SEISMIC ANALYSIS OF STRUCTURE WITH VARIED DAMPING RATIOS ON SEISMIC ZONE 4

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Abstract

More than 50% area in India is prone to damaging earthquakes. Some great Indian earthquakes such as earthquake on west coast of India (1819), Assam earthquake (1897), Bihar Nepal earthquake (1934) and the damage caused due to them creates a need for earthquake resistance in high rise buildings. And as a future civil engineer it is very important for us to learn how to design such structures and know more about it. This project is our attempt and experiment to study the relation between seismic zone and damping ratio and finding the optimum damping ratio to be used. Our project is to design a 15 storey building on etabs assuming all the required information referring IS code 456:2000 and IS code 1893:2002 (for earthquake). This structure is further subjected to different damping ratios on a particular seismic zone giving us the optimum damping ratio for that seismic zone. In our paper, we have taken seismic zone 4 and subjected the structure to damping ratio 0.5%,5%,10% and 20% respectively.

Keywords: Earthquake, Seismic, Response Spectrum, Drift, Damping, Damping ratio.

INTRODUCTION

Starting with the discussion of the basics of Earthquakes and the forces that acts on the structure during earthquakes, discussing about the difference in wind action and earthquake action with respect to the basis of design and ending the introduction with basic aspects of seismic design and construction of a structure. Seismic design forces with detailed investigation and detailed discussion of all aspects with respect to earthquake resistant characteristics and different design practices. Earthquake capacity of structures with respect to different geometries, structural system and components and load paths and further. This discussion can be made with respect to the difference between elastic and inelastic behaviour of the structure. For this project, it is not feasible to conduct a live experiment of a modelled structure henceforth E-TABS can be used for getting the results. E-TABS also has an option to control the damping level which can give different results too.

LITERATURE REVIEW

Sudhir K Jain, November 1998, More than 50% area in India is prone to damaging earthquake. Main cause of earthquake in India is movement of the Indian plate towards the Eurasian plate at rate of about 50mm per year. Earthquake magnitude: measure of the size of the earthquake reflecting the elastic energy released by the earthquake (Richter scale).[1]

C.V.R. Murty, Some great Indian earthquakes 1819: 8.3 magnitude earthquake on west coast of India (largest intraplate earthquake in the world) 1897: Assam earthquake (Shillong) 8.7 magnitude 1934: Bihar Nepal earthquake 8.4 magnitude.[2]

C.V.R. Murty, Rupen Goswami, A.R. Vijayanarayanan, Vipul V. Mehta, The basic concepts in earthquake resistant design of buildings were clarified through this book. We first studied it at conceptual level and then articulated it further through numerical examples given in the book. Some concepts include: -basic aspects of seismic design, seismic structural configuration, structural stiffness, strength and ductility, earthquake demand vs earthquake capacity, seismic design force dynamic characteristics of building, ground motion characteristics elastic behavior inelastic behavior. Indian seismic code recommends the use of 5% damping for all natural modes of oscillations of reinforced concrete building and 2% for steel structures.[3]

A.V. Bhaskararao, R.S. Jangid, In the mentioned paper it is given that, closed form expressions for the analytical responses of two adjacent SDOF structures connected with friction dampers are derived under earthquake excitation. The seismic responses predicted by the analytical and the numerical models of frictional force in the connected damper closely match. The friction dampers are found to be very effective in reducing the earthquake responses of the adjacent connected structures.It is not necessary to connect two adjacent structures by dampers at all floors but lesser dampers at appropriate locations can significantly reduce the earthquake responses of the combined system.The neighbouring floors having more relative displacement should be chosen for optimal damper locations.[4]

Mahmad Sabeer and D. Gouse Peera, August 2015, From the design results of beams, we may conclude, results that etabs gave lesser area of required steel as compared to staad-pro. Similarly, the columns section required area of steel similar in both softwares.[5]

