“Seismic Analysis and Design of Multi Storey RC Buildings with and without Fluid Viscous Dampers’’

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Abstract - Earthquakes are one among the foremost destructive of natural hazards. Earthquake occurs due to sudden transition motion of the ground as a result of release of energy in a matter of few seconds. This recent events remind us of the vulnerability of our society to natural hazards. The protection of civil structures, including material content and human occupants is, doubtless, a worldwide priority. The challenge of structural engineers is to raised withstand these natural hazards. In the present study reinforced concrete moment resisting frame building of G+20 are considered. The building is taken into account to be located in the seismic zone (v) and intended for commercial purpose. Model-I Building without dampers, Model-II –Building with dampers. The building of G+20 has been modeled by providing with and without damper providing all parameters using SAP2000 software. When the structure is connected to the fluid viscous dampers (FVD), the building's displacements and accelerations may be controlled. Further damper at appropriate locations can significantly decrease the earthquake response.

Keywords – SAP 2000, pushover analysis, base shear, lateral displacement, storey drifts.

I. Introduction

Earthquakes are one among the foremost destructive of natural hazards. Earthquake occurs thanks to sudden transient motion of the bottom as a results of release of energy during a matter of few seconds. The impact of the event is most traumatic because it affect large area, occurs all of a sudden and unpredictable. Vibrations induced within the earth’s crust thanks to internal or external causes that virtually shake up a neighborhood of the crust and every one the structures and living and non-living things existing thereon they will cause large scale loss of life, property and disrupts essential services like water system , sewerage systems, communication, power and transport etc. The aftermath results in destabilize the economic and social organization of the state . the first objective of earthquake resistant design is to stop building collapse during earthquakes therefore minimizing the danger of death or injury to people in or around those buildings. Earthquake force is generated by the dynamic response of the building to earthquake induced ground motion. This makes earthquake actions Basicly different from the other imposed loads. Dynamic responses are stresses, strains, displacement, etc. the planning of buildings for seismic loads is special, when compares to the planning for gravity loads (dead loads and live loads). Gravity load is relatively constant, in terms of their magnitude and are treated as ‘static’ loads. In contrast, seismic load are predominantly horizontal (lateral), reversible (the forces are back-andforth), dynamic (the forces rapidly vary with time) and of very short duration. The seismic loads are more uncertain than the traditional gravity loads in terms of magnitude, variation with time and instance of occurrence. The variation of the forces with time affect the resistance of the building. the utmost magnitudes of the interior forces and their locations within the structural members are different from those thanks to gravity loads. so as to form a building seismoresistant, it should have good building configuration, lateral strength, lateral stiffness, ductility, stability and integrity. Data required from the NESDIS National Geophysical Data Centre, Significant Earthquake Database. Table 1.1 can be seen the Loss of Life and Property Damage for Recent Earthquake Disaster.

II. Modelling and Seismic Analysis

a) Modelling of the Multistorey Building

The most of buildings in which floor diaphragms are sufficiently stiff in their planes, the dynamic analysis can be acted upon by using decreased 3D model. This is based on the following presumptions:

i. The floors are stiff in their planes having 3 DOF's, to horizontal translations and a unique rotation about a vertical axis.

ii. The mass of building and mass moment of inertia are lumped at the floor levels at the corresponding degrees of freedom.

iii. The inertia forces or movements due to vertical or rotational components of joint motions are negligible, therefore ignored.

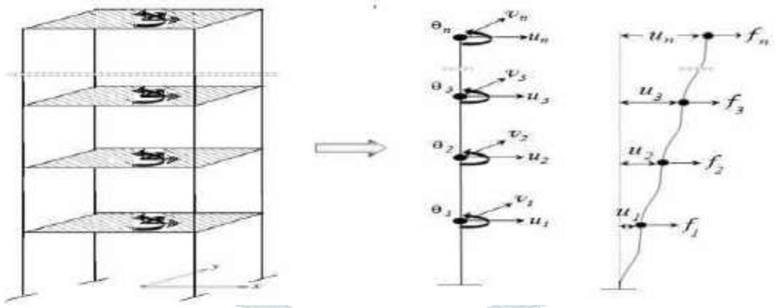


Figure 3.1 Building Model with 3DOFs

The simplified model with above presumptions is shown in Fig. 3.1. The dynamic degrees of freedom are drastically decreased by static condensation and yet it produces quite accurate results. In case, the floor diaphragms are not enough stiff in buildings with very stiff vertically resisting elements much like elevator cores, and diaphragms having large openings, irregular shapes etc., the in-plane stiff presumption is not valid. In this cases, a more complex model with extra degrees of freedom is considered to properly represent in-plane flexibility. The floor slabs in this cases can be idealized as an assemblage of finite elements.

