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Seismic Analysis of Multi Storey RC Building with and Without Fluid Viscous Damper

Varun M[1], B S Sureshchandra[2]

[1]M Tech Student in Structural Engineering, [2]Associate Professor,
[1,2] Department of Civil Engineering, Dr Ambedkar Institute of Technology, Bengaluru, Karnataka, India

ABSTRACT

Earthquake is the important term that comes to mind while designing any multistory building. Earthquake is one of the most disastrous of natural criteria. Seismic waves are the main reason for development of vibration in the ground, impact of this will cause damage to the building. In this study G+12 storey building of rectangular plan is considered for the seismic analysis. The equivalent static method and response sectrum method is used for seismic evaluation of building with and without fluid viscous damper. ETABs 2017 software used for the analysis of the building, by considering seismic zone V and medium soil (Type II) as per IS 1893-2016. Storey displacement, storey shear, storey drift and modal periods and frequencies are considered for checking the performances of the building. Objective of this study is to compare results obtained from static and response spectrum analysis in both longitudinal and transverse direction for with and without damper building.

KEYWORDS: *Fluid viscous damper, Seismic analysis, Response spectrum method, Equivalent static method, storey responses*

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1. INTRODUCTION

Earthquake is the important term that comes to mind while designing any multi storey building. This earthquake are one of the most disastrous of natural criteria, This earthquake is known as 'Along fault plane the vibration and shaking takes place at the earth surface due to underground ground motion. There is a huge loss of life, property and many essential services. For this we have to take care while constructing the building, the structure should be a earthquake resistant. The earthquake resistant structures are the structures which can resist the largest earthquake that can possibly occur in particular area as per the standard codes. The structure should be having a good building configuration than it is a earth quake resistant structure it should be having better lateral stiffeness, ductiity, lateral strength, stability and integrity .The structure to be made earthquake resistant many technologies are developed in that seismic control devices are now more widely used in buildings.

Mainly there are three types of structural control systems, they are active energy dissipation system, semi active energy dissipation system, and passive energy dissipation system. For the seismic effects the passive energy systems are used. Damping may be defined as the process by which the free vibration of a vibrating body decreases in the amplitude. The range of damping is depending on the different types of materials used in construction, construction type and also the non structural elements. Measuring of damping done through critical damping. Dampers are placed in a structure to absorb the energy developed and lesser the shaking of the structure and reduction in the damage of the building.

Seismic control devices are Dampers During earthquake ground motion high magnitude energy is developed that develop a forces on building if the building is free of damping its stiffeness is less and vibration in the structure is more, or else the structure is damped it increases the stiffeness of the building as of the vibration reduces. Among various passive energy dissipating devices Fluid viscous dampers are more widely used in buildings. Fluid viscous dampers are enhance the performance of the building.

A. Fluid viscous damper

Fluid viscous dampers are one of the passive energy vanishing devices, for controlling vibration caused in structure and mechanical systems. In military and aerospace industry they use extensively these type of dampers from past years now a days these are used in the buildings to control the vibrations caused by wind and earthquakes. One of the greatest unique capacity of the dampers is it will together decreases both the stress and deflection within the structure subjected to transient. This is because the dampers vary its force only with the velocity, due to flexing of the structure the response that is permanently out of phases with the stresses. To vanishes the energy in the building these dampers are used because these dampers are velocity dependent. To reduce the responses in the building these effective damping should be done by using these type of dampers. FVDs are frequency independent devices without a stiffness component.

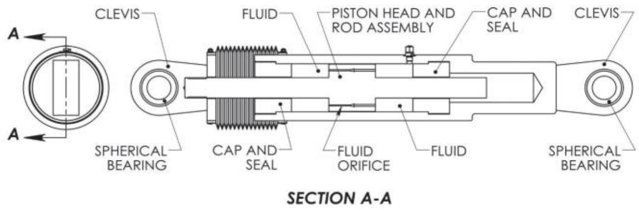


Fig 1: Longitudinal section of Fluid viscous damper

The figure shows in which dampers is in mid stroke position. The main pressure chamber is called cylinder, it consists full of fluid inside .It including the volume on both sides of piston. Piston head is connected with the piston rod. Clevis is present at the left hand side of the piston rod to attach the structure. These piston rod, piston head and clevis act as a single unit during dynamic phase they all move as one component and other components remains stationary. The fluid present in the cylinder is compress able viscous fluid silicone oil which is stable for heat, toxic free, inflammable and also environmental friendly.