Tom Irvine, November 8, 2004, Discusses about the damping properties of the various materials and their static properties poissions ratio, shear modulus, elastic modulus density) and dynamic properties (propagation velocity of torsional and longitudinal wave, longitudinal loss factor and flexural loss factor) at 200^0C[6]

Toshiharu Arakawa And Kazuya Yamamoto, August 6, 2004, Frequency is decreased with the passage of time for the natural frequencies gradually and certainly. The decreases of the natural frequencies on each mode in every direction are 3.0% on 60 months.[7]

Kishor Bajad & Rahul Watile, Gives the information about the application of dampers to the RCC structure and Displacement and Velocity dependent dampers. Also tells us about the active, passive and semi active dampers in short. In this paper mainly tuned mass damper, friction damper and x-plate damper are discussed.[8]

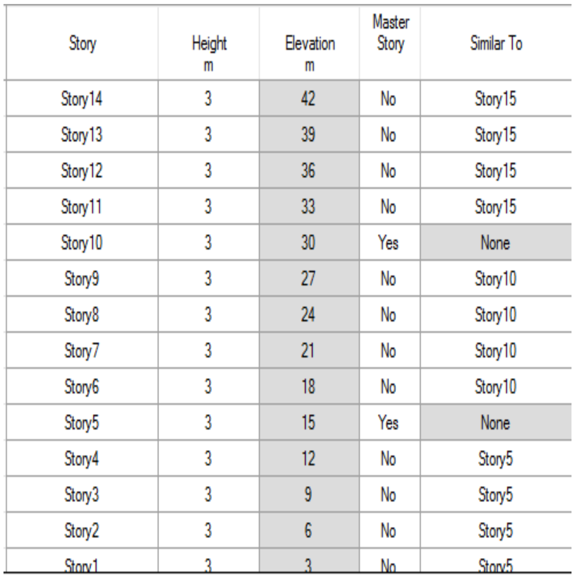
Ramesh Chandra, Moti Masand, S K Nandi, C P Tripathi, Rashmi Pall And Avtar Pall, The use of Pall friction-dampers has shown to provide a practical and economical solution for the seismic control of structures. As the seismic forces exerted on the structure are significantly reduced, the system offers saving in construction materials. The analytical studies have shown that the friction-damped structure should perform satisfactorily in the event of a major earthquake, with possibly reduced damage to building and its contents.[9]

MODELLING IN ETABS

An analytical model of a 15 storey building is made using etabs.The area of the structure is taken as 30x48m and the height is taken as 46m. The structure is assumed to be built on FSI 1.2.

The dimensions of the structural members are given in the table as follows:

Table 1 Story details



Story	Height m	Elevation m	Master Story	Similar To
Story14	3	42	No	Story15
Story13	3	39	No	Story15
Story12	3	36	No	Story15
Story11	3	33	No	Story15
Story10	3	30	Yes	None
Story9	3	27	No	Story10
Story8	3	24	No	Story10
Story7	3	21	No	Story10
Story6	3	18	No	Story10
Story5	3	15	Yes	None
Story4	3	12	No	Story5
Story3	3	9	No	Story5
Story2	3	6	No	Story5
Story1	3	3	No	Story5

Table 2 Dimensions of structural members

Columns (mm)	Beams(mm)	Walls (mm)	Slab thickness(mm)
400 x 600, 400 x 500, 400 x 450	230x450, 300x450	300 mm thick	150mm

The columns were of reducing dimensions changing after every five floors. The columns in the structure were placed alternately at the distance of 6m from each other so that the errors can easily be found and rectified.