b) Analysis Using Sap 2000 The entire analysis has completed for all the 3D models using SAP 2000 non-linear version software. The answer will be tabulated in order to focus the parameters much like time period, base shear, story drift and lateral displacements in linear analysis.

c) Response Spectrum Method Dynamic analysis of the building models is performed using SAP 2000. The lateral loads generated by ETABS correspond to the seismic zone V and 5% damped response spectrum given in IS 1893 (Part 1): 2002. The basic natural period values are calculated by SAP 2000, by solving the Eigen value problem of the model. Therefore, the total earthquake load generated and its distribution along the height corresponds to the mass and stiffness distribution as modeled by SAP 2000. Here, as in the equivalent static analysis, the seismic mass is calculated using full dead load plus 25% of live load. The 5% damped response spectrum is considered for all modes of the building. For the modal combination the square root of sum of squares (SRSS) method is considered, because in this method of modal combination coupling of the modes doesn't take place. For each displacement and force in the structure, the modal combinations produce a unique positive results for each direction of acceleration, these directional value for a given response quantity have to be combined to produce a unique positive result, and for this directional combination, CQC method is adopted. After defining the response spectrum case, analysis is acted upon.

d) Pushover Analysis

After the linear static analysis the designing of 3D Building model for gravity load combinations as per IS 456-2000 has completed. Later assign the default hinge properties available in SAP 2000 Non-linear as per ATC- 40 to the frame elements. For the beam default hinge that yields based upon the flexure (M3) is assigned, for the column default hinge that yields based upon the interaction of the axial force and bending moment (P M2 M3) is assigned. Define three static pushover cases. In the first case gravity load is put in to the structure, in the second case lateral load is put in to the structure along X-direction and in the third case lateral load is put in to the structure along Y-direction. The buildings are pushed to a displacement of 4% of height of the building to reach collapse point as per ATC 40 (Put in Technology Council). Tabulate the non-linear results in order to achieve the inelastic behavior. The successful stiffness of friction damper is (0.2 to 1.2 times the initial stiffness (ki) of the frame structures) and damping coefficient. Initial elastic stiffness of modelled frame structures is determined from non-linear static analysis (Pushover curve) and damping ratio is a function of structure mass, stiffness and damping ratio. In the present study damping ratio is taken as 5% of the critical value and mass of the frame structure is computed by using total gravity dead loads.

Where,

Damping Coefficient=ξ x 2$\sqrt{}$ ξ = Damping ratio Ki = Initial stiffness.

e) Details of Selected Building

In the present study reinforced concrete moment resisting frame building of G+20 are considered. The plan layout, elevations and 3D view of all storeyed buildings with and without dampers are as shown in the below Figures. The building is considered to be located in the seismic zone v and intended for commercial purpose.

Model-I Building without dampers.

Model-II –Building with dampers.

The building of G+20 has been modeled by providing with and without damper providing all parameters using SAP 2000 software. The building considered to model as shown in following figures.

