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Response of High Rise R.C. Frames with Exponential Dampers Under Seismically Activated Condition

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Abstract: *When a structure is subjected to Earthquake, The seismic forces drives the structure into motion. Due to this action a significant amount of energy is induced to the structures. The means by which this energy is dissipated decides the damage level of the structures.Sometimes the structures are designed ductile so that energy is dissipated by the system's elements by bending, twisting or degradation. If the amount of energy induced in the structure can be controlled or, if part of it can be dissipated mechanically by independent structures, the seismic response of the buildings is improved and the potential damage is greatly reduced.In this paper various models with dampers has been studied and their response has been shown.*

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I. Introduction

1.1 General

All, the structures which are constructed with a lot of expenses and the structures with due importance specially situated in seismically activated areas demands safety for them. The design of such structures demands improved response when these structures come across a challenge to resist earthquakes. During Earthquakes the structures are induced to very large stresses the dissipation of which is necessary so as to make the structures less prone for failure.The means by which this energy is dissipated, determines the level of structural degradation. Special emphasis is placed on avoiding loss of human lives due to the earthquake action. In order to achieve this, the structures are designed ductile so that energy is dissipated by the system's elements by bending, twisting or degradation. If the amount of energy induced in the structure can be controlled or, if part of it can be dissipated mechanically by independent structures, the seismic response of the buildings is improved and the potential damage greatly reduced.

1.2 Dampers

A device which is used to dissipate the energy induced due to lateral forces resulted because of earthquake are termed as dampers. Every structure have some amount of damping capacity with itself. But it is very difficult to determine the capacity of a structure to dissipate this energy. Hence, Dampers provide more precised and controllable damping for this energy dissipation. Dampers are used in machines, car suspension system and clothes washing machine. Damping system in a building uses friction to absorb some of the forces from vibrations. A damping system is much larger and is also designed to absorb the violent shocks of an earthquake. The behavior of dampers is dependent on the type of damper used in a structure and the position of its application. Some of the arrangements of dampers has been suggested below in fig 1.1.

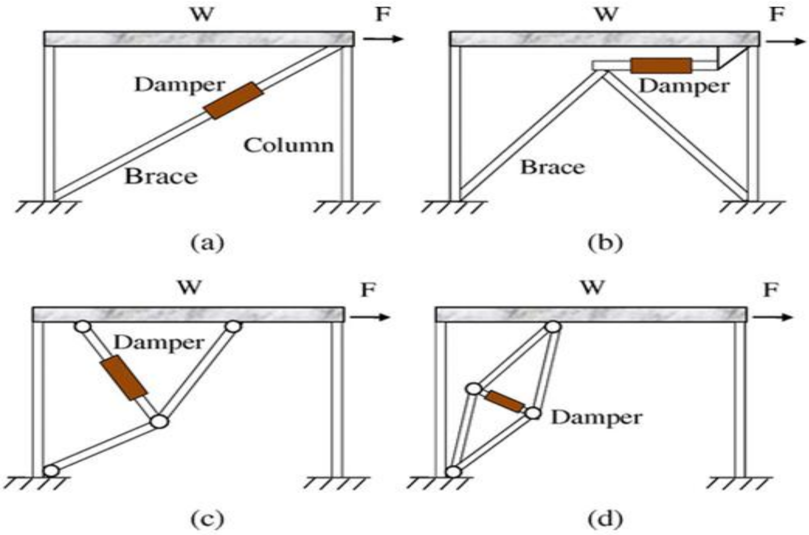

Figure 1: Different arrangements of dampers in a frame

1.3 Types of dampers:

Dampers are classified based on their performance of friction, metal (flowing), viscous, viscoelastic; shape memory alloys (SMA) and mass dampers. Among the advantages of using dampers we can infer to high energy absorbance, easy to install and replace them as well as coordination to other structure members.

