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Response Spectrum Analysis of RC Framed Structure using Dampers

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Abstract: Dampers are the energy dissipating device which also resists displacement of RC building during earthquake. Dampers are used to resist lateral forces coming on the structure. At the time of earthquake multi-storey building is damaged and large deformation occurred in multi-storey building. Dampers reduce vibration and deformation of RC building during earthquake. The excessive deformations of reinforcement concrete (RC) structure are the main cause of the collapse during earthquake excitation. Nowadays, the application of earthquake energy dissipation device, such as structural dampers, is being widely considered to protect RC structure which is designed to withstand severe seismic loads. Therefore, this study offers a comprehensive investigation oh how damper devices influence the deformation of RC building subjected to seismic excitation.

***Index Terms* - RC frame building, dampers, Response Spectrum Analysis, deformation, base shear.**

I. INTRODUCTION

An Earthquake is Earth's Shaking or in other words release of energy due to the movement of tectonic plates. This can be destructive enough to kill thousands of people and bring huge economic loss. This natural disaster has many adverse effects on earth like ground shaking, landslides; rock falls from cliffs, liquefaction, fire, tsunami etc. Buildings are highly affected by an earthquake, and in some cases they are shattered down to the ground level. When the ground shaking occurs beneath the building's foundations they vibrate in an analogous manner with that of the surrounding ground. The inertia force of a structure can develop shearing effect on it which in turn causes stress concentration on the connections in structure. This results in partial or full failure of structure. The excitement and prevalence of shaking depends on the orientation of the building. High rise structures have the tendency to magnify the magnitude of long time periodic motions when comparing to the smaller one. Every construction has a resonant prevalence which are the characteristics of structure. Taller buildings have a tendency for long time periods than shorter one which make them relatively more susceptible to damage. Hence, one has to be careful while performing the analysis of a tall structure. To reduce the seismic effects on tall buildings several equipment is used like dampers.

Now-a-days innumerable high rise building has been constructed all over the world and the number is increasing day by day. This is not only due to concerned over high density of population in the cities, commercial zones and space saving but also to establish country land marks and to prove that their countries are up to the standards. As the seismic load acting on a structure is a function of the self-weight of the structure these structures are made comparatively light and flexible which have relatively low natural damping. Results make the structures more vibration prone under earthquake loading. In many cases this type of large displacements may not be a threat to integrity of the structure but steady state of vibration can cause considerable discomfort and even illness to the building occupant.

In every field in the world conservation of energy is followed. If the energy imposed on the structure by earthquake load is fully dissipated in some way the structure will vibrate less. Every structure naturally releases some energy through various mechanisms such as internal stressing, rubbing, and plastic deformation. In large modern structures, the total damping is almost 5% of the critical. So new generation high rise building is equipped with artificial damping device for vibration control through energy dissipation. The various vibration control methods include passive, active, semi-active, hybrid. Various factors that affect the selection of a particular type of vibration control device are efficiency, compactness and weight, capital cost, operating cost, maintenance requirements and safety.

For this study secondary data has been collected. From the website of KSE the monthly stock prices for the sample firms are obtained from Jan 2010 to Dec 2014. And from the website of SBP the data for the macroeconomic variables are collected for the period of five years. The time series monthly data is collected on stock prices for sample firmsand relative macroeconomic variables for the period of 5 years. The data collection period is ranging from January 2010 to Dec 2014. Monthly prices of KSE -100 Index is taken from yahoo finance.

II. TYPE OF DAMPERS

There are several types of seismic dampers namely viscous damper, friction damper, yielding damper, magnetic damper, and tuned mass damper.

III. TUNED MASS DAMPER (TMD)

Tuned Mass Damper (TMD), also known as vibration absorbers or vibration dampers, is a passive control device mounted to a specific location in a structure so as to reduce the amplitude of vibration to an acceptable level whenever a strong lateral force such as an earthquake or high winds hit. The application of tuned mass damper can prevent discomfort, damage, or outright structural failure. They are frequently used in power transmission, automobiles and tall buildings.

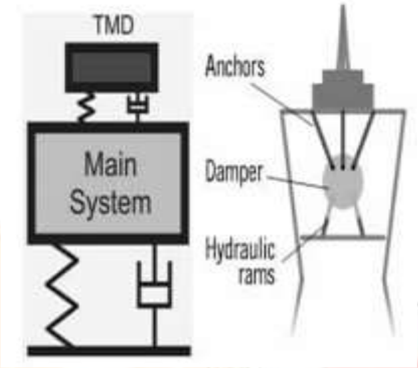


FIG1.1: TUNED MASS DAMPER

IV. THEORETICAL FRAMEWORK

Damper and its applications Components of tuned mass damper is include Spring (K2), Oscillating Mass (M2) and Viscodamper Tuned mass damper (also called vibration absorbers or vibration dampers) is a device mounted to a specific location in a structure, so as to reduce the amplitude of vibration to an acceptable level whenever a strong lateral force such as an earthquake or high lateral force hit. Consequently, discomfort, damage, or outright structural failure caused by vibration in the structure will be prevented. This article presents different aspects of tuned mass (C2).