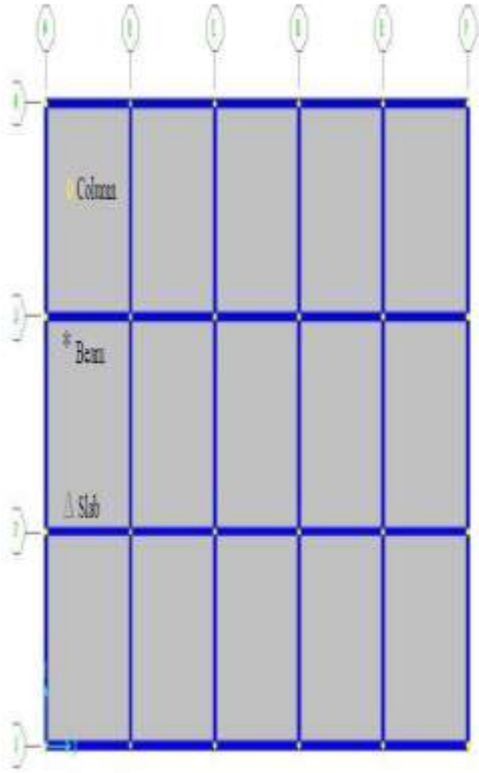


Figure 3.2 Plan of Selected Multistorey Building Model

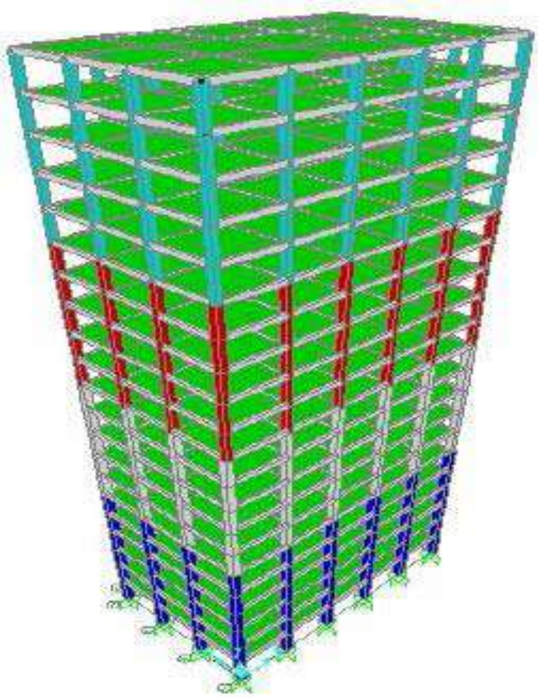


Figure 3.3 Model G+20 without FVD

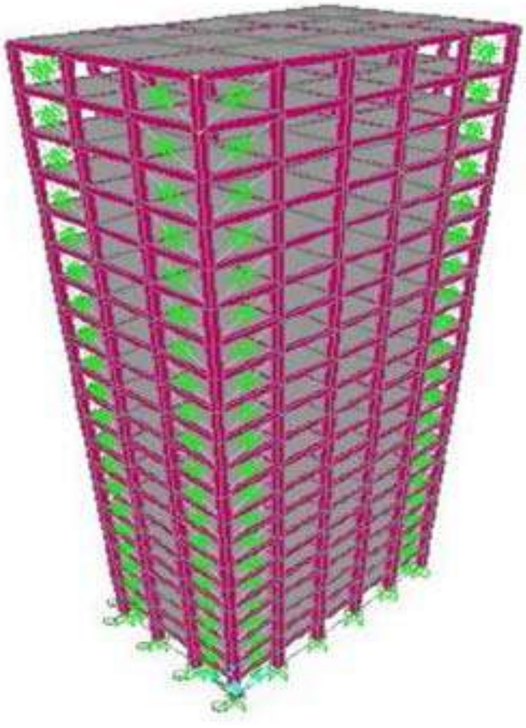


Figure 3.4 Model G+20 with FVD

The analysis has been acted upon by Equivalent Static Method and Response Spectrum Method. The results of Time period, Lateral displacement, Base shear, Storey drift were determined for all models.

f) Load Combinations

The following load combinations are considered for the analysis and design as per IS: 1893-2002.

Figure 3.1 Load combinations as per IS: 1893-2002 and IS: 875 (Part3)-1987

Load Combination	Load Factors
Gravity analysis	1.5(DL+LL)
Equivalent static analysis	1.2(DL+LL±EQX) 1.2(DL+LL±EQY) 1.5(DL±EQX) 1.5(DL±EQY) 0.9(DL±EQX) 0.9(DL±EQY)
Response spectrum analysis	1.2(DL+LL±RSX) 1.2(DL+LL±RSY) 1.5(DL±RSX) 1.5(DL±RSY) 0.9(DL±RSX) 0.9(DL±RSY)

The example of buildings considered in the present study is appropriately modeled in SAP 2000 by giving all the required input data mentioned in the APPENDIX A. The building models are analysed separately as per the analysis methods mentioned in Table 3.1 with respect to the load combinations.

IV. Results and Discussions

a) Natural Time Periods

The natural time periods achieveed from seismic code IS 1893 (Part 1) -2000 and analytical results achieveed using (SAP 2000) are given in Table 4.1 and Fig.4.1.