- Friction Dampers: These dampers are designed to have moving parts that slides over each other during strong earthquake and create friction. This friction is created by using some energy from the earthquake energy which has entered into the building. Generally these are installed parallel to the bracings.
- PVD dampers: damper can be used to create necessary damping for flexible structures, such as bending steel frame or to provide effective damping to relative stiffness of structures. These dampers are installed where displacement can generate necessary damping such as installation of metal skeleton brace or concrete moment frame.
- Lead Injection Damper (LED): These dampersare made up of two-chamber cylinder, piston and lead inside piston. The piston moves during earthquake, causing lead to move from larger chamber to smaller chamber due to which plastic deformation takes place and the kinetic energy is wasted as heat.
- Viscous Dampers:In such dampers, by using viscous fluid inside a cylinder, energy is dissipated. Due to ease of installation, adaptability and coordination with other members also diversity in their sizes, viscous dampers have many applications in designing and retrofitting. This type of dampers are connected to the -
  Structure in three ways: (i) Dampers installed in the floor or foundation (in the method of seismic isolation) (ii) Connecting dampers in stern pericardial braces (iii) Damper installation in diagonal braces.
- Mass damper: A tuned mass damper (TMD), also known as a harmonic absorber or seismic damper, is a device mounted in structures to reduce the amplitude of vibrations. Their application can prevent damage, or outright structural failure. They are frequently used in power transmission, automobiles, and buildings.In a mass damper mass is placed on a fulcrum which acts as a roller and it allows the mass to move as a transfer-lateral movement to the floor. Springs and dampers are placed between mass and anchor members to the floor and frame and they are placed relative in "opposite phase" and sometimes are adjacent vertical. These anchor members transmits structural lateral force. Bidirectional transfer dampers are made as a spring-damper in two vertical directionswhich provides controlling the structure movement in two vertical structures.

1.4 Vibration Of A Damped Spring-Mass System

- **Over damped System:** $\varsigma > 1$ $\varsigma > 1$

$$x(t) = \exp(-\varsigma\omega_n t)\left\{\frac{v_0 + (\varsigma\omega_n + \omega_d)x_0}{2\omega_d}\exp(\omega_d t) - \frac{v_0 + (\varsigma\omega_n - \omega_d)x_0}{2\omega_d}\exp(-\omega_d t)\right\}$$

$$x(t) = \exp(-\varsigma\omega_n t)\left\{\frac{v_0 + (\varsigma\omega_n + \omega_d)x_0}{2\omega_d}\exp(\omega_d t) - \frac{v_0 + (\varsigma\omega_n - \omega_d)x_0}{2\omega_d}\exp(-\omega_d t)\right\}$$

Where, $\omega_d = \omega_n\sqrt{\varsigma^2 - 1}$ $\omega_d = \omega_n\sqrt{\varsigma^2 - 1}$

- **Critically Damped System:** $\varsigma = 1$ $\varsigma = 1$

$$x(t) = \{x_0 + [v_0 + \omega_n x_0]t\}\exp(-\omega_n t)$$

$$x(t) = \{x_0 + [v_0 + \omega_n x_0]t\}\exp(-\omega_n t)$$

- **Under damped System:**

$$x(t) = \exp(-\varsigma\omega_n t)\left\{x_0\cos\omega_d t + \frac{v_0 + \varsigma\omega_n x_0}{\omega_d}\sin\omega_d t\right\}$$

$\varsigma < 1$ $\varsigma < 1$ $x(t) = \exp(-\varsigma\omega_n t)\left\{x_0\cos\omega_d t + \frac{v_0 + \varsigma\omega_n x_0}{\omega_d}\sin\omega_d t\right\}$

Where, $\omega_d = \omega_n\sqrt{1 - \varsigma^2}$ $\omega_d = \omega_n\sqrt{1 - \varsigma^2}$ is known as the dampednatural frequency of the system.

