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Effect of Zone Factor on Seismic Performance of Multi-Storied RC Frame

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ABSTRACT
In tall buildings lateral loads are premier one which will increase rapidly with increase in height. The analysis and design takes care of the requirements of strength, rigidity and stability. It is mandatory to do the seismic analysis and design to structural against collapse. It is highly impossible to prevent an earthquake from occurring, but the damage to the buildings can be controlled through proper analysis and design. Structure is analyzed in such a way that reducing damage during an earthquake makes the structure quite uneconomical. In this project a residential of 5 & 10 story building are studied for earthquake load using ETABS 2016. Assuming that material property is linear static and Response spectrum analysis is performed. These analyses are carried out by considering different seismic zones. Different response like story displacements, Time Period and Acceleration, base shear is plotted for different zones.

***Keywords* –** RCC Building, multistory, zones, Response Spectrum Analysis, Disp., Time Period and Acceleration.

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I. INTRODUCTION

The vast devastation of engineered systems and facilities during the past few earthquakes has exposed serious deficiencies in the design and construction practices. In case of Earthquake design, ductility is an essential attribute of a structure that must respond to strong ground motions. Ductility serves as the shock absorber in a building, for it reduces the transmitted force to one that is sustainable. Therefore, the survivability of a structure under strong seismic actions relies on the capacity to deform beyond the elastic range, and to dissipate seismic energy through plastic deformations. So, the ductility is related to the control of whether the structure is able to dissipate the given amount of seismic energy considered in structural analysis. Therefore while designing an earthquake resisting structure these three factors rigidity (serviceability), strength (damageability) and ductility (survivability) should be taken under consideration. But, while designing an earthquake resistant structure the major importance will be given to the increase of ductility of the building (IS 456, 2000). The ductility of the building can be increased by increasing the reinforcement (steel) in the structure. But the reinforcement plays an important role in the economy of the structure.

This project mainly gives the variations in the percentage of the demand forces when the building designed as per IS 456 and when the building is designed in different earthquake zones considering earthquake force as per IS 1893:2002. This gives the approximate percentage increase in the economy compared with normal design.

Earthquakes all over the world have affected the seismic resistant design in different countries and made a revision necessary in many areas. In the present study, the main factors constitute the seismic load have been studied and dynamic analysis results for various structural systems are compared using IS 1893 (Part 1):2002.

Even though the codes differ in detail, they have essential common features and are comparable. At first, the codes and their backgrounds are introduced and the design procedures are described. For calculating the seismic load according to code, the base shear coefficient, seismic zoning, spectral content, fundamental period, structural behavior coefficient, importance factor, effect of soil profile and foundation, and effect of the weight of buildings are precisely discussed and the differences have been mentioned.

This project deals with a study of influence of various zone factors and the codal provisions provided in IS 1893 (Part 1): 2002. Their similarities and differences are presented with dynamic analysis results carried out using modernized structural engineering software package ETABS2016 for various lateral load resisting structural systems with varying zone factors. Response spectrum analysis is carried out for IS code of practices for all structural systems considered in this study

1.2 Necessity of Seismic Zoning In India

Seismic zonation is a process, which provided information about any decision making for urban regional planning or for earthquake design in earthquake areas. In principle, seismic zoning map is the main source for zoning, which is displaying quantities related to the expected frequency and intensity of shaking caused by earthquakes. The task of seismic zoning is multidisciplinary and involves the best of inputs from geologists, geotechnical's, seismologists, earthquake and structural engineers. The rapid urbanization due to population outburst, coming up of mega cities in potential seismic zones is the main reason for seismic hazard in India.