Figure 4.1 Codal and Analytical Time Period (seconds) for all storey building as per IS 1893 (Part I) – 2000

BUILDING	MODELS	GRAVITY ANALYSIS	
		CODAL	1.5(DL+IL)
G+20	Model I	1.8150	3.5177
	Model II	1.8150	1.9832

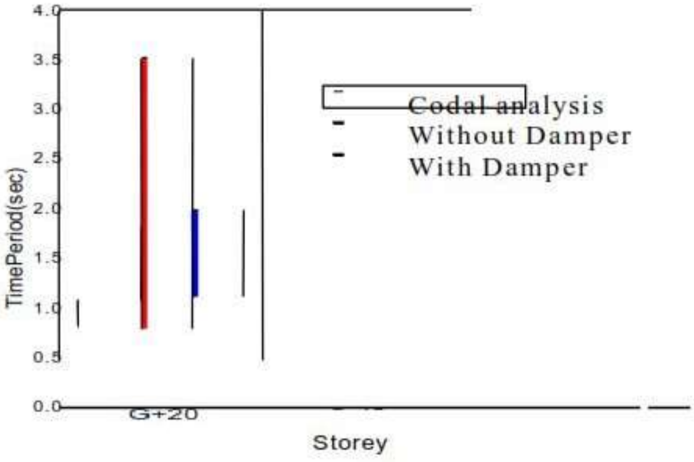


Figure 4.1 Natural time period (seconds) profile for all Storey buildings for codal and analytical load combination as per IS1893 (Part 1) -2000.

(i) Model-I: Building without damper.

(ii) Model-II: Building with damper.

The basic natural periods achieveed for the seismic designed building and gravity models have plotted in Fig. 4.1 From the plot it is very clear that, stiffness of the building is directly proportional to its natural frequency and hence inversely proportional to the natural period. That is, if the stiffness of building is increased the natural period goes on decreasing. And as the natural frequency of the taller buildings is high due to the more mass, the natural period goes on increasing for three different multi storied buildings. The comparison of natural period presented in the table or plot shows that, the code IS 1893 (Part-I) 2002 uses empirical formula to calculate natural period which is directly depends on the height of the building. Whereas the analytical procedure calculates the natural period on the basis of mass and stiffness of the building (Eigen value and Eigen vectors).

b) *Base Shear*

In the response spectrum method the design base shear (VB) is made equal to the base shear achieveed from equivalent static method V B as per clause 7.8.2 of IS: 1893(Part 1):2002 by applying the scaling factors calculated as shown in Table 4.2 to 4.4.

The base shear is a function of mass, stiffness, height, and the natural period of the building structure.

From the previous results it is very clear that the basic natural periods achieveed from the code, fall far short from that of the analytical natural periods. And in the equivalent static method design horizontal acceleration value achieveed by codal natural period is adopted, and the basic presumption in the equivalent static method is that only first mode of vibration of building governs the dynamics and the effect of higher modes are not significant therefore, higher modes are not considered in this method. Hence base shears achieveed from the equivalent static method are larger than the dynamic response spectrum method where in the dynamic response spectrum, all the modes of the building are considered, and first mode governs in the shorter buildings and as the storey increases for tall buildings, the flexibility increases and higher modes come into picture. The base shear for the equivalent static method (VB) and the response spectrum method (V B) as per IS 1893 (Part 1): 2002 for the various building models are listed in the tables below.

Table 4.2 Base shear and scaling factors for all models for 1.2(DL+LL+EQL) Combination

Storey	Base shear in kN for Model-I						Baseshear in kN for Model–II					
	EQX	RSX	Scale Factor	EQY	RSY	Scale Factor	EQX	RSX	Scale Factor	EQY	RSY	Scale Factor
G+20	7957.35	4408.74	1.8049	7995.65	4284.22	1.8663	8804.51	6073.75	1.4496	8827.41	5955.21	1.4823

Table 4.3 : Base shear and scaling factors for all models for 1.5(DL+EQL) combination

Storey	Base shear inkN for Model-I						Base shear in kN forModel-II					
	EQX	RSX	Scale Factor	EQY	RSY	Scale Factor	EQX	RSX	Scale Factor	EQY	RSY	Scale Factor
G+20	9946.69	5268.54	1.8879	9946.69	5201.59	1.9122	11005.69	755.89	1.4558	11005.69	6974.89	1.5779

Table 4.4 : Base shear and scaling factors for all models for 0.9(DL+EQL) combination

Storey	Base shear in kN for Model-I						Base shear in kN for Model–II					
	EQX	RSX	Scale Factor	EQY	RSY	Scale Factor	EQX	RSX	Scale Factor	EQY	RSY	Scale Factor
G+20	9946.69	5268.54	1.8879	9946.69	5201.59	1.9122	11005.69	7559.89	1.4558	11005.69	6974.89	1.5779

(i) Model – I: Building without Damper.

(ii) Model – II: Building with Damper.