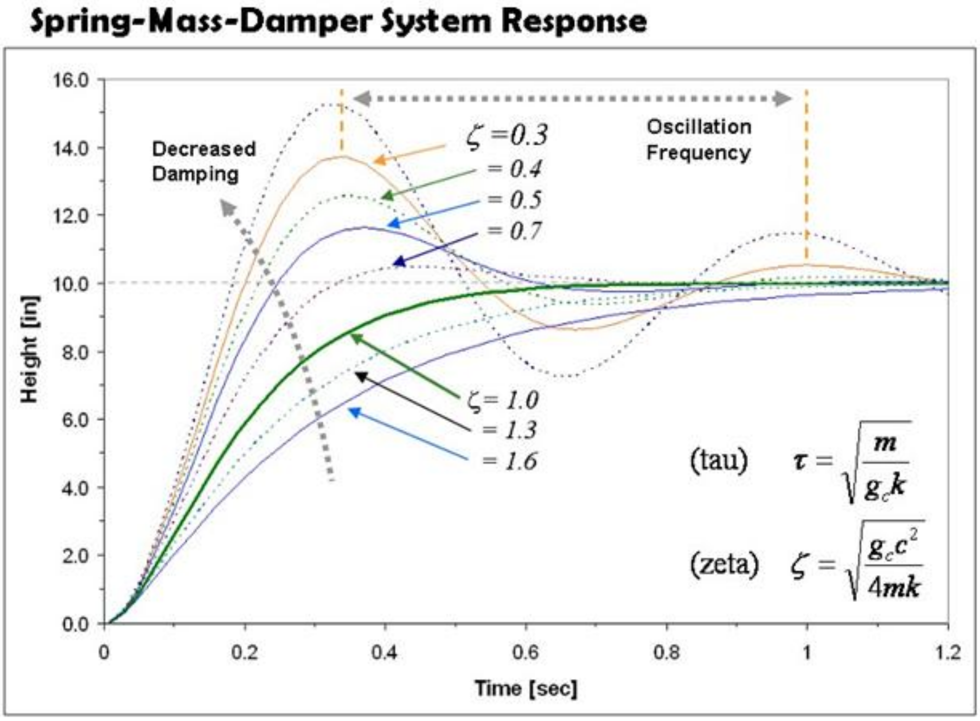

Figure 2: Spring Mass Damper System's Response

II. Literature Review

Hyun-Su Kim, Young-Jinn, Kim [1]: Evaluated the control performance of a shared tuned mass damper (STMD) for reduction of the seismic response of adjacent buildings. In this study they analyzed two structures each of which consisted of eight storied buildings for which the STMD was evaluated. Multi-objective genetic algorithm was employed for optimal design of the stiffness and damping parameters of the STMD. It was shown by numerical analysis that STMD can effectively control the dynamic response of RC structures and also it can reduce the pounding effect between adjacent buildings subjected to earthquake excitations in comparison to a traditional TMD.

Ashish Badave, Vijay Singh Deshmukh, and Sudhir Kulkarni [2]: Investigated on tuned mass vibration absorbers (TMVA). In this study it was shown that TMVA has been used for many sectors in mechanical, civil, aerospace but in this study TMVA was used in its most generic form as a secondary system the parameters of which were controlled to suppress the maximum vibration of a primary system. It was shown that secondary system may be of a common spring mass damper and the TMVA suppress vibrations of a primary system at its point of attachment. Some minor modifications were made and very accurate results were extracted from this setup. It was subsequently suggested that the design can be based on frequency tuning, which leads to equal damping ratio and an accurate explicit approximation was found for the optimal damping parameters. The approach for finding an optimal damping amount was suggested further in this study.

Bandivadekar T.P, Jangid R.S: In this study it was shown that the mass distribution is one of the most important factor for MTMD (multiple tuned mass damper) for reducing the effectively dynamic response of a main system. By controlling mass distribution with other parameters like damping ratio, frequency range, number of dampers etc. the response of structures can be controlled. The effect of various mass distribution like, bell shaped mass distribution and parabolic mass distribution were shown on the response of a system. Lastly it was shown that among all the mass distribution systems the modified bell shaped mass distribution is superior to all others. It was found in this study that reducing dynamic response of structure makes it more flat and increases bandwidth of the flat region. Also it was suggested that lower values of damper damping associated with MTMD makes it more workable.

III. System Development

In this present study three models which were modelled in the finite element modelling software ETABS has been prepared. The plan of the models prepared was kept to be simple rectangular with total length of building 70m and total width of building as 50m. The bays of the building were kept to be 7m long and 5m wide. Each side consisted of 10 no. of bays.The material used were M30 grade of concrete and Fe-415 Grade of steel. The other material properties has been shown in the subsequent pages in table.The three models were having the variation as

- Structure-1: G+10 building without dampers
- Structure-2: G+10 building with exponential dampers of weight = 10kN
- Structure-3: G+10 building with exponential dampers of weight = 1kN

The height of the structures and height of each floor were kept constant. The effect of exponential dampers of 10 KN and 1 KN has been checked. The results of which has been stated in subsequent pages. The plans and extruded views has been shown below:

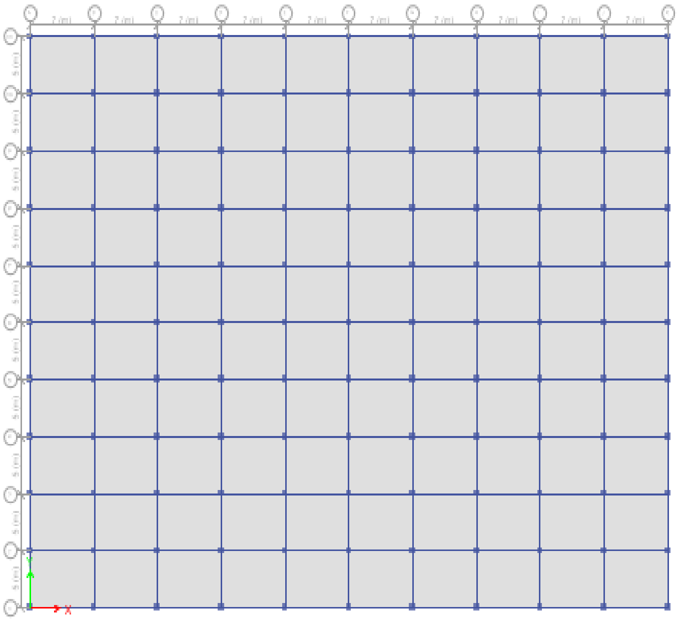

Figure 1: Plan of Structure-I, II, III

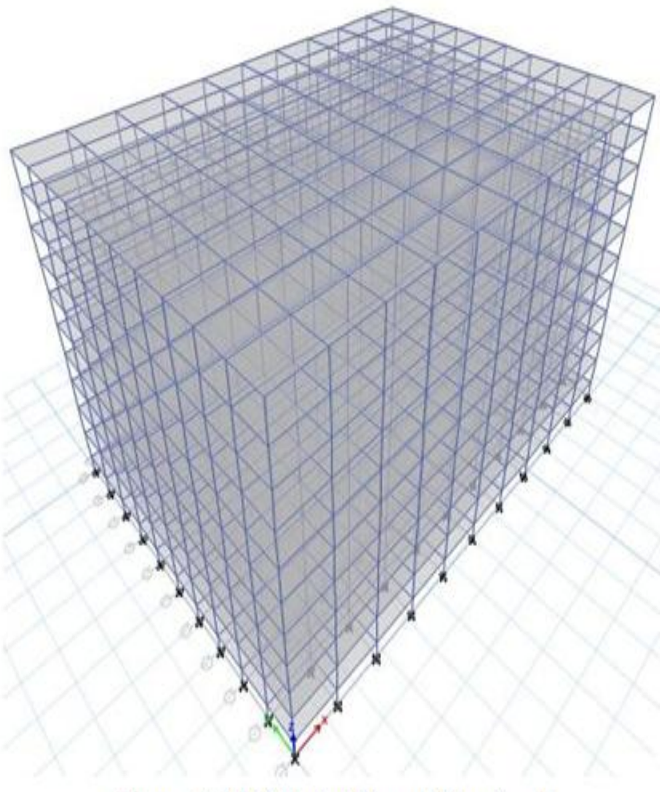

Figure 4: 3D Extruded View of Structure-I

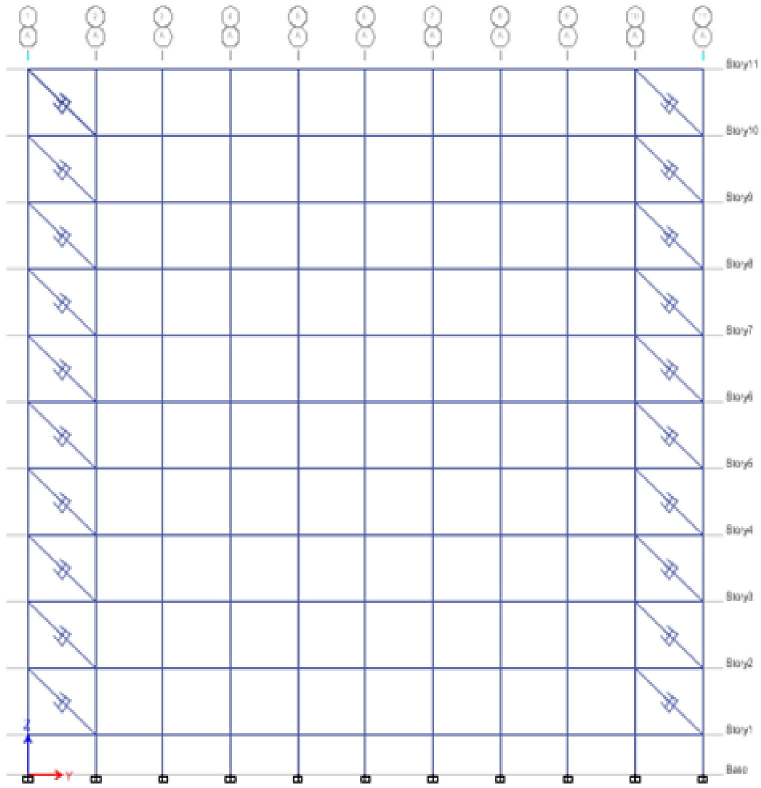

Figure 5: Elevation of Structure-II, III (with dampers)