B. Damping characteristics

The operation of FVD is happens when structure moves and it will add a resisting force and they do not add any stiffeness to structure and do not carry any load. As a request we can add stiifeness to the dampers. In FVDs the pressure is developed when a piston move back and forth. The orifice which is custom designed with piston develop and optimized relationship that produce this pressure that varies with velocity. Higher the velocity, higher the will be the resisting force .This relationship is represented by a equation.

Damping force = Damping constant x velocity $^{\alpha}$
$F\,D = C \times V^{\alpha}$

α is the damping exponent. The value of α a very important role in magnitude of damping force .The damper with α value 1 then its is a linear damper in this case as per above equation the damper force is proportional to the velocity. As per practical application the value of α greater than 1 not still in practice.

The value of damping coefficient varies from the 0.2 to 2.0 depending on the specific application. In some cases it varies with a range of 0.3 to 1.0. Value of α is very important for a present day structure design with seismic characteristics with a range of 0.3 to 0.5 is common.

There are many configurations are available for arrangement of dampers in a structural frame which can avoid significant functional and architectural compromises. The main point is considered is that the damper should be properly connected to points in the structure and act effectively when there is a motion due to sway of building. One of the simplest method to apply distributed damping to the structure the diagonal bracing method is most common to be used.

C. objectives

The following objectives are considered in the present studies

- To know the response of a multistorey buildings for a seismic activity a rectangular plan with rectangular column and beam sections are considered.
- Comparison is made for a building with and without Fluid viscous dampers using both equivalent static method and response spectrum method.
- To check the reduction in the various storey responses (Displacement, Base shear, storey drift, modal periods and frequencies etc..)

2. METHODOLOGY

More than one storey structures are come under the multi degrees of freedom systems. In multi degrees of freedom systems the deformation of whole structure cannot be related by a single displacement, more than one displacement co-ordinates are need for a completely identify the displaced structures. Multi storied buildings are the perfect examples for MDOF. In case of multi storied structure the total mass of buildings is centralized at the floor level. This assumption shows that these are having infinite number of degrees of freedom; structure with many degrees has a lumped mass at the floor levels.

A. Methods of analysis

There are many methods are available for the seismic analysis of a selected building to find out the forces developed in structure due to seismic activity. Mainly analysis is done on the basis of model of structure selected, materials used in the structure and also on the external inputs.

I. **Equivalent static method** is also called as equivalent lateral force method. Seismic analysis on a building is done on a assumption of the horizontal force is similar to the dynamic loading, In the method periods and shape of higher mode of vibration are not required so the effort for the analysis is less, except for the fundamental period. The base shear is calculated depends on the mass of structure, its fundamental periods of vibration and shapes. Firstly the base shear is calculated for a entire structure then along the height of building distribution is done. At each floor level the lateral force obtained are distributed to each structural element. This method is usually adopted for a low to medium height building.

II. **Response spectrum method** is also called as a modal method or mode superposition method. This method is used in a structure where the modes will affect the response of structure other than the fundamental one mainly this method used for a dynamic analysis of a building which are asymmetrical in plan or irregularity in areas. In case of multi storied buildings to find the forces and displacements caused due to medium range earthquake motion this method is used for analysis.

In this method directly from the earthquake design spectrum the peak response of a building is obtained during an earthquake ground motion. Peak responses obtained in this method are quite precise with the structural design application. In this method multiple mode of response are considered. Based on modal frequency and modal mass the individual mode response is read from the response spectrum.

B. Property of FVD in ETABs

The FVD is a velocity dependent and it is not express parallel stiffness with the damping output. For a seismic analysis the analytical modes need not be involve any elastic stiffeness.

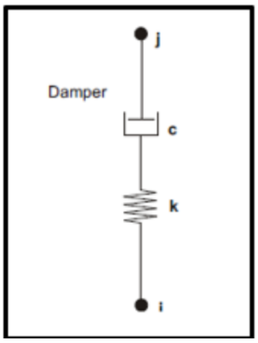


Fig 2: Exponential damper link

k = the series spring constant (Maxwell Stiffness)
c = the damping coefficient

The FVD definition in the ETABs software follows the equation in addition to that the spring constant k as shown in figure. The maxwell model of viscoelasticity is having an exponential viscous damper in series with linear spring is also called as maxwell stiffeness. The elastic flexibility of the damping device are reflected by the maxwell stiffeness. To connect the damping devices from one storey to another by a extender brace having stiffeness kextender. The component of damper stiffeness and brace stiffeness in series is represented as,

$$\frac{1}{k} = \frac{1}{k_d} + \frac{1}{k_e}$$

The stiffeness of extender brace is calculated by its length and section properties,

$K_e = AE/L$

3. MODELLING AND ANALYSIS

G+12 storey building is considered for the analysis and modeling is done in ETABs software.