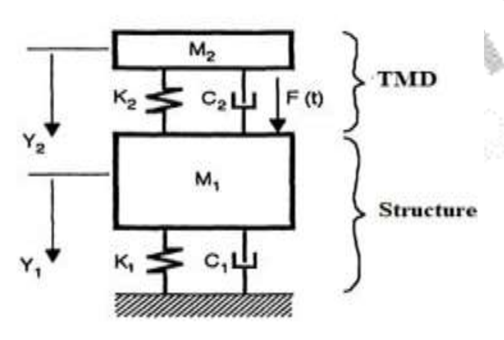


Fig1.2: Operational view of Tuned Mass Damper

Now a day’s TMD theory has been adopted to reduce vibrations of tall buildings and other civil engineering structures. The secondary mass system is designed to have the natural frequency, which is depended on its mass and stiffness, tuned to that of the primary structure. When that particular frequency of the structure gets excited the TMD will resonate out of phase with the structural motion and reduces its response. Then, the excess energy that is built up in the structure can be transferred to a secondary mass and is dissipated by the dashpot due to relative motion between them at a later time. Mass of the secondary system varies from 1-10% of the structural mass. As a particular earthquake contains a large number of frequency content now a days multiple tuned mass dampers (MTMD) has been used to control earthquake induced motion of high rise structure where the more than one TMD is tuned to different unfavorable structural frequency.

V. RESEARCH METHODOLOGY

In this section, Residential building of a 9- storey symmetrical structure in plan, it is the basic model for Response spectrum analysis. And same structures with Tuned Mass Damper having 10, 20 and 40 % of seismic load as generated from basic model are also taken for analysis. Basic model M1, and model M2, M3, M4 having tune mass damper 10%, 20%, 40% of seismic load as generated from basic model respectively. As shown in fig. 1.3. Building consists of 16m in X directions and 16m in Y-direction, with 3.1M storey height. Tune mass damper is installed at the top of building, by using ETAB 2016 software.

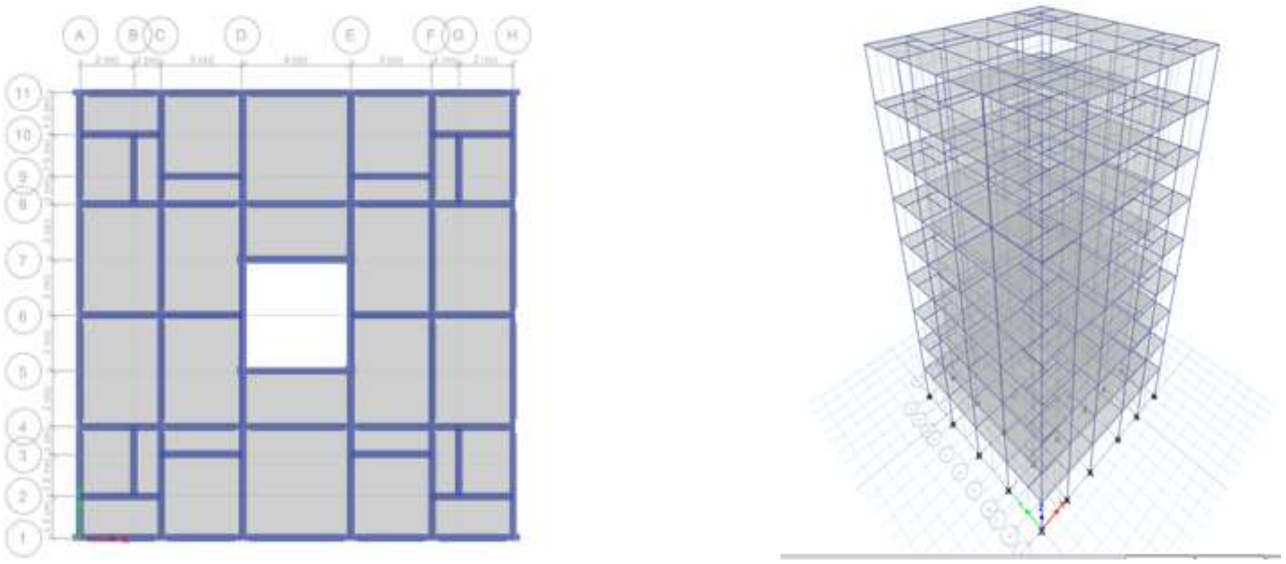


Fig 1.3: showing plan and 3D view of structure

Data and Sources of Data

Column size = 230MM X 530MM
Slab thickness = 115MM (for all span)
Dead load = 13.21 KN /m (for 3.1m height)