The base shear is a function of mass, stiffness, height, and the natural period of the building structure. Moreover the basic presumption in the equivalent static method is that only first mode of vibration of building governs the dynamics of the structures. In dynamic response spectrum method, all the modes of the building are considered, and the first mode governs in the case of shorter buildings and as the number of storeys increase for tall buildings, the flexibility increases and higher modes come into picture. Hence base shears achieveed from the equivalent static method are larger than the base shear achieveed from dynamic response spectrum method. The base shear values achieveed by equivalent static method are higher than those achieveed by Response spectrum method for gravity and seismic analysis for G+20 buildings.

c) *Lateral Displacement*

The lateral displacements achieveed for equivalent static method (EQS) and response spectrum method (RSP) for 11 to 21 storey building models, along both X and Y directions are listed in the tables below. In order to account the effect of torsion the displacements are captured in both directions when force is acting in particular direction. Table 4.5 shows the lateral displacements of G+20 storied building with and without damper, by taking load combinations in consideration. Similarly fig.4.2 to 4.7 indicates the plot of lateral displacements versus storey number for various load combinations.

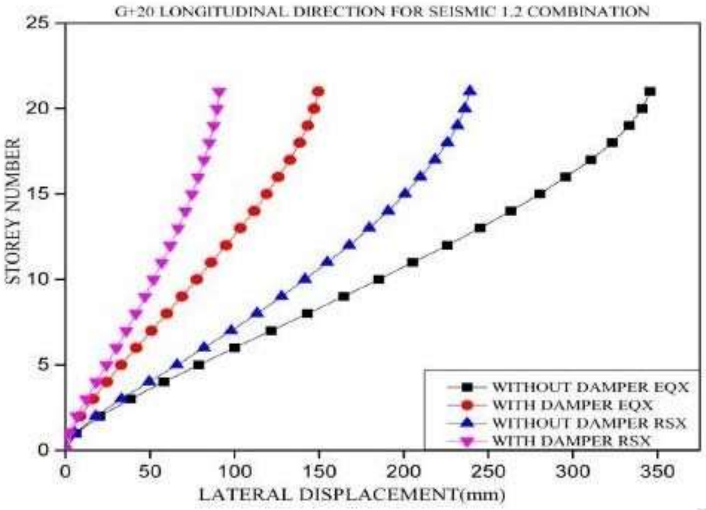


Fig. 4.2 : Lateral displacement (mm) profile for G+20 storey in Longitudinal direction By Seismic 1.2 EQX and RSX

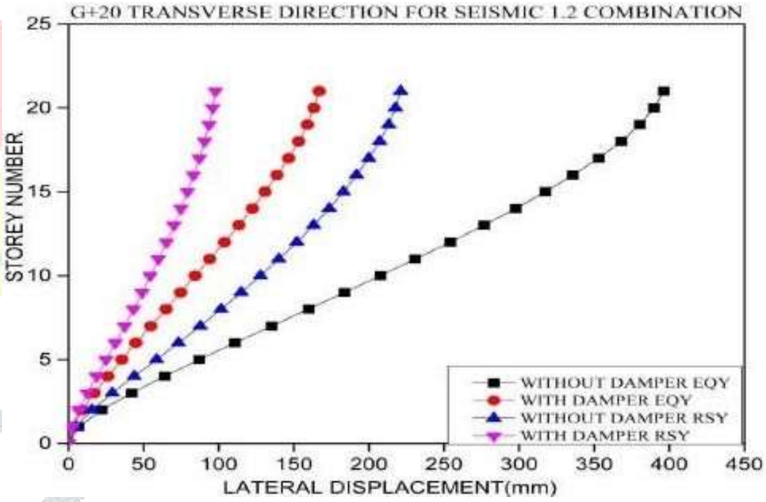


Fig. 4.3 : Lateral displacement (mm) profile for G+20 storey in Transverse direction by Seismic 1.2 EQX and RSY

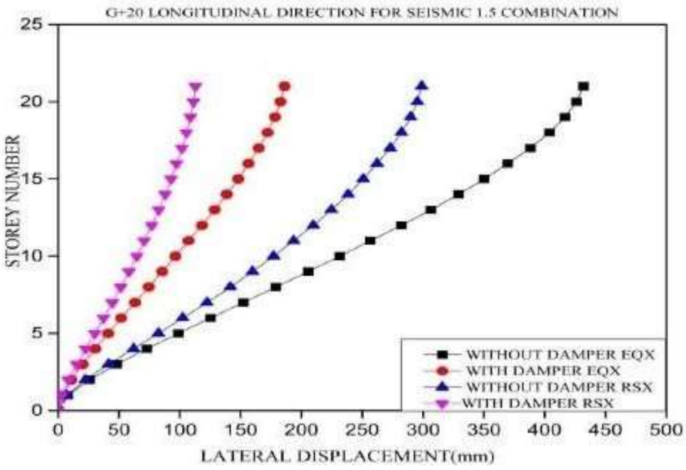


Fig. 4.4 : Lateral displacement (m) profile for G+20 storey in longitudinal direction by Seismic 1.5 EQX and RSX

