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Comparative Study of Story Displacement and Stiffness under Different Seismic Zones for RC Structure

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***Abstract*— Structural developments are increasing rapidly now-a-days throughout the world. Natural calamities like earthquake are happening frequently around the world, hence, the structure has to be designed for the same. The critical seismic analysis of reinforced concrete building, specifically involves the understanding behavior of structure under lateral loads unlike the usual gravity loads such as dead loads and the live loads.**

In order to design an earthquake resistant structure, the analysis of the structure G+9 story is done using ETABS 2013. G + 9 story is analyzed for different types of seismic zones and soil types as per IS 1893:2016. Further the behavior of the structure is studied for the parameters such as Natural period, Displacement, Base shear and Story Stiffness.

***Keywords*— Seismic Zoning, Soil Types, Natural Period, Displacement, Base Shear, Story Stiffness.**

I. INTRODUCTION

Natural calamities like earthquakes are the most dangerous by means of the damage to the structural components and they cannot be predicted and controlled due to sudden occurrence. But attempt can be made to minimize the vulnerable seismic effects. Seismic waves travel through earth's layers as a result shaking of earth surface leads to damage of structure. Also, these lateral loads can develop high stress, produce sway movements or cause vibration. Therefore, it is very important for the structure to have sufficient strength with adequate stiffness to resist lateral forces. The existing buildings are vulnerable to earthquake, so the importance has been given for earthquake resistant of building.

The analysis of structure for the seismic resistance involves the understanding the behavior of the structure under lateral loads and normal loads. In this study structural analysis of building based on the seismic zones of the area and the types of soils is carried out. The seismic zones are II, III, IV and V among these, zone V is the high active region and zone II is the low active region in India. The behavior of structure under various seismic zones and soil types has been studied.

II. METHODOLOGY

A. *Details of Structure and Analysis*

The analysis of G+9 RC Structure is carried out. Seismic analysis according to IS 1893 (Part-1):2016. Analysis is carried out for structure in zone II, III IV and V.

Effects of Earthquake loads applied on the structures are studied in two methods, namely

a. Equivalent static method
b. Dynamic analysis method

B. *Modelling*

The model is analyzed in ETABS 2013 by the following steps

1. Material properties such as grade of concrete, grade of steel is defined.
2. Section Properties are assigned as (beam, column, slab).
3. The columns are restrained at base level.
4. The loads are applied onto the structural members.
5. Different load cases and combinations are carried out.
6. Function is assigned based on seismic parameters considered for analysis of structure.

TABLE 1: MODELS CONSIDERED FOR ANALYSIS

Model number	Description of Models
Model 1	Building with seismic details of Zone-II and Soil type-1
Model 2	Building with seismic details of Zone-II and Soil type-2
Model 3	Building with seismic details of Zone-II and Soil type-3
Model 4	Building with seismic details of Zone-III and Soil type-1
Model 5	Building with seismic details of Zone-III and Soil type-2
Model 6	Building with seismic details of Zone-III and Soil type-3
Model 7	Building with seismic details of Zone-IV and Soil type-1
Model 8	Building with seismic details of Zone-IV and Soil type-2
Model 9	Building with seismic details of Zone-IV and Soil type-3
Model 10	Building with seismic details of Zone-V and Soil type-1
Model 11	Building with seismic details of Zone-V and Soil type-2
Model 12	Building with seismic details of Zone-V and Soil type-3

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C. Structural Properties

TABLE 2: PROPERTIES OF STRUCTURE

Description	Dimension/Properties
Building Dimension	30m × 40m
Height of each Story	3m
Column Size	450mm × 600mm (1st – 5th Story) 300mm × 450mm (6th – 10th Story) 200mm × 300mm (All Story)
Beam Size	300mm × 450mm (1st – 5th Story) 250mm × 300mm (6th – 10th Story)
Wall Thickness	300mm (Periphery wall) 230mm (Partition wall)
Slab Thickness	130mm (1st – 5th Story) 120mm (6th – 10th Story) 100mm (Parking area)

TABLE 3: PROPERTIES OF CONCRETE

Description	Properties
Concrete Grade	M_{25}
Elastic Modulus	25000 MPa
Poisson's Ratio	0.2
Density of Concrete	25 kN/m^3