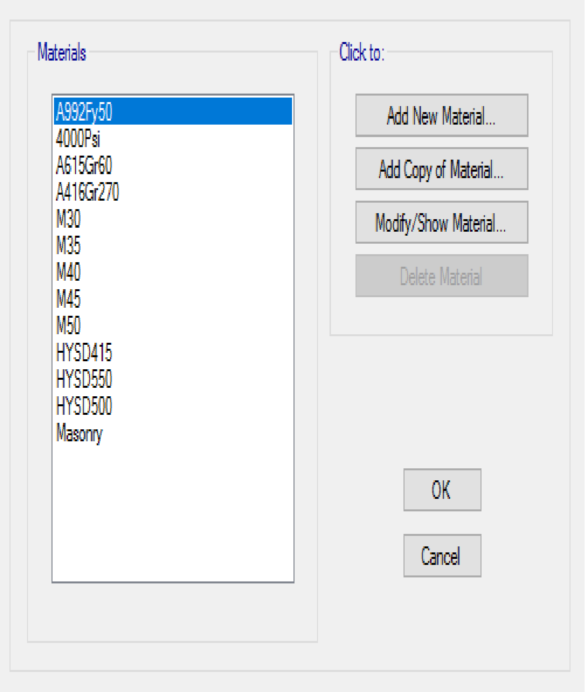
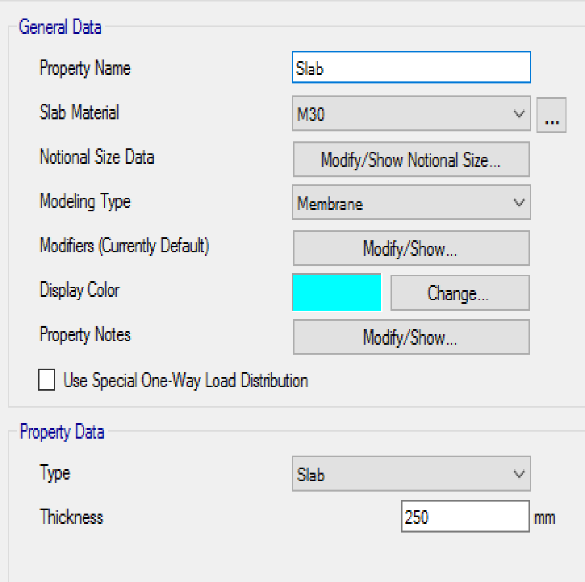
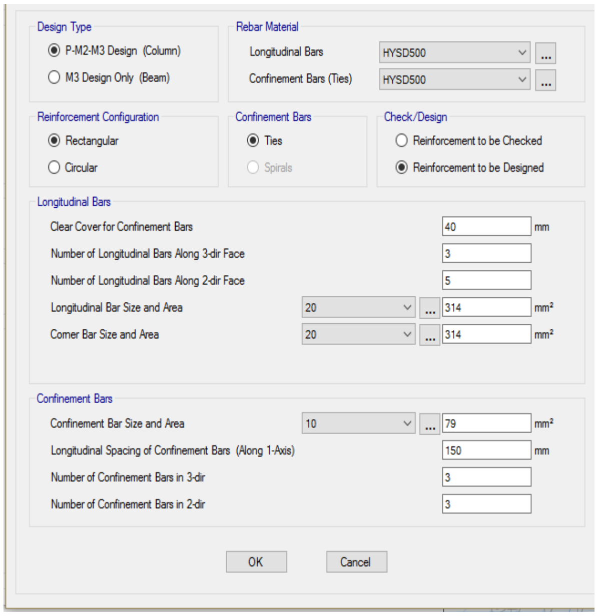

Materials
A992Fy50
4000Psi
A615Gr60
A416Gr270
M30
M35
M40
M45
M50
HYSD415
HYSD550
HYSD500
Masonry

Figure 1 Defining material properties


General Data
Property Name: Slab
Slab Material: M30
Modeling Type: Membrane
Modifiers (Currently Default)
☐ Use Special One-Way Load Distribution

Property Data
Type: Slab
Thickness: 250 mm

Figure 2 Slab property data


Design Type
● P-M2-M3 Design (Column)
○ M3 Design Only (Beam)