Beam size = 230MM X 530MM
Intensity of floor finish load = 1.5 KN /m^2
Intensity of live load = 2 KN /m^2

Seismic Properties (IS 1893-2002)

Response Reduction factor =5
Importance factor =1
Zone factor = 0.36
Slab thickness = 115 MM

Column size = 350mm X 350MM
Beam size = 230MM X 530MM
Soil type = II (Medium)
Building height = 27.9 M

Link Properties

Link Name- Link1
Link type - Damper linear
Weight: Consider 10% of seismic load for model M2, 20% for model M3 and 40% for model M4.
(According to seismic load generated from model no M1)
Height of damper- 2.9m
Link (i) i end or Start point - Restrained U1, U2 and U3
(ii) j end or End point – Free in space

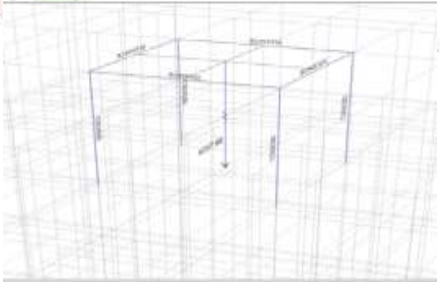


Fig 1.4: showing Link 1 at 9th Floor of structure in model M2

RESULTS AND DISCUSSION

The response of symmetric structure with and without damper is investigated in term of lateral displacement, base shear.

IS1893 2002 Auto Seismic Load Calculation

This calculation presents the automatically generated lateral seismic loads (W) for load pattern EQX & EQY according to IS1893 2002, as calculated by ETABS.

For model M1

Direction	Period Used (sec)	W(kN)		Direction	Period Used (sec)	W (kN)
X	0.628	40579.9545		**Y**	0.628	40579.9545

Following are presentation of Applied Story Forces or Lateral Load on model M1 throughout its height. (Same for X & Y direction)

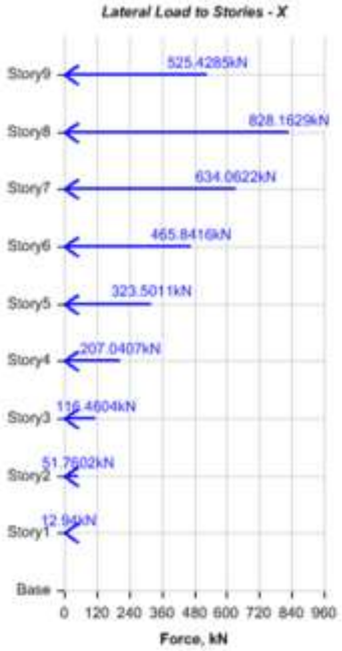


Table 4.1	**Applied Story Forces on model M1**		
Story	**Elevation**	**X-Dir**	**Y-Dir**
	m	**kN**	**kN**
Story9	27.9	525.4285	525.4285
Story8	24.8	828.1629	828.1629
Story7	21.7	634.0622	634.0622
Story6	18.6	465.8416	465.8416
Story5	15.5	323.5011	323.5011
Story4	12.4	207.0407	207.0407
Story3	9.3	116.4604	116.4604
Story2	6.2	51.7602	51.7602
Story1	3.1	12.94	12.94
Base	0	0	0

Fig1.5. Applied Story Forces on model **M1**

For model M2 (TMD having 10 % load of total seismic load generated from model M 1, i.e.10%= 4057.9kN Fig3.3 externally applied lumped mass on TMD)

Direction	**Period Used (sec)**	**W (kN)**		**Direction**	**Period Used (sec)**	**W (kN)**
X	0.628	44637.9445		**Y**	0.628	44637.9445

Following are presentation of Applied Story Forces or Lateral Load on model M2 throughout its height. (Same for X & Y direction)