TABLE 4: PROPERTIES OF STEEL

Description	Properties
Grade of Steel	Fe_{500}
Elastic Modulus	200000 MPa
Poisson's Ratio	0.3

D. Seismic Details

TABLE 5: SEISMIC PROPERTIES ACCORDING TO IS 1893 (PART-1) : 2016

Description	Properties
Soil Type	Type-1-Rock or Hard Soil (Model-1, 4, 7 & 10) Type-2-Medium Soil (Model-2, 5, 8 & 11) Type-3-Soft Soil (Model-3, 6, 9 & 12)
Importance factor (I)	1.5
Reduction factor (R)	5
Zone factor (Z)	Zone-II – 0.10 (1st – 3rd Model) Zone-III – 0.16 (4th – 6th Model) Zone-IV – 0.24 (7th – 9th Model) Zone-V – 0.36 (10th – 12th Model)

III. PLAN AND ELEVATION

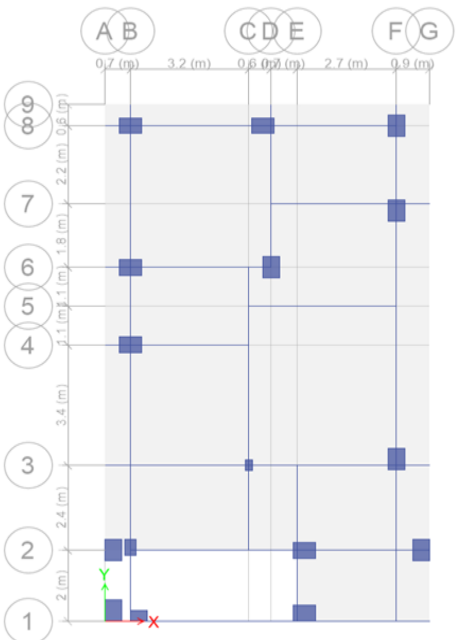


Fig.1Plan of the Structure

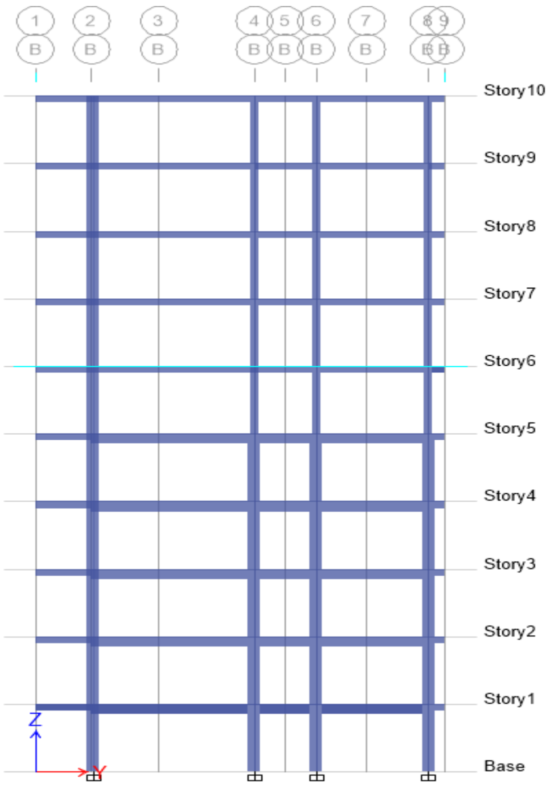


Fig.2 Elevation of the Structure

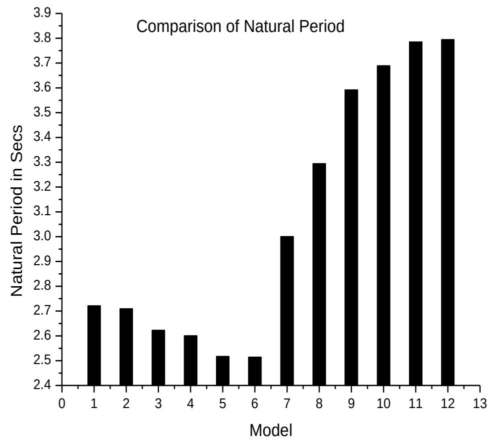
IV. RESULTS AND DISCUSSION

The models are analyzed for Equivalent Static Force Method results of the models for different seismic zones and soil types are discussed below