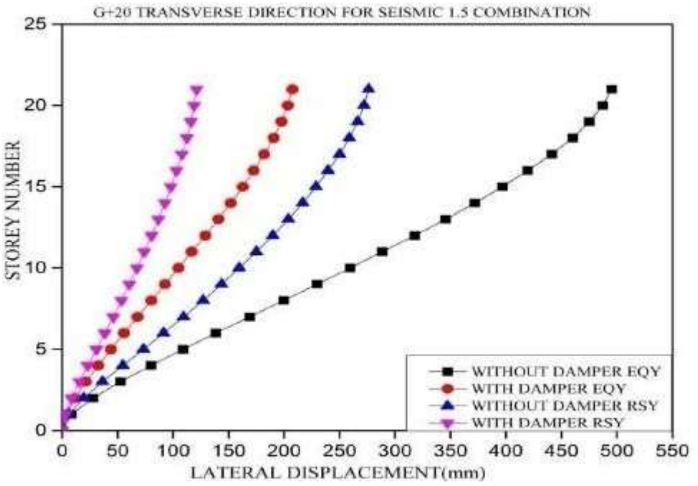


Fig.4.5 : Lateral displacement (mm) profile for G+20 storey in Transverse direction by Seismic 1.5 EQY and RSY

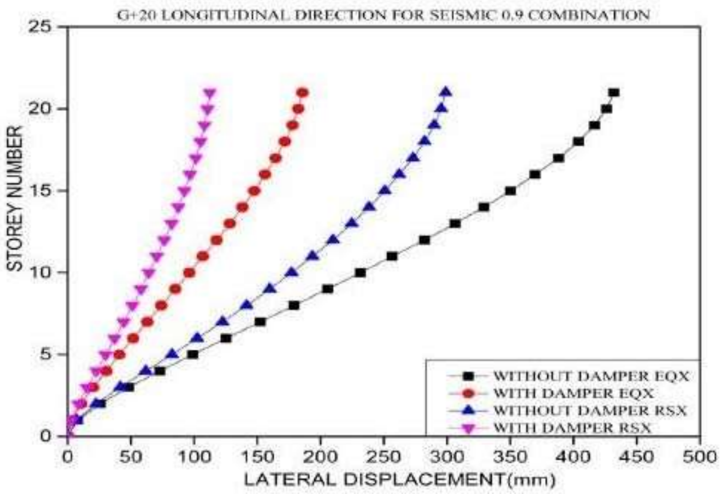


Fig.4.6 : Lateral displacement (mm) profile for G+20 storey in Longitudinal direction by Seismic 0.9 EQX and RSX

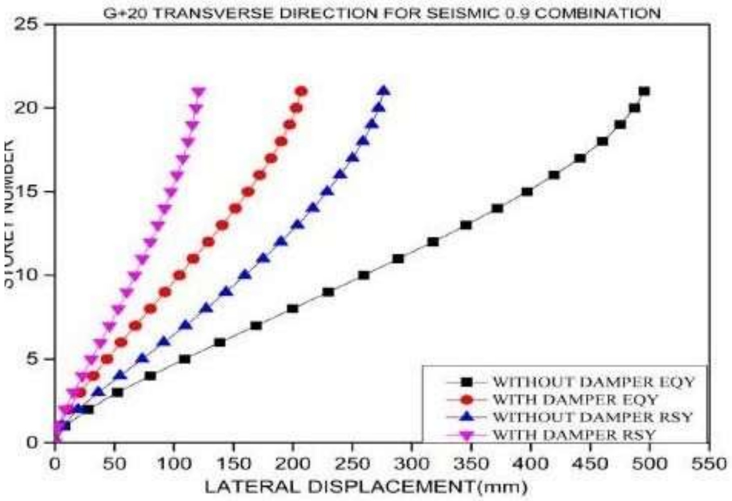


Fig.4.7: Lateral displacement (mm) profile for G+20 storey in Transverse direction by Seismic 0.9 EQY and RSY

