.1	10.3	11
Storey 1	0.9	1.1	1.2	1.3

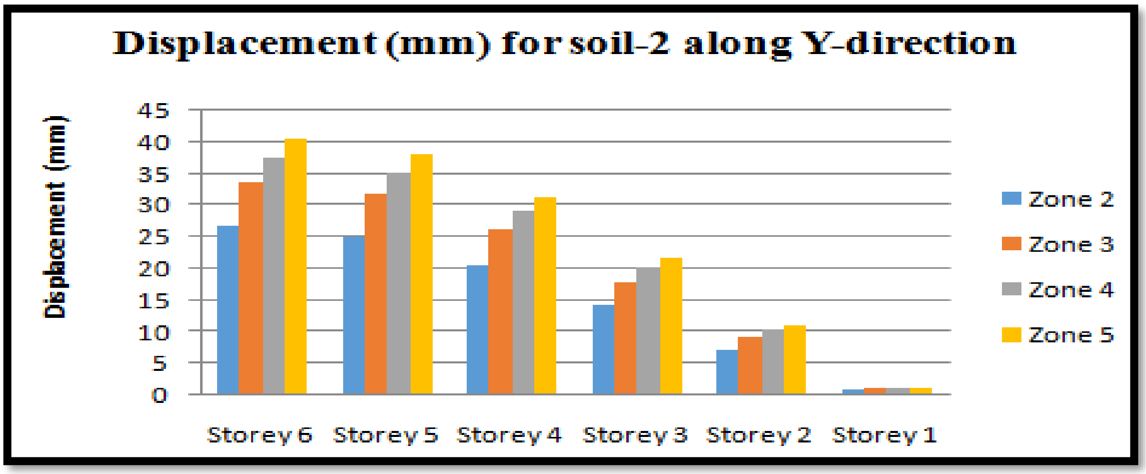


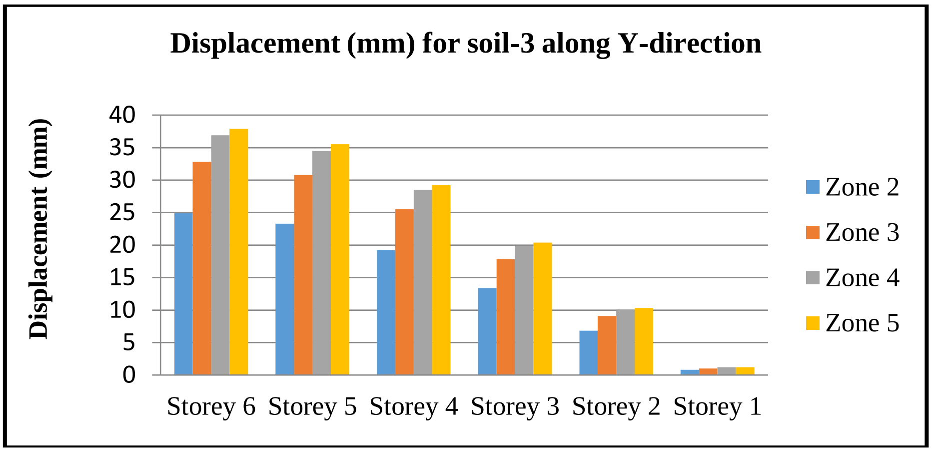
Figure 10: Displacement (mm) for soil-2 along Y-direction

The increase in displacement in zone-5 was nearly 34%, 16%, and 7% compared to zone-2, 3, and 4 for soil-2 along Y-direction at the top floor.

Table 10: Displacement (mm) for soil-3 along Y-direction

No. of stories	Displacement (mm)			
	Zone 2	Zone 3	Zone 4	Zone 5
Storey 6	24.9	32.8	36.9	37.9
Storey 5	23.3	30.8	34.5	35.5
Storey 4	19.2	25.5	28.5	29.2
Storey 3	13.4	17.8	19.9	20.4
Storey 2	6.8	9.1	10.1	10.3
Storey 1	0.8	1	1.2	1.2

Figure 11: Displacement (mm) for soil-3 along Y-direction



The increase in displacement in zone-5 was nearly 34%, 13%, and 2% compared to zone-2, 3, and 4 for soil-3 along Y-direction at the top floor.