1.3 Recent Seismic Zones In India: (Bis-2002)

Following are the varied seismic zones of the nation, which are prominently shown in the map(Fig. no.1.1):

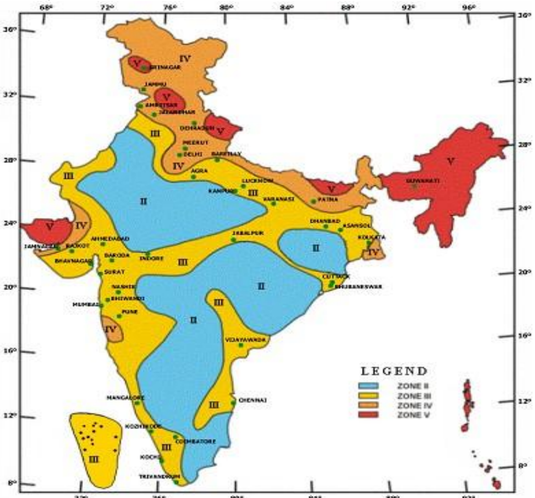

Fig 1: Zones In Indian Map

•Zone - II: This is said to be the least active seismic zone.
•Zone - III: It is included in the moderate seismic zone.
•Zone - IV: This is considered to be the high seismic zone (severe).
•Zone - V: It is the highest seismic zone (very severe).

1.5 IS 1893:2002 Provision For Zones

According to IS 1893 code, Seismic Zonation map of a country is a guide to the seismic status of a region and its susceptibility to earthquakes. India has been divided into four zones with respect to severity of earthquakes

Zone factor (Z) given in Table 1, is for the Maximum Considered Earthquake (MCE) and service life of structure in a zone. For design horizontal seismic coefficient Ah=(Z/2)(Sa/g)(I/R), factor 2 in the denominator of Z is used so as to reduce the Maximum Considered Earthquake zone factor to the factor for Design Basis Earthquake (DBE).
For any structure with T <0.1 s, the value of Ah will not be taken less than Z/2 whatever be the value of I/R.

Table 1 Zone Factor, Z (Clause 6.4.2)

Seismic Zone	II	III	IV	V
Intensity	Low	Moderate	Severe	Very Severe
Z	0.10	0.16	0.24	0.36

1.6 Methods of seismic analysis

Once the structural model is selected, it is necessary to perform analysis to determine the seismically induced forces in the structure. Lot of research is carried out in this area to propose simplified methods that will predict results with reasonable accuracy. So there are different methods of analysis are invented which provide different degrees of accuracy. The analysis process can be categorized on the basis of three factors: the type of externally applied loads, the behavior of structure or the structural materials and the type of structural model selected.

`Based on the type of external action and behavior of structure, the analysis can be further classified as linear static analysis, linear dynamic analysis, nonlinear static analysis, or non-linear dynamic analysis. Linear static analysis or equivalent static analysis used only for regular structure with limited height. Linear dynamic analysis (i.e. Response Spectrum Analysis) considers the effect of the higher mode of vibration and the actual distribution of forces in the elastic range in a better way.

II. ANALYTICAL WORK

2.1Types of cases used for analysis of structure

There is each of four basic cases of same moment resisting frame to analyze 5 & 10-storey structure so that assignment of effect of seismic intensity can be predicted.
(1)Building Located at Seismic Zone II (**Modal 1.II** for 5 story & **Model 5.II** for 10 story building): Building model has considered in lowest seismic intensity area. i.e. Seismic Intensity, Z=0.10
(2)Building Located at Seismic Zone III **(Modal 2.III** for 5 story & **Model 6.III** for 10 story

building): Building model has considered in Moderate seismic intensity area. i.e. Seismic Intensity, Z=0.16

(3)Building Located at Seismic Zone IV (**Modal 3.IV** for 5 story & **Model 6.IV** for 10 story building): Building model has considered in Severe seismic intensity area. i.e. Seismic Intensity, Z=0.24

(4)Building Located at Seismic Zone V (**Modal 4.V** for 5 story & **Model 8.V** for 10 story building): Building model has considered in Very Severe seismic intensity area. i.e. Seismic Intensity, Z=0.36

2.2Structural Data

Building consists of 22.56m in X directions and 21.6m in Y-direction (as shown in Fig. no.2) for Perform Response Spectrum Analysis on computer program ETABS2016 to estimate response of the structure for different zones. The sizes of various structural members were estimated as follows