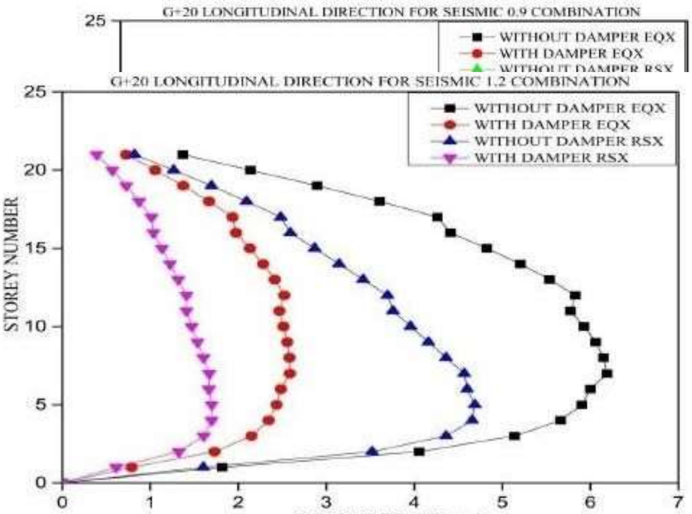
For all the load combination the lateral displacement is maximum at roof level has a maximum value of 432.06mm for model I compared to model II maximum value of 186.06mm in longitudinal direction for equivalent static method. And in response spectrum method model I and model II have displaced maximum values of 298.85mm and 112.96mm respectively in longitudinal direction. Similarly, in transverse direction model I has displaced 495.35mm and model II 207.57mm for equivalent static method, in response spectrum method model I and model II have displaced 276.34mm and 121.31mm respectively.

This clearly shows that the fluid viscous damper are successful reducing the lateral displacement due to seismic loads.

From the results of roof displacement for Model I (bare frame without FVD) and Model II (building with FVD) it can be observed that Model I gives maximum displacement for G+20 storey buildings analysed for seismic loads which gives maximum displacement for Model I. Lateral displacements increases as the number of stories increases. So the lateral displacement can be decreased by introduction of FVD in building.

d) *Storey Drifts*

Inter Storey drifts for different models achieveed from the analysis are shown in Table.4.6 below. Inter Storey drifts profile can also be observed in Fig. 4.8 to 4.13. According to IS 1893(Part 1):2002 clause 7.11.1 Storey drifts limitations are explained that the Storey drifts in any storey due to the minimum specified design lateral force, with partial load factor of 1.0 shall not exceed 0.004 times the storey height. For 3.5 m storey height has got 14.00 mm.



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longitudinal direction by Seismic 0.9 EQX and RSX

Fig.4.8 : Storey drifts profile for G+20 storey in longitudinal direction by Seismic 1.2 EQX and RSX

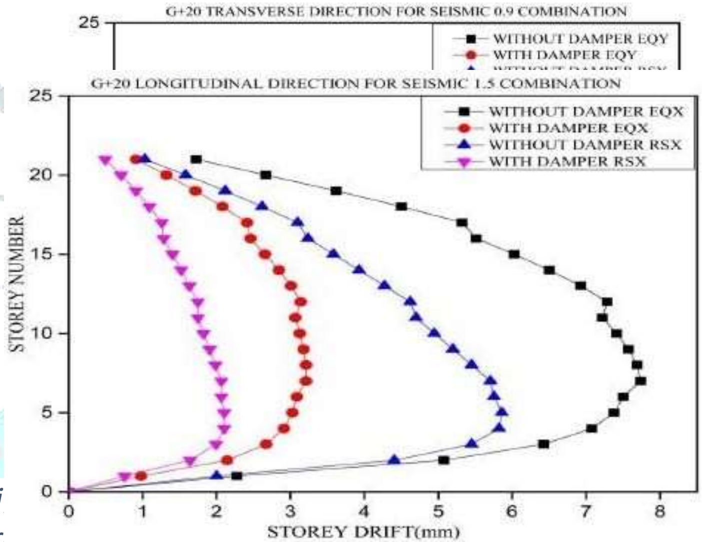

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Fig. 4.9 : Storey drifts profile for G+20 storey in longitudinal direction by Seismic 1.5EQX and RSX