Rebar Material
Longitudinal Bars: HYSD500
Confinement Bars (Ties): HYSD500

Reinforcement Configuration
● Rectangular
○ Circular

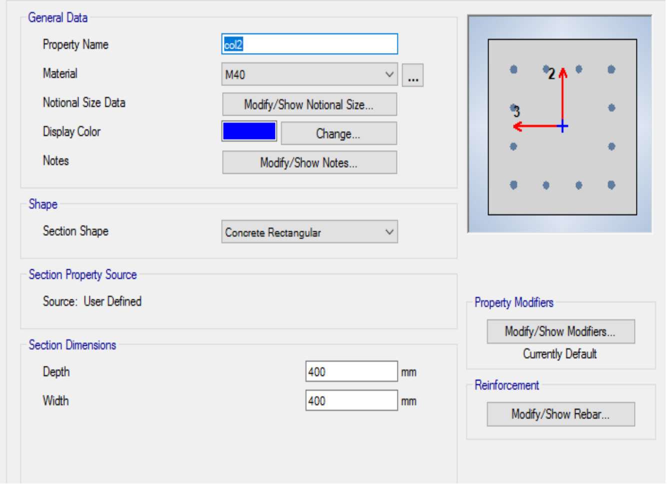
Confinement Bars
● Ties
○ Spirals

Check/Design
○ Reinforcement to be Checked
● Reinforcement to be Designed

Longitudinal Bars
Clear Cover for Confinement Bars: 40 mm
Number of Longitudinal Bars Along 3-dir Face: 3
Number of Longitudinal Bars Along 2-dir Face: 5
Longitudinal Bar Size and Area: 20, 314 mm²
Corner Bar Size and Area: 20, 314 mm²

Confinement Bars
Confinement Bar Size and Area: 10, 79 mm²
Longitudinal Spacing of Confinement Bars (Along 1-Axis): 150 mm
Number of Confinement Bars in 3-dir: 3
Number of Confinement Bars in 2-dir: 3

Figure 3(a) Column property details


General Data
Property Name: col2
Material: M40

Shape
Section Shape: Concrete Rectangular

Section Property Source
Source: User Defined

Section Dimensions
Depth: 400 mm
Width: 400 mm

Property Modifiers
Currently Default

Figure 3(b) Column property details

Table 3 Load cases

Name	Type
Dead	Linear Static
Live	Linear Static
eqx	Linear Static
eqy	Linear Static
seismic	Response Spectrum
windx	Linear Static
windy	Linear Static

Table 4 Load patterns

Name	Type	Self Weight Multiplier	Auto Load
Dead	Dead	1	
Live	Live	0	
eqx	Seismic	0	IS1893 2002
eqy	Seismic	0	IS1893 2002
windx	Wind	0	Indian IS875:1987
windy	Wind	0	Indian IS875:1987

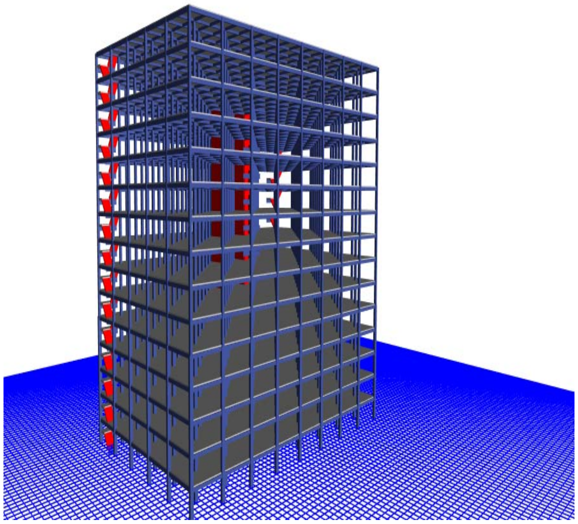


Figure 4 Complete structure

ANALYZING THE STRUCTURE

Load combinations were assigned initially by the default combinations from the e-tabs software. Then the load referring various IS codes were taken. Wind load was calculated using IS 875 part 3. The time period value was taken for the calculation of earthquake load eq_x and eq_y considering the formula $T_{ax} = 0.09h/\sqrt{d}$, $T_{ay} = 0.09h/\sqrt{d}$. Assuming the structure to be in the seismic zone 4 taking the soil type as type II and the zone factor as 0.24 the response spectrum method of analysis was selected as per IS 1893:2002.