Estimation for RC Building

Table 11: Cost estimation for building elements

Zones	Soil	Concrete quantities (m³)	Rates (Rs.)	Amount (Rs.)	Steel quantities (tonnes)	Rates (Rs.)	Amount	Amount concrete+steel (Rs.)
Without earthquake		177.289	2600	460951	15.48	46000	712080	1173031
Zone 2	**Soil-1**	205.95	2600	535470	15.194	46000	698924	1234394
	Soil-2	204.1	2600	530660	16.73	46000	769580	1300240
	Soil-3	201.109	2600	522883	16.69	46000	767740	1290623
Zone 3	**Soil-1**	216.901	2600	563943	20.56	46000	945760	1509703
	Soil-2	218.032	2600	566883	19.53	46000	898380	1465263
	Soil-3	224.065	2600	582569	19.05	46000	876300	1458869
Zone 4	**Soil-1**	203.792	2600	529859	18.54	46000	852840	1382699
	Soil-2	209.933	2600	545826	18.04	46000	829840	1375666
	Soil-3	214.613	2600	557994	18.51	46000	851460	1409454
Zone 5	**Soil-1**	240.659	2600	625713	22.96	46000	1056160	1681873
	Soil-2	236.147	2600	613982	22.81	46000	1049260	1663242
	Soil-3	252.19	2600	655694	22.94	46000	1055240	1710934

V. CONCLUSION

The equivalent static lateral force method is adopted for the seismic analysis. The response quantities such as base shear, mode period & storey displacement are tabulated and discussed in the previous section. Based on the results and discussion the conclusions are drawn.

1. Mode period increases in mode-1 when compared with mode-2 and mode-3 for all zones and soil conditions respectively. As zone (II, III, IV, V) and soil (Hard, Medium, and Soft) increase with a decrease in Mode period because Mode period is inversely proportional to stiffness. The column and beam sections are increases with an increase in zones and soil and this depends on design criteria. As section increases with an increase in stiffness. So, the mode period will slightly decrease with an increase in zones and soils.
2. Base shear is maximum in zone-5, and soil-3 when compared with all zones and soil conditions because the mass participation factor is more in this zone compared with all other models. This shows base shear is directly proportional to the weight of the building.
3. The displacement is maximum in zone-5, and soil-3 when compared with all zones and soil conditions because the stiffness participation factor is less in this zone compared with all other models. Stiffness decreases with an increase in displacement. This shows that stiffness is inversely proportional to displacement. The displacement is maximum along Y-direction compared with the X-direction because the length of the member is more in Y-direction. As length increases with a decrease in stiffness.
4. It clearly shows that the quantities for concrete and steel and cost estimation increase with the increase in zones and soil conditions.
5. The quantities for concrete are less in all models when compared with steel and cost estimation is also more in steel compared with concrete. The estimation and cost are maximum in zone 5 compared with all other zones and without the earthquake model. When compared without the earthquake model, the cost increases by 10%, 24%, 20%, and 45% in zone-2, 3, 4, and 5 for soft soil.

REFERENCES

[1] Arvind reddy& R.J.Fernandes, “Seismic analysis of RC regular and irregular frame structures”, International Research Journal of Engineering and Technology (IRJET) Volume: 02 Issue: 05, 2015.
[2] IS 875: (1987), “Code of practice for Design Loads (other than Earthquake) for Buildings and Structures”, Part 1: Dead loads, Part 2: Imposed loads, *Bureau of Indian Standards,* New Delhi,
[3] IS 456: (2000), “Plain and reinforced concrete code of practice-Code of practice”, *Bureau of Indian Standards,* New Delhi, 4th Revision.
[4] IS 1893: part 1 (2016), “Criteria for Earthquake Resistant Design of Structures”, part 1 General provisions, and Buildings (6th Revision), *Bureau of Indian Standards,* New Delhi.
[5] Mohammad Umar, “Reinforced Concrete Buildings of Seismic Behaviour under Significance of Fluctuating Frequency” International Journal of Advance Research in Science and Engineering, 2015.
[6] Pankaj Agarwal and Manish Shrikhande (2006), “Earthquake Resistant Design of Structures”, *PHI Learning Pvt. Ltd.,.*
[7] Smita, “Study of irregular multi-storey RC frame subjected to seismic condition analysis with STAAD Pro V8i software”, International Journal of Innovative Research in Advanced Engineering, 2020.