Brick masonry wall Thickness: 230mm
Story height: 3m for all floors.
Grade of steel: Fe-500
Grade of concrete: M-30
Column Size: 230X600mm
Beam Size: 230X 530mm
Slab thickness: 125 mm
Staircase slab thickness: 150mm
Dead Load (DL):
Intensity of wall (Ext.& Int. wall) = 12.7 KN /m
Intensity of floor finish load =1 KN /m^2
Load Intensity on staircase slab =2.5 KN /m^2
Live load (LL):
Intensity of live load =2 KN /m^2
Lateral loading **(**IS 1893 (Part I):2002):
Building under consideration is in Zones II, III, IV & V

For 5-Story Building Models:
Period Calculation: Program Calculated
Top Storey: Storey- 5th
Bottom Storey: Base
Response reduction factor, R = 5
Importance factor, I = 1
Building Height H = 15 m
Soil Type = II (Medium Soil)

For 10-Story Building Models:
Period Calculation: Program Calculated
Top Storey: Storey- 10th
Bottom Storey: Base
Response reduction factor, R = 5
Importance factor, I = 1
Building Height H = 30 m
Soil Type = II (Medium Soil)

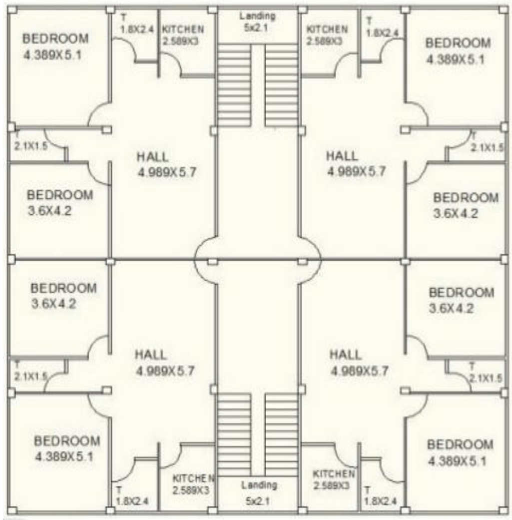

Fig 2: Plan of structure in Auto CAD

III. RESULTS & DISCUSSION

3.1Maximum Lateral Displacement:

3.1.1 Maximum Lateral Displacement of 5 story building

Table3: Comparison of Models 1.II, 2.III, 3.IV & 4.V

Maximum displacement in X-direction

	Height	**Models(mm)**			
Story	**(m)**	**1.II**	**2.III**	**3.IV**	**4.V**
5	15	15.87	25.39	38.09	57.13
4	12	14.78	23.64	35.47	53.20
3	9	12.33	19.74	29.61	44.41
2	6	8.773	14.03	21.05	31.58
1	3	4.306	6.889	10.33	15.5
Base	0	0	0	0	0

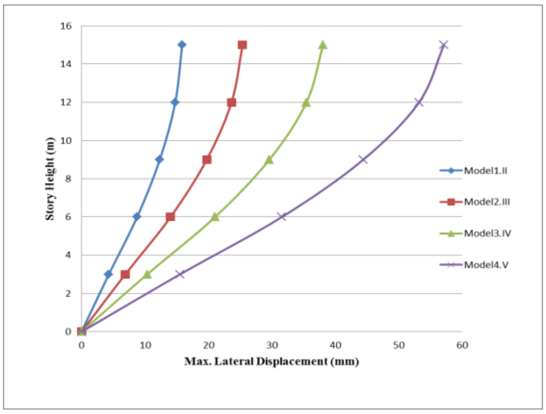

Fig 3: Comparison of Maximum displacement in X-dir. of Building Models 1.II, 2.III, 3.IV & 4.V with respect to height.