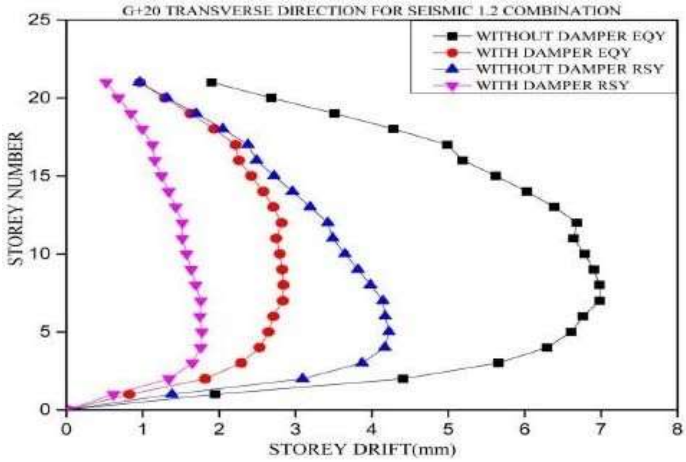

Fig. 4.10 : Storey drifts profile for G+20 storey in transverse direction by Seismic 1.2 EQY and RSY

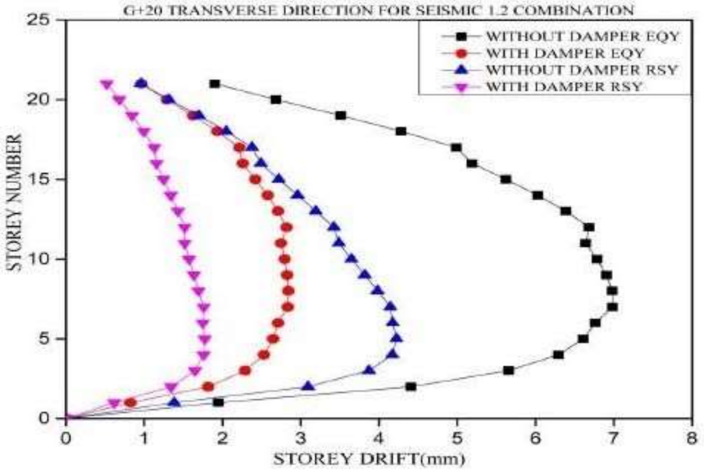

Fig. 4.11 : Storey drifts profile for G+20 storey in transverse direction by Seismic 1.5 EQY and RSY

(i) Model-I: Building without FVD

(ii) Model-II: Building with FVD

For all the load combination the storey drift is maximum for model I compared to model II the model I has a maximum value of 7.74mm for model I compared to model II maximum value of 3.21mm in longitudinal direction for equivalent static method. And in response spectrum method model I and model II have drifted maximum values of 5.86mm and 2.10mm respectively in longitudinal direction. Similarly in transverse direction model I has drifted 8.73mm and model II 3.52mm for equivalent static method, in response spectrum method model I and model II have drifted 5.28mm and 2.20mm respectively.

This clearly shows that the fluid viscous dampers are successful reducing the storey drift due to seismic loads.

As per Clause 7.11.1 of IS 1893 (Part 1)2002 the inter storey drift in any storey should not exceed 0.004 times the storey height. From the results mentioned above it can be observed that Model I, Model II doesn’t crosses inter storey drift limits for equivalent static method and also Response spectrum method none of the buildings has crossed the drift limits in any direction for G+20 storey models.

From above results for Model I i.e. regular building has got more Storey drifts for G+20 and for Model II (building with fluid viscous dampers) has less storey drift compared to Model-I. The inter storey drift is more at the bottom storey than at the top storey and also as the number of storey increases the relative drift of the storey also increase. The introduction of fluid viscous dampers in the building drastically decreases the inter storey drift in the building.

III. Conclusions

The Present study is focused on the study of Seismic demands of different R.C buildings high rise buildings using numerous analytical techniques for the buildings located in seismic zone V of India medium soil. The achievement of the building is studied in terms of time period, base shear, lateral displacements, storey drifts in linear static and linear dynamic analysis for with and without fluid viscous dampers building G+20 storey models.

The seismic analysis is acted upon by equivalent static method and response spectrum method for G+20 storey building with unsymmetrical in plan. The below are the answer that can be concluded from the present study, which are as follows.

1. The basic natural period of the structure rises due to the lesser stiffness of the bare frame buildings compared to buildings having fluid viscous dampers.

2. The base shears due to seismic forces for the building with fluid viscous dampers are greater than the base shear achieveed for without fluid viscous dampers.

3. Compared to the regular building the storey displacement decreases for the buildings having fluid viscous dampers. Addition of fluid viscous dampers in the building will result in drastic depletion of lateral displacement of the building there by in turn assures the safety of the structure.

4. The storey drift rises in regular building as compared to building having fluid viscous dampers. The addition of fluid viscous dampers in the building drastically decreases the inter storey drift as compared to that of building without fluid viscous dampers.

IV. References

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