Response Spectrum analysis is the method of analysis which measures the contribution from each mode of natural vibration to indicate maximum seismic response of an essentially elastic structure.The analysis was run and the the values of spectural acceleration and time period values for a particular damping ratio was taken. Similarly for different values of damping ratios the values of spectural acceleration and time period were taken and the graph of it was plotted.

The time period value was taken for the calculation of earthquake load eq_x and eq_y considering the formula

$T_{ax} = 0.09h/\sqrt{d} = 0.756$ (for d= 30m)

$T_{ay} = 0.09h/\sqrt{d} = 0.597$ (for d=48 m)

Indian IS875:1987 Auto Wind Load Calculation

This calculation presents the automatically generated lateral wind loads for load pattern wind according to Indian IS875:1987, as calculated by ETABS.

Exposure Parameters

Exposure From = Diaphragms
Structure Class = Class B
Terrain Category = Category 2
Wind Direction = 0;90 degrees
Basic Wind Speed, V_b [IS Fig. 1] $V_b = 47$ m/s
Windward Coefficient, $C_{p,wind}$ $C_{p,wind} = 0.8$
Leeward Coefficient, $C_{p,lee}$ $C_{p,lee} = 0.5$

Top Story = Story15
Bottom Story = Base
Include Parapet = No

Factors and Coefficients

Risk Coefficient, k_1 [IS 5.3.1] $k_1 = 1$
Topography Factor, k_3 [IS 5.3.3] $k_3 = 1$

Lateral Loading

Design Wind Speed, V_z [IS 5.3] $V_z = V_b k_1 k_2 k_3$
Design Wind Pressure, p_z [IS 5.4] $p_z = 0.6 V_z^2$

IS1893 2002 Auto Seismic Load Calculation

This calculation presents the automatically generated lateral seismic loads for load pattern eqx according to IS1893 2002, as calculated by ETABS.

Direction and Eccentricity

Direction = X

Structural Period

Period Calculation Method = Program Calculated

Factors and Coefficients

Seismic Zone Factor, Z [IS Table 2] $Z = 0.24$

Response Reduction Factor, R [IS Table 7] $R = 5$

Importance Factor, I [IS Table 6] $I = 1$

Site Type [IS Table 1] = II

Seismic Response

Spectral Acceleration Coefficient, S_a /g [IS 6.4.5] $\frac{S_a}{g} = \frac{1.36}{T} = 1.185041$