A. Natural Period for all the Models

TABLE 6: COMPARTIVE RESULTS FOR NATURAL PERIOD

Model	Natural Period (secs)
1	2.722
2	2.710
3	2.623
4	2.601
5	2.518
6	2.515
7	3.001
8	3.295
9	3.593
10	3.690
11	3.786
12	3.795



GRAPH 1: COMPARISON OF NATURAL PERIOD (SECS)

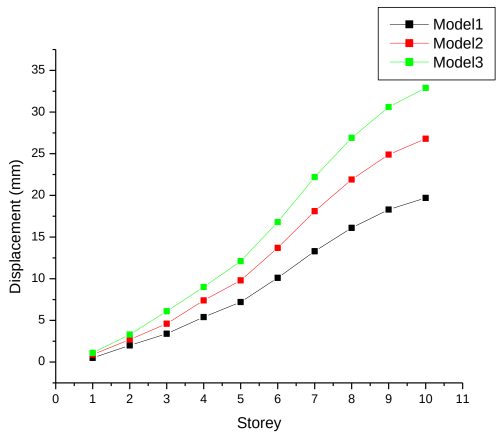
1. The natural period for Model – 6 is the least with comparing to other models.
2. The natural period for Models – 11 & 12 are the highest with comparing to other models, as they are under seismic zone V. They are almost 1.5 times greater than the least model value.
3. From the Graph 1, it is observed that Model 4, 5 & 6 shows the least affected by the seismic forces. (which lies in seismic zone III)

B. Displacements for all the Models

The displacement comparison is done on the basis of different seismic zones

TABLE 7: COMPARTIVE RESULTS FOR DISPLACEMENT FOR THE MODELS IN SEISMIC ZONE II

Results for Displacements (mm) Zone-II			
Story	**Model 1**	**Model 2**	**Model 3**
10	19.7	26.8	32.9
9	18.3	24.9	30.6
8	16.1	21.9	26.9
7	13.3	18.1	22.2
6	10.1	13.7	16.8
5	7.2	9.8	12.1
4	5.4	7.4	9
3	3.4	4.6	6.1
2	2	2.7	3.3
1	0.5	0.9	1.1

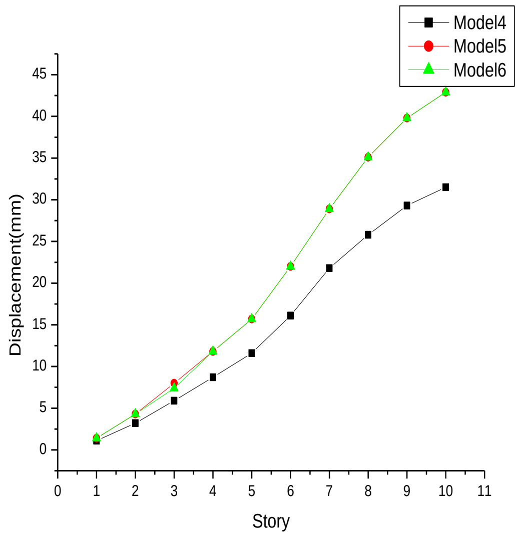


GRAPH 2: COMPARISON OF DISPLACEMENTS FOR MODELS IN SEISMIC ZONE II

From the Graph 2, it is observed that Model 3 has the highest displacement which is 1.67 times higher than the Model 1 and 0.81 times higher than Model 2. This is due to the Model 3 is present in Soft Soil.