Table 4: Comparison of Models 1.II, 2.III, 3.IV & 4.V

Maximum displacement in Y-direction

	Height	**Models(mm)**			
Story	**(m)**	**1.II**	**2.III**	**3.IV**	**4.V**
5	15	6.67	10.6	16.00	24.01
4	12	6.038	9.66	14.49	21.73
3	9	4.845	7.751	11.62	17.44
2	6	3.159	5.055	7.582	11.37
1	3	1.255	2.007	3.011	4.516
Base	0	0	0	0	0

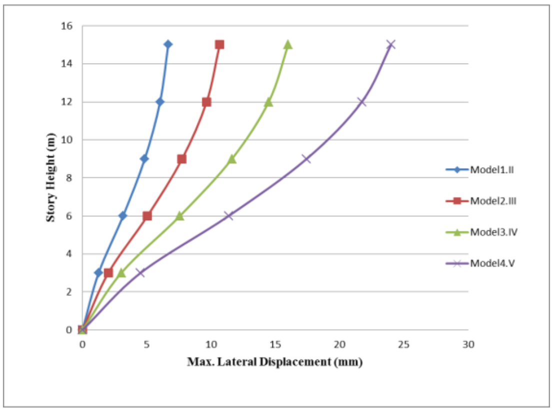

Fig 4: Comparison of Maximum displacement in Y-dir. of Building Models 1.II, 2.III, 3.IV & 4.V with respect to height

3.1.2 Maximum Lateral Displacement of 10 story building

Table5: Comparison of Models 5.II, 6.III, 7.IV & 8.V

Maximum displacement in X-direction

	Height	**Models(mm)**			
Story	**(m)**	**5.II**	**6.III**	**7.IV**	**8.V**
10	30	32.45	51.92	77.88	116.83
9	27	31.74	50.78	76.17	114.2
8	24	30.26	48.42	72.64	108.9
7	21	28.11	44.99	67.48	101.2
6	18	25.37	40.60	60.91	91.36
5	15	22.10	35.36	53.05	79.57
4	12	18.34	29.35	44.03	66.055
3	9	14.15	22.64	33.96	50.94
2	6	9.527	15.24	22.86	34.296
1	3	4.511	7.217	10.82	16.239
Base	0	0	0	0	0

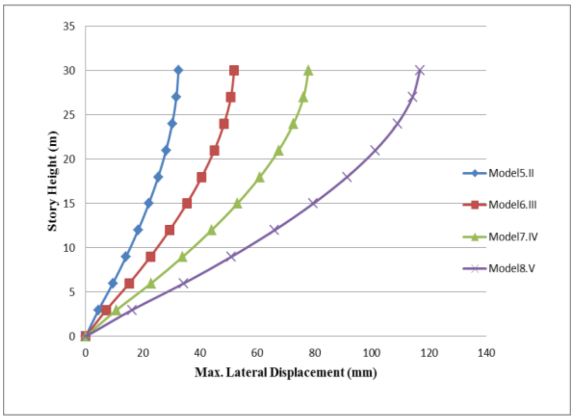

Fig 5: Comparison of Maximum displacement in X-dir. of Building Models 5.II, 6.III, 7.IV & 8.V with respect to height

Table6: Comparison of Models 5.II, 6.III, 7.IV & 8.V

Maximum displacement in Y-direction

	Height	**Models (mm)**			
Story	**(m)**	**5.II**	**6.III**	**7.IV**	**8.V**
10	30	14.29	22.86	34.29	51.44
9	27	13.85	22.17	33.25	49.88
8	24	13.11	20.98	31.47	47.21
7	21	12.07	19.32	28.98	43.47
6	18	10.77	17.24	25.86	38.79
5	15	9.244	14.79	22.18	33.278
4	12	7.497	11.99	17.99	26.989
3	9	5.545	8.872	13.30	19.961
2	6	3.424	5.479	8.219	12.328
1	3	1.314	2.102	3.154	4.73
Base	0	0	0	0	0