Equivalent Lateral Forces

Seismic Coefficient, A_h [IS 6.4.2] $A_h = \frac{ZI\frac{S_a}{g}}{2R}$

Calculated Base Shear

Table 5 Base shear

Direction	Period Used (sec)	W (kN)	V_b (kN)
X	1.148	65384.7366	1859.6063

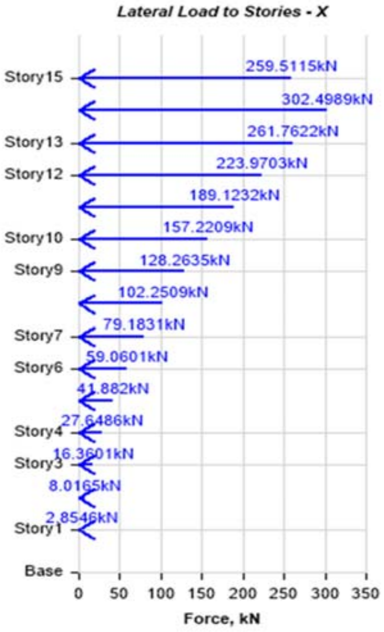


Figure 5 Lateral load acting due to eq_x

Table 6 Lateral load acting due to eq_x

Story	Elevation m	X-Dir kN	Y-Dir kN
Story15	46	259.5115	0
Story14	43	302.4989	0
Story13	40	261.7622	0
Story12	37	223.9703	0
Story11	34	189.1232	0
Story10	31	157.2209	0
Story9	28	128.2635	0
Story8	25	102.2509	0
Story7	22	79.1831	0
Story6	19	59.0601	0
Story5	16	41.882	0
Story4	13	27.6486	0
Story3	10	16.3601	0
Story2	7	8.0165	0
Story1	4	2.8546	0
Base	0	0	0

IS1893 2002 Auto Seismic Load Calculation

This calculation presents the automatically generated lateral seismic loads for load pattern eqy according to IS1893 2002, as calculated by ETABS.

Direction and Eccentricity

Direction = Y

Structural Period

Period Calculation Method = Program Calculated

Factors and Coefficients

Seismic Zone Factor, Z [IS Table 2] $Z = 0.24$

Response Reduction Factor, R [IS Table 7] $R = 5$

Importance Factor, I [IS Table 6] $I = 1$

Site Type [IS Table 1] = II

Seismic Response

Spectral Acceleration Coefficient, S_a /g [IS 6.4.5] $\frac{S_a}{g} = \frac{1.36}{T}$

Equivalent Lateral Forces

Seismic Coefficient, A_h [IS 6.4.2] $A_h = \frac{ZI\frac{S_a}{g}}{2R}$

Table 7 Calculated base shear

Direction	Period Used (sec)	W (kN)	V_b (kN)
Y	1.189	65384.7366	1794.3926

Figure 6 Load acting due to eq_y

Table 8 Lateral load acting due to eq_y

Story	Elevation	X-Dir	Y-Dir
	M	kN	kN
Story15	46	0	250.4108
Story14	43	0	291.8907
Story13	40	0	252.5826
Story12	37	0	216.116
Story11	34	0	182.4909
Story10	31	0	151.7074
Story9	28	0	123.7655
Story8	25	0	98.6651
Story7	22	0	76.4062
Story6	19	0	56.9889
Story5	16	0	40.4132
Story4	13	0	26.679
Story3	10	0	15.7864
Story2	7	0	7.7353
Story1	4	0	2.7545
Base	0	0	0

IS1893 2002 Auto Seismic Load Calculation

This calculation presents the automatically generated lateral seismic loads for load pattern seismic according to IS1893 2002, as calculated by ETABS.

Direction and Eccentricity

Direction = Multiple

Structural Period

Period Calculation Method = Program Calculated

Factors and Coefficients

Seismic Zone Factor, Z [IS Table 2] $Z = 0.24$

Response Reduction Factor, R [IS Table 7] $R = 5$

Importance Factor, I [IS Table 6] $I = 1$

Site Type [IS Table 1] = II

Seismic Response

Spectral Acceleration Coefficient, S_a/g [IS 6.4.5] $\frac{S_a}{g} = \frac{1.36}{T}$

Equivalent Lateral Forces

Seismic Coefficient, A_h [IS 6.4.2]

$$A_h = \frac{ZI\frac{S_a}{g}}{2R}$$

Table 9 Calculated base shear

Direction	Period Used (sec)	W (kN)	V_b (kN)
X	1.148	65384.7366	1859.6063
Y	1.189	65384.7366	1794.3926