A. Description of building model

Geometric details	
Dimension of building	(42x30)m
Type of building	Commercial
No of bays in X direction	7
No of bays in Y direction	5
Each bay width	6m
Storey height	3.1m
Column size	(700x1200)mm
Beam size	(450x600)mm
Slab thickness	125mm
Grade of concrete	M20&M40
Grade of steel	Fe500
Primary load cases	
Roof live	2 KN /m^2
Floor live	4 KN /m^2
Roof and floor finish	0.75 KN /m^2
Seismic load in X and Y	IS 1893:2016
Seismic properties	
Zone factor Z	0.36(ZONE V)
Response reduction factor R	5(SMRF)
Importance factor I	1.5
Soil type	II(Medium soil)
Damping ratio	5%

Table 1: Building model details

Brick Infill is not taken into consider in this study so the fundamental natural period can be calculated by using equation as per clause 7.6.1 of IS 1893; 2016
Fundamental natural period in both the direction is 1.2 sec

B. Damper data

The dampers placed with a single diagonal bracing are active in axial direction. Therefore the U1 directional property is chosen and all the other are kept fixed because damper behavior is non linear .During defining the damper property non linear option is selected ,in that the value of stiffeness ,damping constant and damping exponent values are entered. Rotating properties R1, R2 and R3 are entered zero because there is no provision for rotation of damper.

For the present study the damper data used are tabulated below, these values are entered in the ETABs while defining of damper. Dampers data are taken from the Taylor devices Inc US. Dampers are placed at the exterior corner of the building in all stories.

Damper type	FVD 250
Mass in Kg	44Kg
Damping constant KN-s/m	460
Damping exponent α	0.3