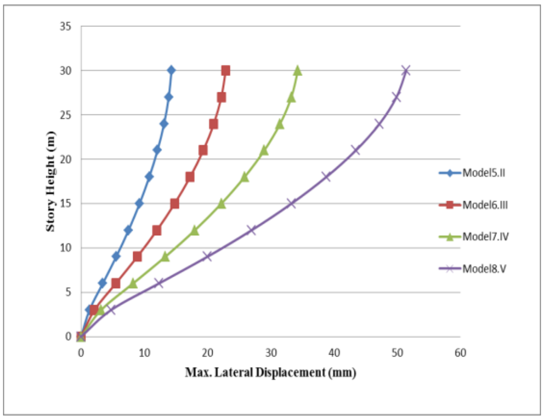

Fig 6: Comparison of Maximum displacement in Y-dir. of Building Models 5.II, 6.III, 7.IV & 8.V with respect to height

The story displacements of considered models for X-direction and Y-direction are shown in above Tables and its graphical representation are also shown in respectively. For more simplified way to understand behavior of structure, also shown comparison of 5-Story building models in Table 3 & Table 4 and 10-Story building models in Table 5 & Table 6 for X-direction and Y-direction respectively. It can be seen from tables that in case of all 5-Story building models similarly in case of all 10-Story building models, displacement is increasing averagely 53.33% in ascending order for building which is like different seismic intensity in both SPECX and SPCEY cases.

It is also noted that displacement of building models at lower earthquake zone for both X and Y directions is small as compared to building models at higher earthquake zone. By reason of the difference in displacement for each building model is increase when seismic intensity is increases.

3.2 Time Period and Acceleration:

3.2.1 Time Period and Acceleration of 5 story building.

Table7: Acceleration values for particular time period of Model 1.II

Mode	SPECX		SPECY	
	Period	Acc.	Period	Acc.
	sec	mm/sec^2	sec	mm/sec^2
1	1.342	271.82	1.342	179.83
2	0.916	401.03	0.916	265.32
3	0.831	439.64	0.831	290.86
4	0.452	667.15	0.452	441.38
5	0.293	667.15	0.293	441.38
6	0.279	667.15	0.279	441.38
7	0.26	667.15	0.26	441.38
8	0.213	667.15	0.213	441.38
9	0.185	667.15	0.185	441.38
10	0.168	667.15	0.168	441.38
11	0.144	667.15	0.144	441.38
12	0.118	667.15	0.118	441.38

Table8: Acceleration values for particular time period of Model 2.III

Mode	SPECX		SPECY	
	Period	Acc.	Period	Acc.
	sec	mm/sec^2	sec	mm/sec^2
1	1.342	434.91	1.342	287.73
2	0.916	641.65	0.916	424.5
3	0.831	703.42	0.831	465.37
4	0.452	1067.44	0.452	706.2
5	0.293	1067.44	0.293	706.2
6	0.279	1067.44	0.279	706.2
7	0.26	1067.44	0.26	706.2
8	0.213	1067.44	0.213	706.2
9	0.185	1067.44	0.185	706.2
10	0.168	1067.44	0.168	706.2
11	0.144	1067.44	0.144	706.2
12	0.118	1067.44	0.118	706.2

Table9: Acceleration values for particular time period of Model 3.IV

Mode	SPECX		SPECY	
	Period	Acc.	Period	Acc.
	sec	mm/sec^2	sec	mm/sec^2
1	1.342	652.37	1.342	431.6
2	0.916	962.48	0.916	636.76
3	0.831	1055.13	0.831	698.06
4	0.452	1601.16	0.452	1059.3
5	0.293	1601.16	0.293	1059.3
6	0.279	1601.16	0.279	1059.3
7	0.26	1601.16	0.26	1059.3
8	0.213	1601.16	0.213	1059.3
9	0.185	1601.16	0.185	1059.3
10	0.168	1601.16	0.168	1059.3
11	0.144	1601.16	0.144	1059.3
12	0.118	1601.16	0.118	1059.3

Table10: Acceleration values for particular time period of Model 4.V

Mode	SPECX		SPECY	
	Period	Acc.	Period	Acc.
	sec	mm/sec^2	sec	mm/sec^2
1	1.342	978.56	1.342	647.4
2	0.916	1443.71	0.916	955.14
3	0.831	1582.7	0.831	1047.08
4	0.452	2401.74	0.452	1588.95
5	0.293	2401.74	0.293	1588.95
6	0.279	2401.74	0.279	1588.95
7	0.26	2401.74	0.26	1588.95
8	0.213	2401.74	0.213	1588.95
9	0.185	2401.74	0.185	1588.95
10	0.168	2401.74	0.168	1588.95
11	0.144	2401.74	0.144	1588.95
12	0.118	2401.74	0.118	1588.95