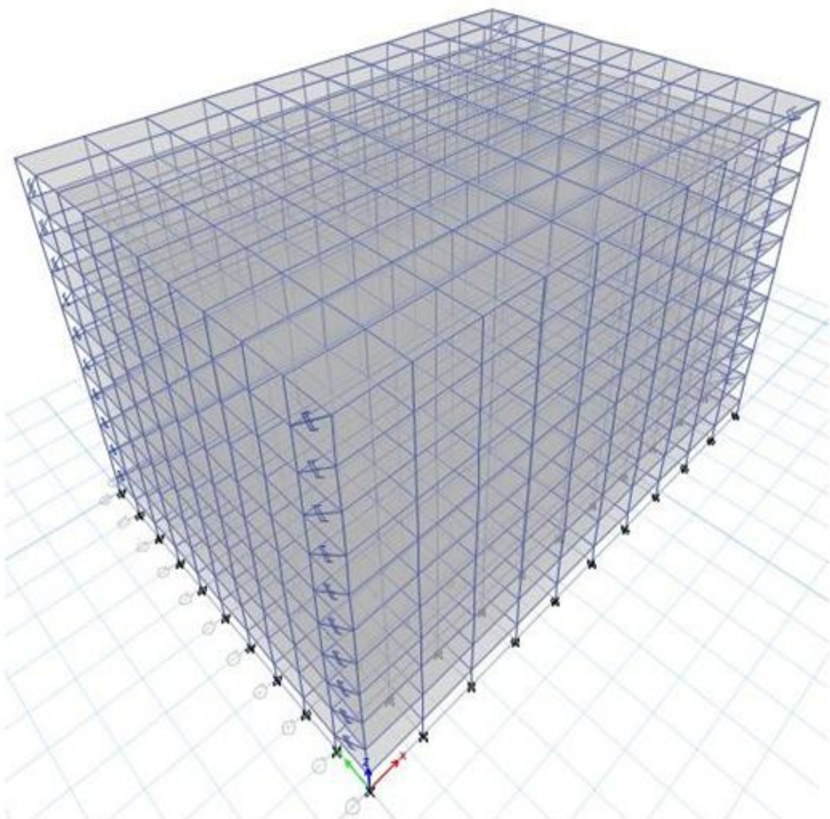

Figure 6: 3D Extruded View of Structure-II, Structure-III (With Dampers)

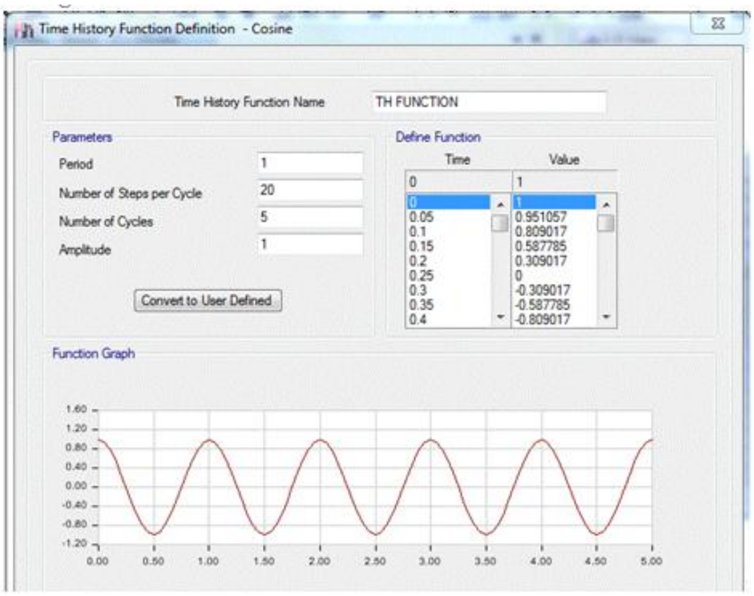

Figure 7: Cosine Curve for Time History Analysis

The properties which were used for the modelling purpose of the structures has been shown below in the tables:

Table 1: Material Specifications

1.	Grade of concrete	M30
2.	Grade of reinforcing steel	Fe 415
3.	Density of concrete	25 KN/m^3
4.	Density of brick masonry	19 KN/m^3

Table 2: General Specifications of the buildings

1.	Type of Building	Residential RCC
2.	Plan Dimensions	70m X 50m
3.	Height of the structure	47 m
4.	Height of storeys	4.2m
5.	Thickness of Slabs	150 mm
6.	Internal Wall thickness	150 mm
7.	External wall thickness	150 mm
8.	Waist slab thickness	150 mm
9.	Depth of footings	2.5 m

Table 3: Structural Specifications

1.	Type of sections	R.C.C.
Sizes of Column sections		
2.	Columns (C1)	300 X 500
Sizes of beam sections		
3.	All Beams	600 X 600
Type of support considered		
4.	Support Conditions for all columns	Fixed

Table 4: Loading Specifications

1.	Live load	3.0 KN/m^2
2.	External Load	10 KN/m
3.	Code for RCC	IS 456 (2000)
4.	Code for Earthquake analysis	IS 1893 (1984)
5.	Code for Wind analysis	IS 875-III (1987)
5.	Zone	II, III, IV, V
6.	Zone factor (Z)	Accordingly
7.	Method used for Analysis	Non-Linear THA
10.	Importance factor	1.0
11.	Moment resisting frame type	SMRF
12.	Response reduction factor	5.0
13.	Site soil type	III

Table 5: Load Combinations

1.	DL
2.	LL
3.	ELX
4.	ELY
5.	1.5 (DL+LL)

6.	1.2 (DL+LL+ELY)
7.	1.2 (DL+LL+ELY)
8.	1.5 (DL+ELX)
9.	1.5 (DL+ELY)
10.	0.9DL+1.2ELX
11.	0.9DL+1.2ELY

IV. Results And Discussion

The modelling and analysis of the all the RCC structures has been done finite element based software ETABS 2016. For comparative study of various parameters total three RCC structures were modelled. The parameters such asstorey displacement, Storey Shear and overturning moments has been considered for this study.All the seismic parameters which were necessary for the analytical purpose were considered from IS 1893-(1984).