Table 2: Damper input data

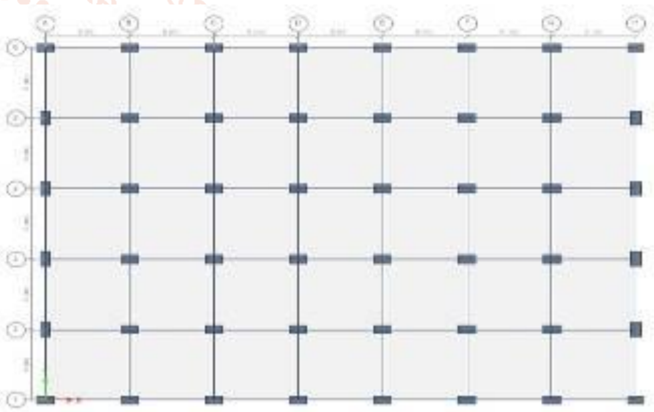


Fig 3: Normal building plan

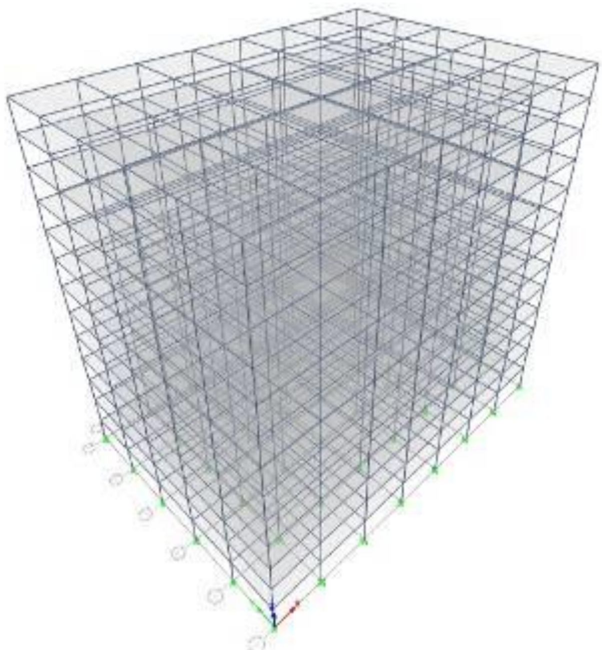


Fig 4: Isometric view

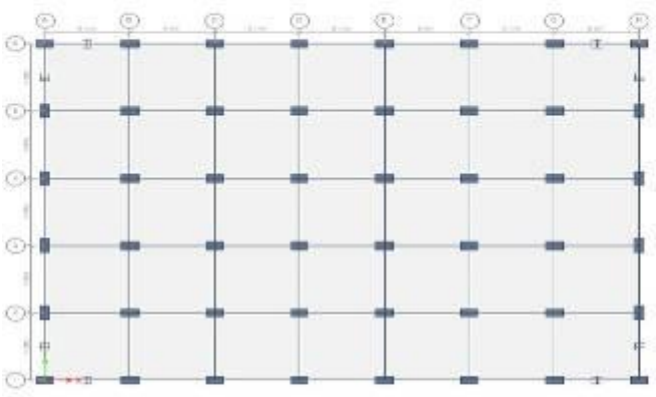


Fig 5: plan of FVD at exterior corner

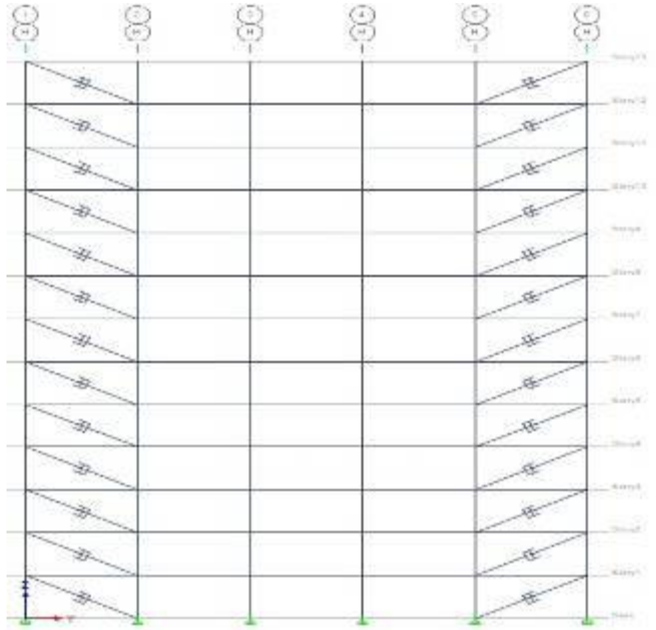


Fig 6: FVD at exterior corner Elevation in YZ plane

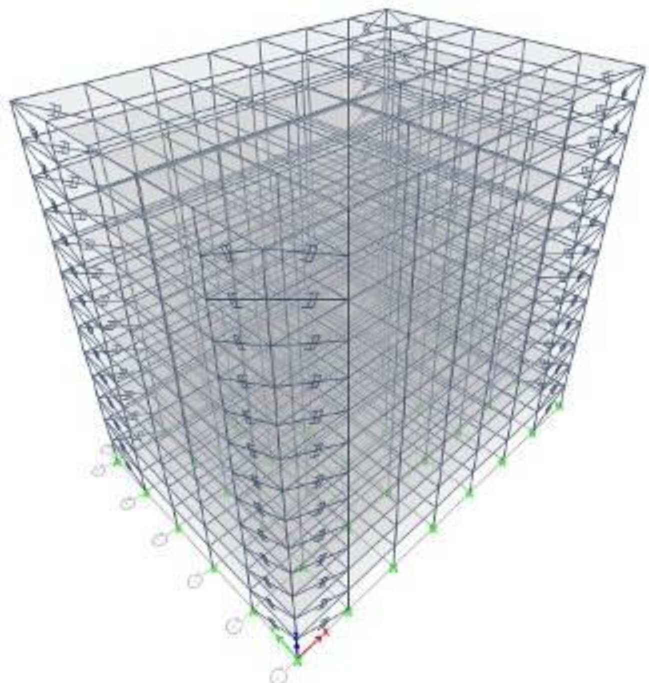


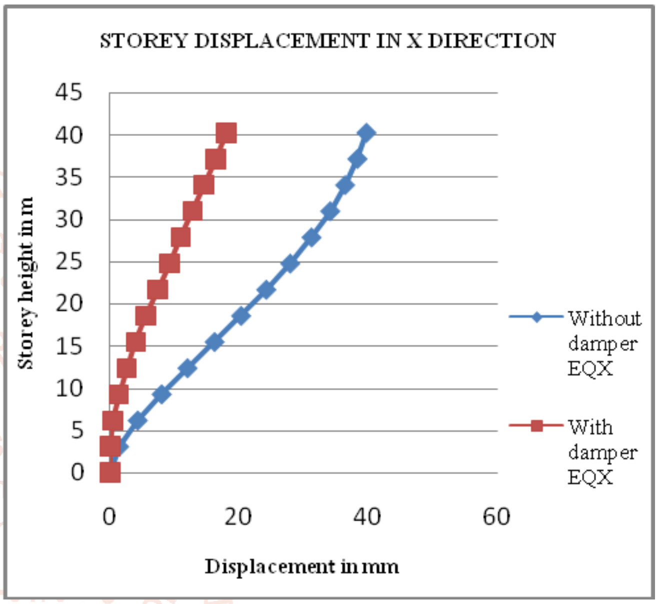
Fig 7: FVD at exterior corner Isometric view