3.2.2 Time Period and Acceleration of 10 story building

Table10: Acceleration values for particular time period of Model 5.II

Mode	SPECX		SPECY	
	Period	Acc.	Period	Acc.
	sec	mm/sec^2	sec	mm/sec^2
1	2.718	134.16	2.718	89.66
2	1.918	189.16	1.918	126.41
3	1.78	203.48	1.78	135.98
4	0.906	404.18	0.906	270.1
5	0.628	598.57	0.628	400
6	0.577	642.13	0.577	429.11
7	0.541	664.98	0.541	444.38
8	0.389	664.98	0.389	444.38

9	0.364	664.98	0.364	444.38
10	0.327	664.98	0.327	444.38
11	0.306	664.98	0.306	444.38
12	0.255	664.98	0.255	444.38

Table11: Acceleration values for particular time period of Model 6.III

Mode	SPECX		SPECY	
	Period	Acc.	Period	Acc.
	sec	mm/sec^2	sec	mm/sec^2
1	2.718	214.66	2.718	143.45
2	1.918	302.66	1.918	202.26
3	1.78	325.57	1.78	217.57
4	0.906	646.69	0.906	432.16
5	0.628	957.72	0.628	640
6	0.577	1027.41	0.577	686.57
7	0.541	1063.96	0.541	711
8	0.389	1063.96	0.389	711
9	0.364	1063.96	0.364	711
10	0.327	1063.96	0.327	711
11	0.306	1063.96	0.306	711
12	0.255	1063.96	0.255	711

Table12: Acceleration values for particular time period of Model 7.IV

Mode	SPECX		SPECY	
	Period	Acc.	Period	Acc.
	sec	mm/sec^2	sec	mm/sec^2
1	2.718	321.99	2.718	215.17
2	1.918	453.99	1.918	303.38
3	1.78	488.36	1.78	326.35
4	0.906	970.04	0.906	648.24
5	0.628	1436.58	0.628	960
6	0.577	1541.11	0.577	1029.86
7	0.541	1595.94	0.541	1066.5
8	0.389	1595.94	0.389	1066.5
9	0.364	1595.94	0.364	1066.5
10	0.327	1595.94	0.327	1066.5
11	0.306	1595.94	0.306	1066.5
12	0.255	1595.94	0.255	1066.5

Table13: Acceleration values for particular time period of Model 8.V

Mode	SPECX		SPECY	
	Period	Acc.	Period	Acc.
	sec	mm/sec^2	sec	mm/sec^2
1	2.718	482.99	2.718	322.76
2	1.918	680.99	1.918	455.07
3	1.78	732.54	1.78	489.53
4	0.906	1455.06	0.906	972.36
5	0.628	2154.86	0.628	1440
6	0.577	2311.67	0.577	1544.79
7	0.541	2393.91	0.541	1599.75
8	0.389	2393.91	0.389	1599.75
9	0.364	2393.91	0.364	1599.75
10	0.327	2393.91	0.327	1599.75
11	0.306	2393.91	0.306	1599.75
12	0.255	2393.91	0.255	1599.75

Table 7 to Table 13 shows, acceleration values with time interval for each building model is increase when seismic intensity is increases. In 5-Story building models, for the same period i.e. 1.342secModel1.IIgives271.82mm/sq.sec&179.83mm/sq.sec,Model2.IIIgives434.91mm/sq.sec&287.73 mm/sq.secModel3.IVgives652.37mm/sq.sec&431.6 mm/sq.secandModel4.Vgives978.56mm/sq.sec&647 .4mm/sq. sec along X and Y directions. In 10-Story building models, for the same period i.e. 2.718sec Model5.II gives 134.16mm/sq. sec &89.66mm/sq. sec, Model6.III gives214.66mm/sq. sec &143.45mm/sq. sec, Model7.IV gives 321.99mm/sq. sec &215.17mm/sq. sec and Model8.V gives 482.99mm/sq. sec &322.76mm/sq. sec along X and Y directions These acceleration values are obtained in first mode and it increases with increasing seismic intensity of zones.