Storey Displacements

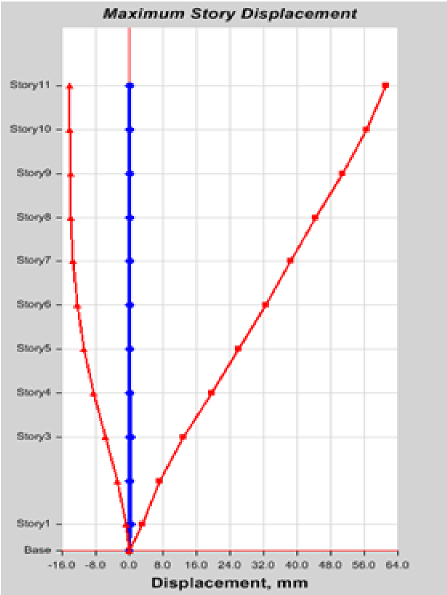

Figure 8: Storey Displacement for Structure-I

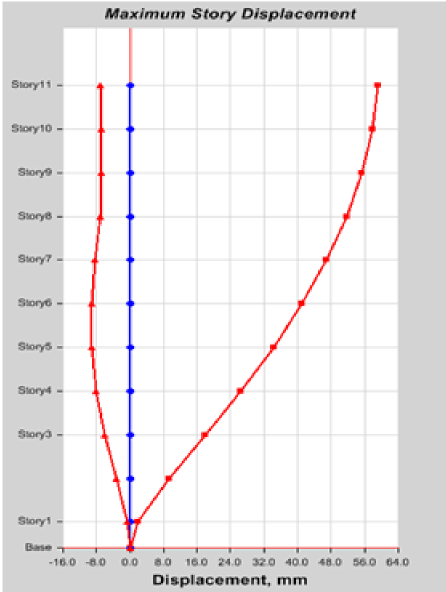

Figure 9: Storey Displacement for Structure-I

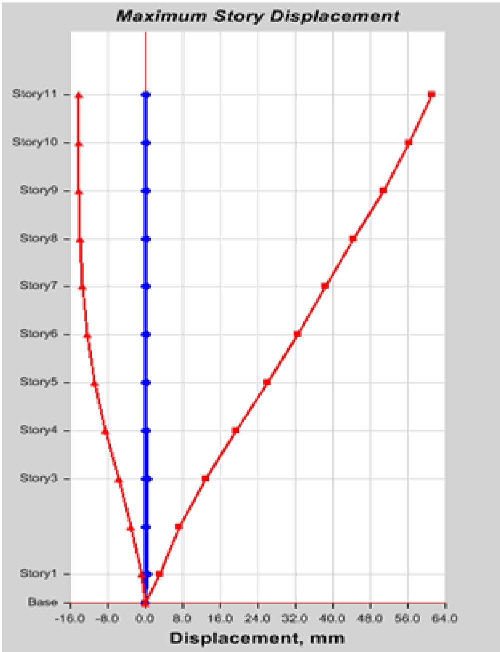

Figure 10: Storey Displacement for Structure-III

1.5 Storey Shear:

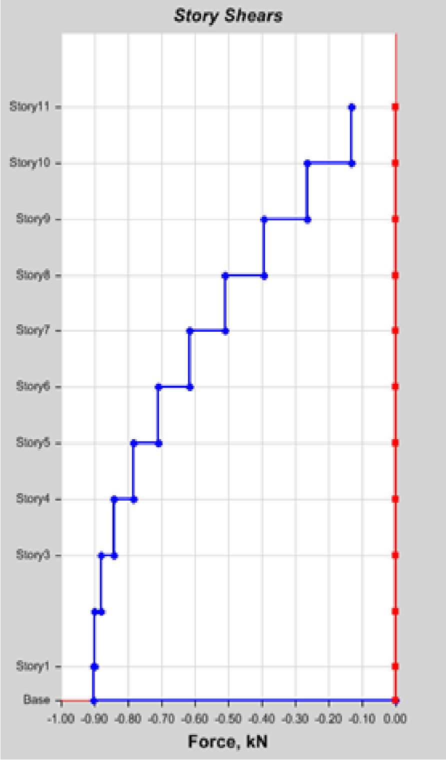

Figure 11: Storey Shear for Structure-I

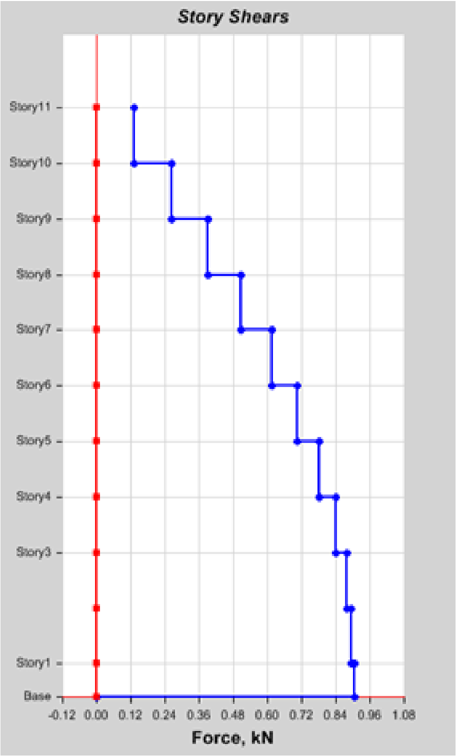

Figure 12: Storey Shear for Structure-II

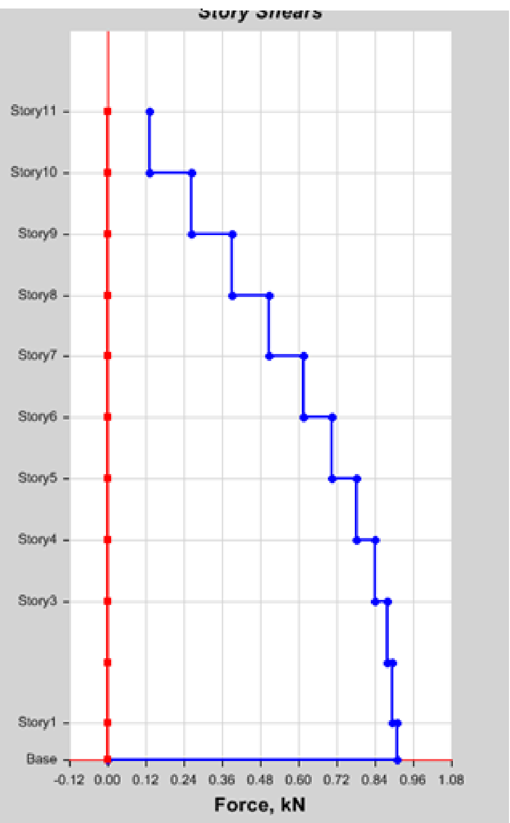

Figure 13: Storey Shear for Structure-III

1.6 Overturning moments :

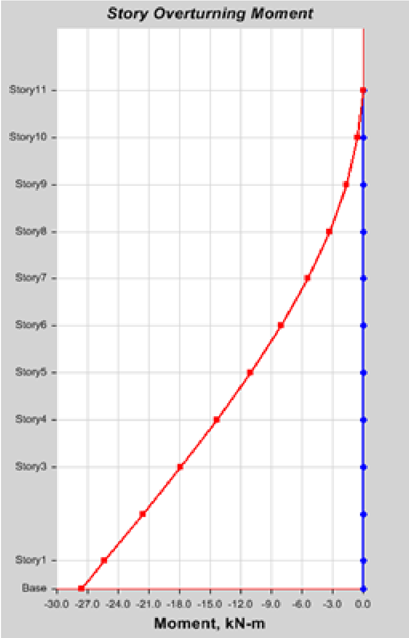

Figure 14: Overturning Moments for Structure-I

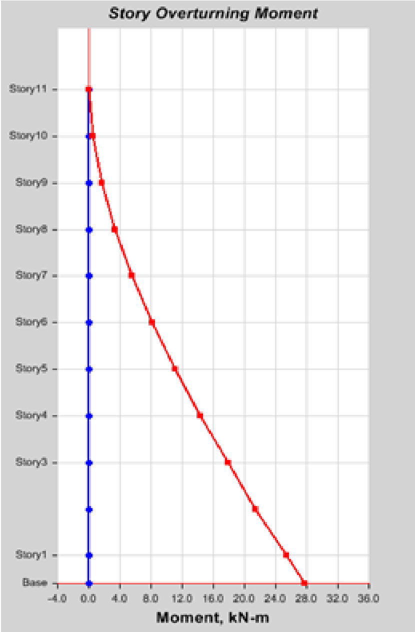

Figure 15: Overturning Moments for Structure-II

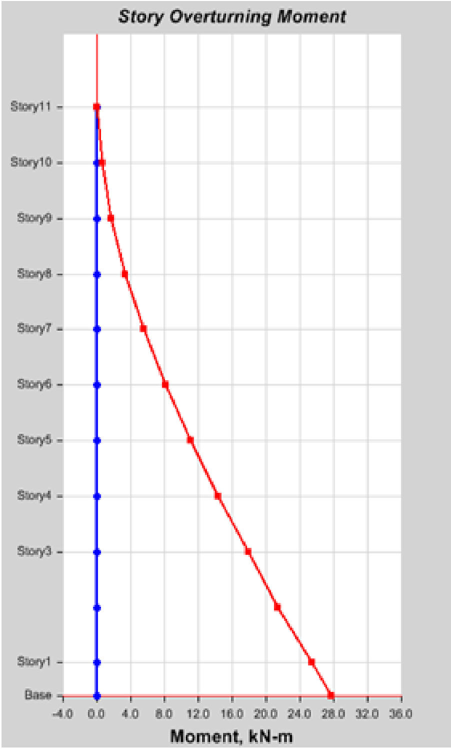

Figure 16: Overturning Moments for Structure-III

V. Conclusions

This comparative study has been carried out so as to show the difference between the structures without dampers, with exponential damper of weight 1KN and with exponential damper of weight 10KN. Based on the study of all the results the following conclusions has been drawn:

- The maximum storey displacements for structure-1, structure-2 and structure-3 were 16mm,7mm and 14mm with the provision of dampers, the storey displacement was reduced by 56.25% (structure-2) and 12.5% (structure-3) when compared with structure-1
- Storey shear and overturning moments at base of the structures are constant for structure-1, structure-2 and structure-3.
- Provision of dampers increases time period of the structures, time period for structure-1, structure-2 and structure-3 are 2.5sec, 3.5sec and 4.7sec respectively.

- Time period was increased by 40% (structure-2) and 88% (structure-3) when compared with structure-1.

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