4. RESULTS AND DISCUSSION

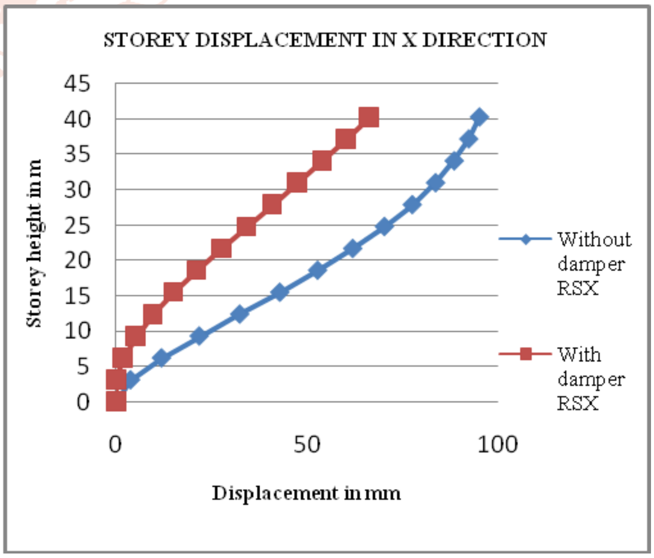
Modeling of building is done with the all the defined loads as per the codal provisions. Then the analysis of the structure is done with both Equivalent static method and Response spectrum method. After the analysis various storey responses are compared and comment should be made on those results. A storey response includes storey displacement storey drifts, storey shear and Modal time and frequencies are considered and compared.

A. Storey displacement

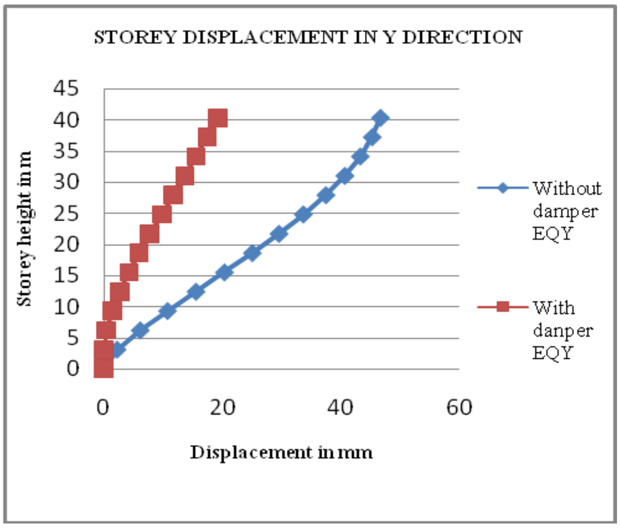
Storey displacement is an main storey response that get reduced after adding dampers to the structures. For a G+12 storey building with and without viscous dampers the displacement value obtained for both equivalent static method and response spectrum method along both x and y direction



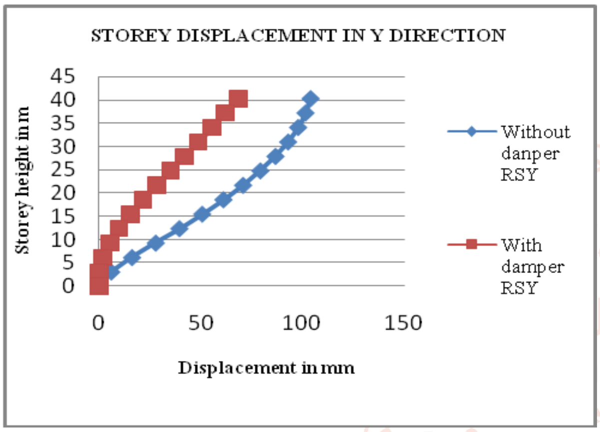
Graph 1: Storey displacement in x direction for Static method