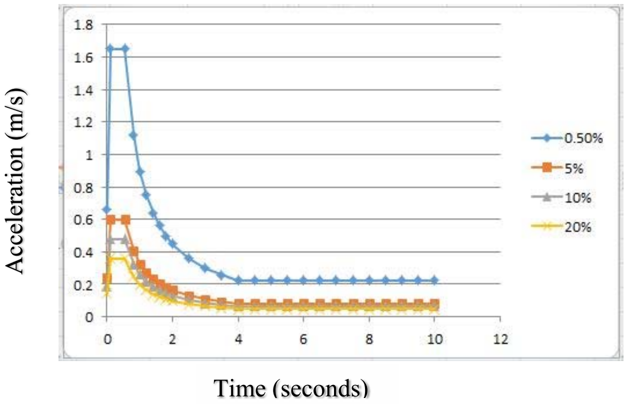


Figure 7 Response spectrum for seismic zone 4

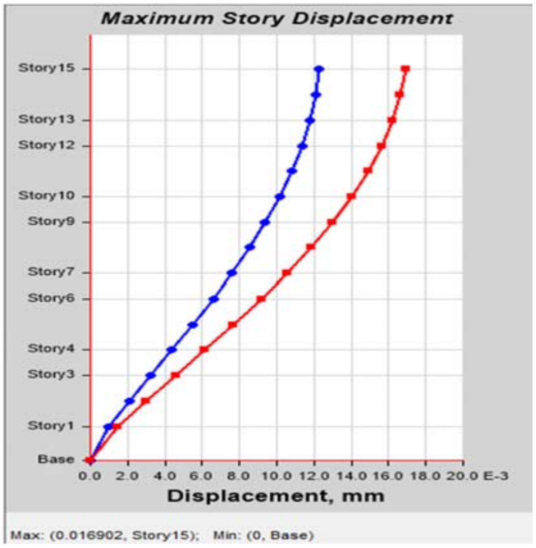


Figure 8 Maximum storey displacement

Story	Load Case/Combo	Direction	Drift
Story 15	Dead	Y	1.5E-05
Story 15	Eqx	X	0.000427
Story 15	Eqy	Y	0.00046
Story 15	Seismic max	X	4.328E-07
Story 15	Seismic max	Y	7.947E-08
Story 14	Dead	Y	1E-05
Story 14	Eqx	X	0.000437
Story 14	Eqy	Y	0.000474
Story 14	Seismic max	X	4.446E-07
Story 14	Seismic max	Y	1.174-07

Table 10 Story drift

CONCLUSION

- Lateral drifts on the building are to be found within 0.004H as per is 1893(part 1:2002) Clause 7.11.1 and within 0.002H as per IS 456.
- The response spectrum graph shows that less damped system are subjected to more spectural acceleration.
- The optimum damping ratio is found to be 5% for seismic zone 4, as the difference in decrease in acceleration is marginally high for 5% damping.
- According to is 1893:2002, damping ratio 5% is optimum for reinforced concrete buildings. This is satisfied by seismic zone 4.
- The storey displacement goes on increasing with the height of the structure. The maximum displacement is observed on the top floors which is to be 0.0169mm

REFERENCES

1. Sudhir K Jain, *“Indian Earthquakes: An overview”,* The Indian Concrete Journal,Vol.72,No 11,November 1998.
2. C.V.R. Murty, *“Earthquakes in India”,* IITK, bmptc.
3. C.V.R. Murty, Rupen Goswami, A.R. Vijayanarayanan, Vipul V. Mehta,“*Earthquake behavior of buildings*”, GujaratvState Disaster ManagementvAuthority.
4. A.V. Bhaskararao, R.S. Jangid, *“Seismic analysis of structures connected with friction dampers”,* ISJRDV3I40313
5. Mahmad Sabeer and D. Gouse Peera, *“Comparison design result of rcc building using staad pro and e-tabs software”,* International Journal of Innovative Research in Advanced engineering (IJIRAE) ISSN:2349-2163 Issue 8, volume 2 (August 2015)
6. Tom Irvine, “ *damping properties of materials*”, November 8, 2004