TABLE 8: COMPARTIVE RESULTS FOR DISPLACEMENT FOR THE MODELS IN SEISMIC ZONE III

Results for Displacements (mm) Zone-III			
Story	**Model 4**	**Model 5**	**Model 6**
10	31.5	42.9	42.9
9	29.3	39.8	39.8
8	25.8	35.1	35.1
7	21.8	28.9	28.9
6	16.1	22	22
5	11.6	15.7	15.7
4	8.7	11.8	11.8
3	5.9	8	7.4
2	3.2	4.3	4.3
1	1.1	1.4	1.4

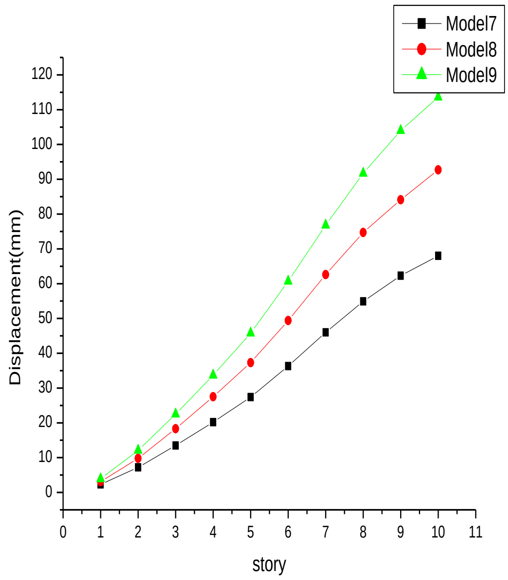


GRAPH 3: COMPARISON OF DISPLACEMENTS FOR MODELS IN SEISMIC ZONE III

From the Graph 3, it is observed that Model 5 & 6 has the highest displacement and almost same and both are 1.36 times higher than the Model 4. The displacement is less in Model 4 as it lies in Hard Soil.

TABLE 9: COMPARTIVE RESULTS FOR DISPLACEMENT FOR THE MODELS IN SEISMIC ZONE IV

Results for Displacements (mm) Zone-IV			
Story	**Model 7**	**Model 8**	**Model 9**
10	68	92.7	113.6
9	62.3	84.1	104
8	54.9	74.7	91.7
7	46	62.6	76.8
6	36.3	49.4	60.7
5	27.4	37.3	45.8
4	20.2	27.5	33.7
3	13.5	18.3	22.5
2	7.2	9.8	12.1
1	2.3	3.1	3.9

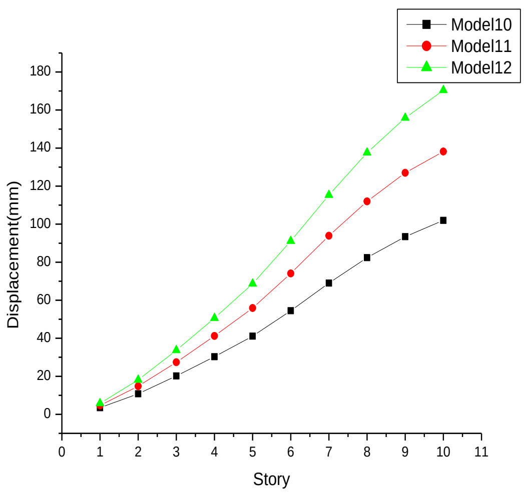


GRAPH 4: COMPARISON OF DISPLACEMENTS FOR MODELS IN SEISMIC ZONE IV

From the Graph 4, it is observed that Model 9 has the highest displacement which is 1.67 times higher than the Model 7 and 1.22 times higher than Model 8. This is due to the Model 9 is present in Soft Soil.

TABLE 10: COMPARTIVE RESULTS FOR DISPLACEMENT FOR THE MODELS IN SEISMIC ZONE V

Results for Displacements (mm) Zone-V			
Story	Model 10	Model 11	Model 12
10	102	138.2	170.4
9	93.4	127	155.9
8	82.4	112	137.6
7	69	93.9	115.3
6	54.5	74.1	91.1
5	41.1	55.9	68.7
4	30.3	41.2	50.6
3	20.2	27.4	33.7
2	10.8	14.8	18.1
1	3.5	4.7	5.8



GRAPH 5: COMPARISON OF DISPLACEMENTS FOR MODELS IN SEISMIC ZONE V

From the Graph 5, it is observed that Model 12 has the highest displacement which is 1.67 times higher than the Model 10 and 1.23 times higher than Model 11. This is due to the Model 12 is present in Soft Soil.