3.3 Base Shear:

3.3.1 Base Shear of 5 story building

Table14:

Model	SPECX (KN)	SPECY (KN)
Model1.II	785.8242	785.8388
Model2.III	1257.3188	1257.3421
Model3.IV	1885.9782	1886.0131
Model4.V	2828.9673	2829.0196

3.3.2 Base Shear of 10 story building

Table15:

Model	SPECX (KN)	SPECY (KN)
Model5.II	816.8399	799.2817
Model6.III	1306.9438	1278.8507
Model7.IV	1960.4157	1918.276
Model8.V	2940.6236	2877.4141

Table 14 & Table 15 are observed that the difference in distribution of the program calculated base shear force in all the considered models. The base shear will increase drastically as the height increases. The seismic base shear for 5-Story building models, it has been found that maximum base shear of Model 2.III is 60% higher than Model 1.II, similarly Model 3.IV is 50% higher than Model 2.III & Model 4.V is 50% higher than Model 3.IV along X and Y direction respt. And the seismic base shear for 10-Story building models, it has been also found that maximum base shear of Model 6.III is 60% higher than Model 5.II, similarly Model 7.IV is 50% higher than Model 6.III & Model 8.V is 50%

higher than Model 7.IV.along X and Y direction respt.

A quantitative comparison of the base shear for four models is presented. However their seismic performance during the seismic events will vary. Although the different systems have different attributes, they all have acceptable performance and are expected to behave desirably in seismic events.

3.4 Modal Load Participation ratio for all Models:

Table16: Modal Case			
Item Type		Static %	Dynamic %
	For 5 story building Models		
Acc.	UX	100	100
	UY	99.96	97.42
	For 10 story building Models		
Acc.	UX	100	99.44
	UY	99.94	94.5

As per code IS 1893: 2002 clause 7.8.4.2 page 25, The number of modes to be used should be such that the sum of total of modal masses of all modes considered is at least 90% of total seismic mass in IS code of practices. In the present study, the initial modes are found to be in translation for all structural system based on various codes of practices and excite more than 90% of the total mass. All the above considered models are satisfied the clause.

IV. CONCLUSION:

In the present study, the main factors constitute the seismic load have been studied and dynamic analyses results for same structural systems with various zone factors are compared using in IS 1893 (Part 1):2002. Codes. To illustrate the various seismic parameters governing the seismic forces on the building, analytical study is carried out using the modernized structural engineering software package ETABS for structural systems and the similarities and differences are presented for all considered model. From overall study following conclusion has been made

1. In case of 5-Story building models (i.e. Model 1.II, Model 2.III, Model 3.IV & Model 4.V) and 10-Story building models (i.e. Model 5.II, Model 6.III, Model 7.IV & Model 8.V) of lateral displacement is increasing nearly 53.33% (average) in ascending order for building which is like different seismic intensity in both SPECX and SPCEY cases.

2. Acceleration values are obtained at top in first mode and it increases with increasing seismic intensity of zones with time interval. This increasing acceleration values are nearly 50% to 60% more than below one zone for all considered models. The energy (vibrations) gets dissipated after getting transferred up to full length of structure hence the top portion has maximum acceleration.

3. The acceleration can be affected by the natural period of the building, or a complete oscillation, which is dependent on the building stiffness.

4. Time Period increases as the height of the building increases because mass of the overall building increases as time period is directly proportional to the mass.

5. A quantitative comparison of the base shear for four zones is presented. However their seismic performance during the seismic events will vary. Although the four zones have different attributes.

6. All the considered models are excite more than 90% of the total mass as per IS1893, means to adopt maximum lateral force on structure for seismic analysis.

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