Graph 2: Storey displacement in x direction for response spectrum method



Graph 3: Storey displacement in Y direction for Static method

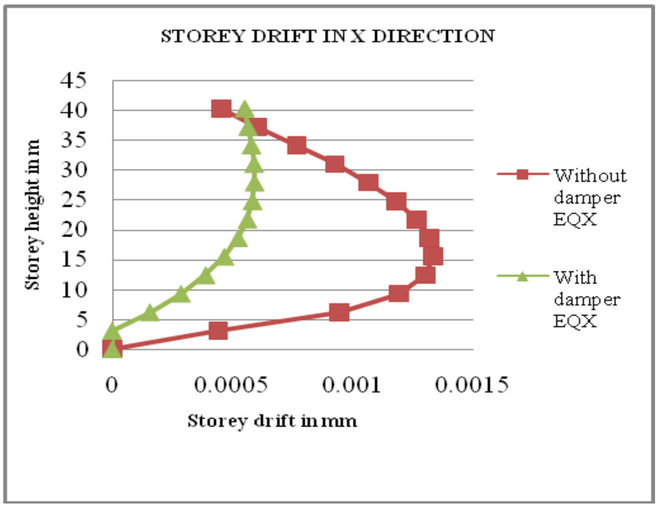


Graph 4: Storey displacement in Y direction for response spectrum method

By observing all the above results the placing of FVD in the building will reduces the storey displacement due to seismic loads effectively in both directions. From the results of storey displacements bare framed building without a FVD having maximum displacement when compared with a building with FVD.

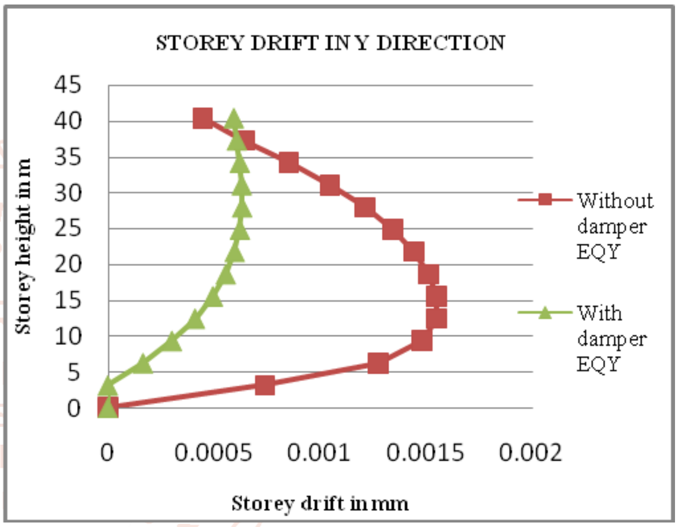
B. Storey drifts

The inter storey drifts values for the considered building along x and y direction are tabulated below. As per IS 1893:2016 for a storey with minimum assigned lateral force, having partial load factor 1.0 the storey drift value does not exceed 0.004 times the height of a storey.