Referring to the Graph 2, 4 and 5, the behavior of structure is similar in soil types I, II and III. The soil type III shows the higher displacement of the structure.

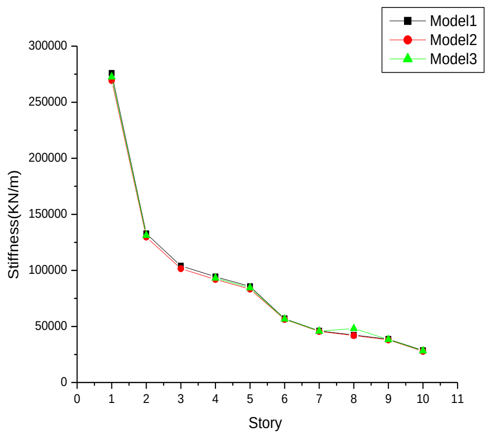
Referring to Graph 3, the behavior of the structure is similar in soil types II and III. The soil type I shows the least displacement of the structure.

C. Stiffness of all the Models

The Stiffness comparison is done on the basis of different seismic zones

TABLE 11: COMPARTIVE RESULTS FOR STIFFNESS FOR THE MODELS IN SEISMIC ZONE II

Results for Stiffness (kN/m) – Zone-II			
Story	Model 1	Model 2	Model 3
10	28584	27743.05	28157.253
9	38689.75	38040.265	38363.263
8	42382.83	41863.195	48121.41
7	45986.967	45571.64	45778.361
6	56932.417	56296.551	56612.699
5	85667.99	83258.342	84444.438
4	94325.538	91903.338	93098.686
3	103994.431	101519.964	1O2742.301
2	132794.71	129703.08	131230.69
1	275937.313	269338.355	272597.903

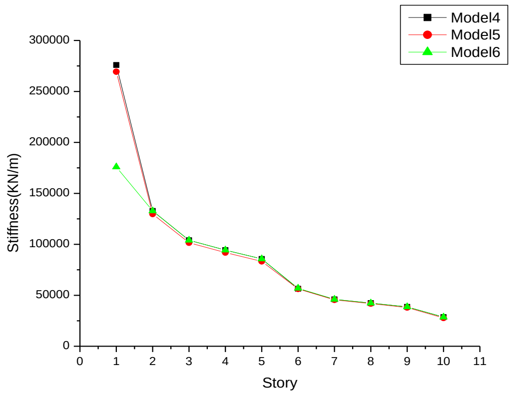


GRAPH 6: COMPARISON OF STIFFNESS FOR MODELS IN SEISMIC ZONE II

From the Graph 6, it is observed that all Models behaves similar.

TABLE 12: COMPARTIVE RESULTS FOR STIFFNESS FOR THE MODELS IN SEISMIC ZONE III

Results for Stiffness (kN/m) – Zone-III			
Story	Model 4	Model 5	Model 6
10	28584.008	27743.054	28584.008
9	38689.758	38040.265	38689.758
8	42382.83	41863.195	42382.83
7	45986.967	45571.64	45986.967
6	56432.417	56296.551	56932.417
5	85667.993	83255.342	85667.993
4	94325.538	91903.338	94325.538
3	103994.431	101519.964	103994.431
2	132794.071	129701.083	132794.71
1	275937.313	269338.355	175937.313

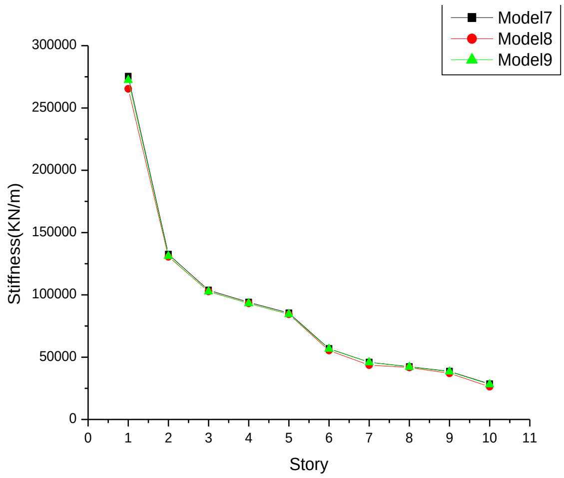


GRAPH 7: COMPARISON OF STIFFNESS FOR MODELS IN SEISMIC ZONE III

From the Graph 7, it is observed that all Models behaves similar for Story 2 to 10. The variation is observed for the story 1 in the Model 6 having least stiffness.