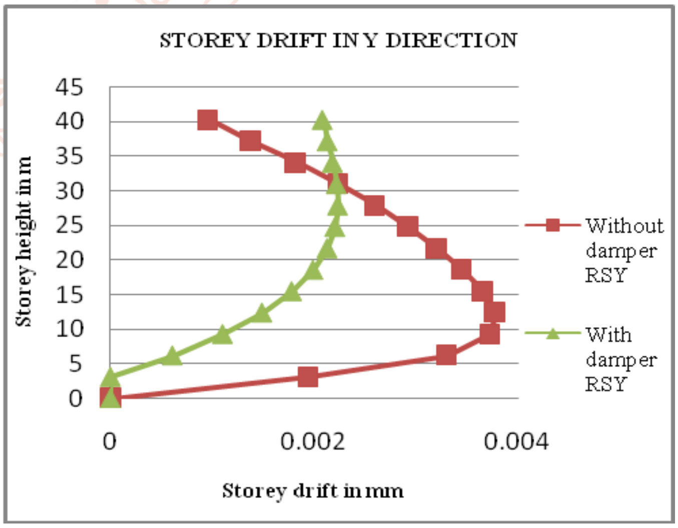


Graph 5: Storey drift in x direction for Static method

Graph 6: Storey drift in x direction for response spectrum method



Graph 7: Storey drift in Y direction for Static method

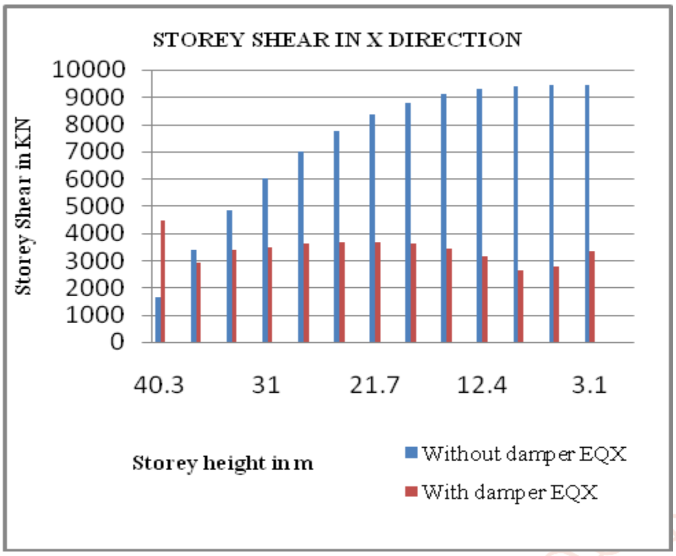


Graph 8: Storey drift in Y direction for response spectrum method

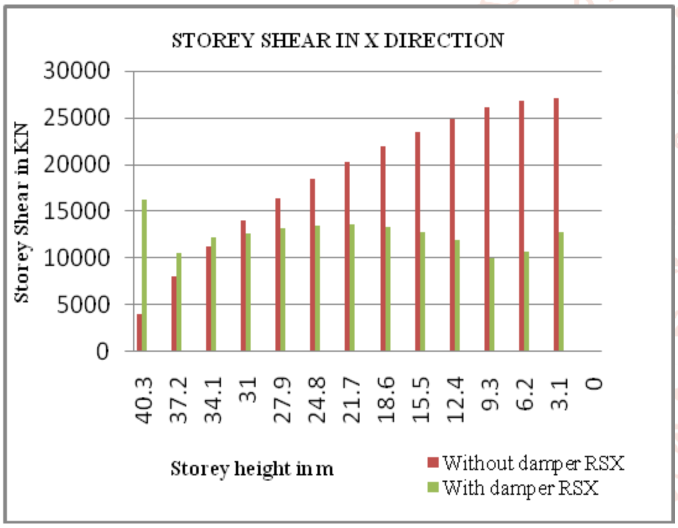
From the above observation the storey drift will be max for a building without damper as compared to building with damper. The max drift value for any building does not exceed the limited value specified by the IS standards. By placing the dampers in the building will reduce the drift value.

C. Storey shear

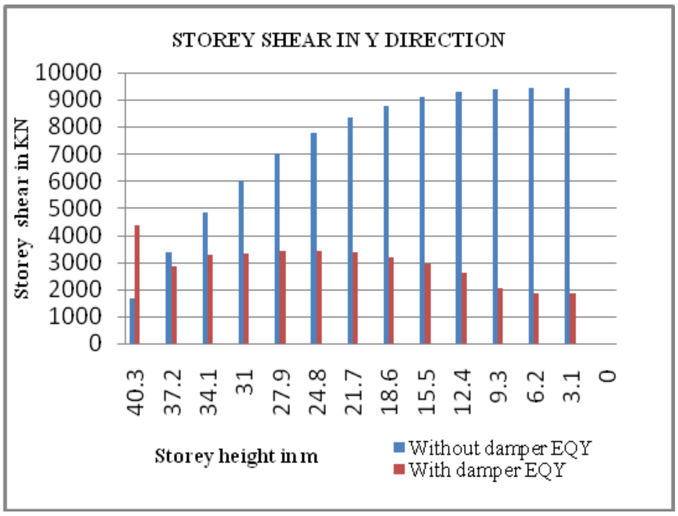
The storey shear is the shear value computed from the adding of design lateral forces at the levels above the storey consideration of the structure. Usually the storey shear value is maximum at the lower stories and minimum at the higher storeis.



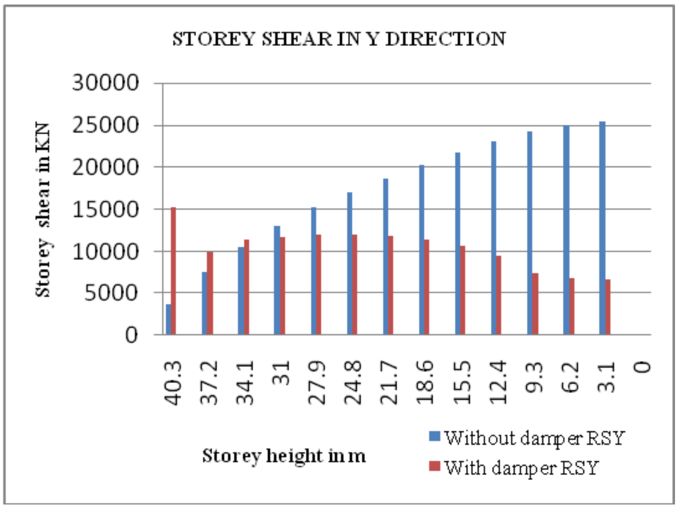
Graph 9: Storey shear in x direction for Static method



Graph 10 : Storey shear in x direction for response spectrum method



Graph 11: Storey shear in Y direction for Static method

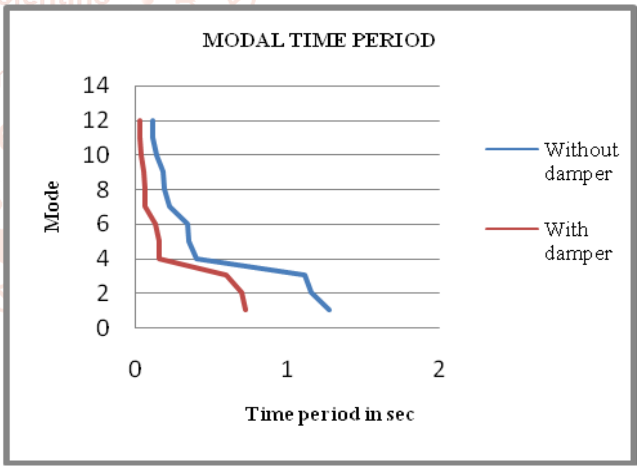


Graph 12: Storey shear in Y direction for response spectrum method

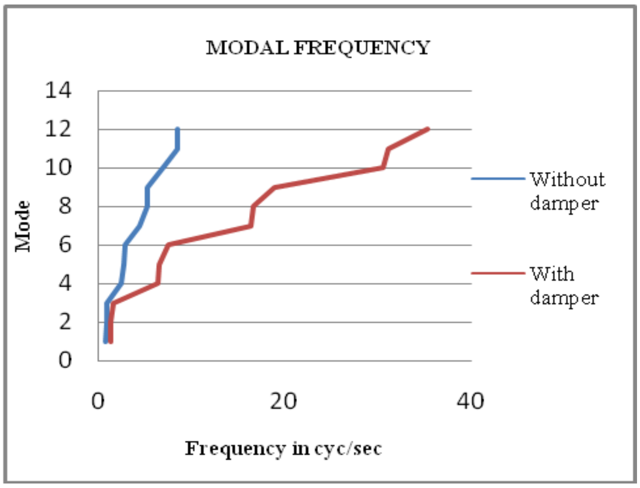
From the above observation we seen that the shear value is increases towards the bottom stories in case of without damped building, But in case of damped building the shear value is increases towards the upper stories. By adding dampers to the building the max shear value will be reduced in a building. Shear at the base will be reduced in damped building.

D. Modal periods and frequencies

During earthquake or wind, all modes are excited in different manner .Depends on the spatial distribution and frequency content of the load the length of dynamic loading excites the modes of vibration. In this study 12 modes are considered and their time period and frequencies.



Graph 13: Modal periods



Graph 14: Modal frequency

The time period for a without damping building is more as compared to the damping building. The time period is inversely proportional to the frequency of the structure. So the natural frequency of the damped building is more compared to the building without damper. As the frequency of the structure increases the stiffeness of structure is also increases because stiffeness is directly proportional to the frequency. For a higher elevation building the frequency is more because of more mass.

5. CONCLUSIONS

For a G+12 storey symmetric building the earthquake analysis is carried out by equivalent static method and response spectrum method and following are the observation made and concluded from the present study, they are

- Storey displacement in a regular building not having dampers will have a maximum displacement value when compared to a building provided with damper. By the addition of dampers to the structures will drastically reduce the displacement value and increase the stability of the structure. As the height of the building increases the displacement value also increases so in order to reduce storey displacement dampers are used.
- Storey drift value for a regular building will be more when compared to the building with damper. By adding damper to the structure the drift value will be reduced and the max drift value of a building does not exceed the limited value specified by the Indian standards.
- Storey shear value for a building without damper will be maximum at the base and for a building with damper will have a max shear value at the top storey, but the shear value of a undammed building will be more compared to the damped building.
- Time periods for 12 modes for a undammed building is more due to which frequency are reduces. But for a damped building time period are less frequency is more. Observed that 75% of frequency increases so that stiffeness of building increases effectively by using FVD 250 dampers at the exterior corners of the building.

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