TABLE 13: COMPARTIVE RESULTS FOR STIFFNESS FOR THE MODELS IN SEISMIC ZONE IV

Results for Stiffness (kN/m) – Zone-IV			
Story	**Model 7**	**Model 8**	**Model 9**
10	28520.538	26310.567	28121.563
9	38633.837	37030.637	38334.853
8	42336.805	41736.613	42136.952
7	45950.586	43570.706	45751.934
6	56877.788	55405.052	56572.520
5	85453.006	84423.136	84451.152
4	94109.291	93167.543	93091.354
3	103775.054	102775.652	102631.168
2	132523.308	130523.115	131030.254
1	275360.425	265330.932	272350.183

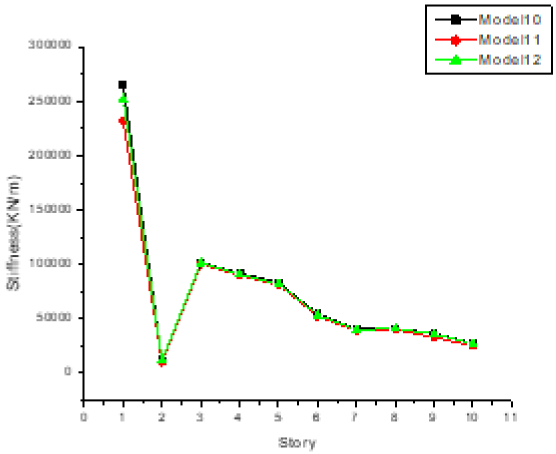


GRAPH 8: COMPARISON OF STIFFNESS FOR MODELS IN SEISMIC ZONE IV

From the Graph 8, it is observed that all Models behaves similar.

TABLE 14: COMPARTIVE RESULTS FOR STIFFNESS FOR THE MODELS IN SEISMIC ZONE V

Results for Stiffness (kN/m) – Zone-V			
Story	**Model 10**	**Model 11**	**Model 12**
10	27520.538	25310.835	27215.675
9	36633.837	33126.378	36215.632
8	41336.805	40129.058	41013.313
7	40950.586	39320.193	40150.130
6	54877.788	52143.189	53312.635
5	83453.006	81231.216	82152.165
4	92109.921	90126.319	91102.219
3	101775.054	100563.132	101435.013
2	12353.308	10132.231	12053.156
1	265360.425	232180.025	252130.269



GRAPH 9: COMPARISON OF STIFFNESS FOR MODELS IN SEISMIC ZONE V

From the Graph 9, it is observed that all Models behaves similar. In story 2 has least stiffness which could affect the structure

CONCLUSIONS

1. From Table 1, it is seen that the natural period is the least for model 6 being in Seismic zone III.
2. Natural Period is higher for the model 8,9,10,11 & 12 having seismic zone IV and V. They are having almost 1.5 times more than the models under seismic zone II & III.
3. From Graph 1 and Table 1, it is observed that the Natural Period is more in case of Models under Soft Soils.
4. From Graph 2,3,4,5, it is observed that the displacement is having similar behavior in all stories in all models.
5. From Displacements comparison it is observed that the displacements are higher for models under soft soils.
6. Displacements are higher on the upper stories, due to the effects of different seismic zones and Soil types.
7. Displacements for models with soil type III are almost 1.67 times higher than that of Models with Soil Type I.
8. From Graph 6,7,8,9 it is observed that the stiffness is higher in lower stories and for the models under soil type I.
9. From Story stiffness comparison tables, it is observed to have least story stiffness in 2nd story for the models with seismic zone IV & V and Soil Type II.

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10. From the study it is observed that for models with seismic zone II are the least affected with the seismic forces as compared to the other models.

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