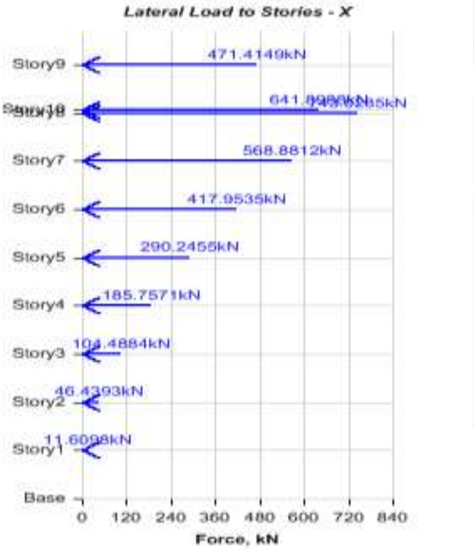


Table 4.2	Applied Story Forces on model M2		
Story	**Elevation**	**X-Dir**	**Y-Dir**
	m	**kN**	**kN**
Story9	27.9	471.4149	471.4149
Story10 **(TMD is located)**	25	641.8988	641.8988
Story8	24.8	743.0285	743.0285
Story7	21.7	568.8812	568.8812
Story6	18.6	417.9535	417.9535
Story5	15.5	290.2455	290.2455
Story4	12.4	185.7571	185.7571
Story3	9.3	104.4884	104.4884
Story2	6.2	46.4393	46.4393
Story1	3.1	11.6098	11.6098
Base	0	0	0

Fig.4.2: Applied Story Forces on model **M2**

For model M3 (TMD having 20 % load of total seismic load generated from model M 1, i.e.20%= 8115.99kN externally acted lumped mass on TMD)

Direction	**Period Used (Sec)**	**W (kN)**		**Direction**	**Period Used (sec)**	**W (kN)**
X	0.628	48695.9445		**Y**	0.628	48695.9445

Following are presentation of Applied Story Forces or Lateral Load on model M3 throughout its height. (Same for X & Y direction)

Table 4.3	**Applied Story Forces on model M3**

Story	Elevation	X-Dir	Y-Dir
	m	kN	kN
Story9	27.9	434.2172	434.2172
Story10 **(TMD is located)**	25	1182.4991	1182.4991
Story8	24.8	684.3987	684.3987
Story7	21.7	523.9927	523.9927
Story6	18.6	384.9743	384.9743
Story5	15.5	267.3432	267.3432
Story4	12.4	171.0997	171.0997
Story3	9.3	96.2436	96.2436
Story2	6.2	42.7749	42.7749
Story1	3.1	10.6937	10.6937
Base	0	0	0

Fig.4.3: Applied Story Forces on model **M3**

For model M4 (TMD having 40 % load of total seismic load generated from model M 1, i.e.40%= 16231.98kN externally acted lumped mass on TMD)

Direction	Period Used (sec)	W (kN)		Direction	Period Used (sec)	W (kN)
X	0.628	56811.9345		**Y**	0.628	56811.9345

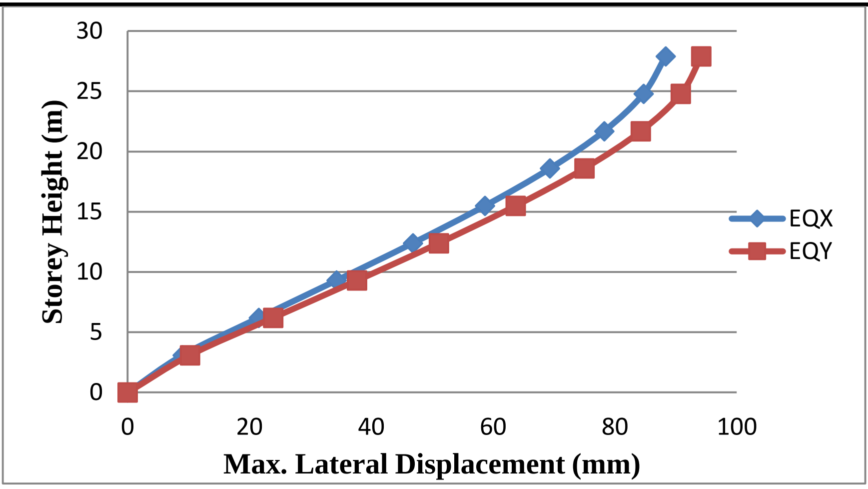
Following are presentation of Applied Story Forces or Lateral Load on model M4 throughout its height. (Same for X & Y direction)

Table 4.4	**Applied Story Forces on model M4**		
Story	**Elevation**	**X-Dir**	**Y-Dir**
	m	**kN**	**kN**
Story9	27.9	386.3157	386.3157
Story10 **(TMD is located)**	25	2104.0988	2104.0988
Story8	24.8	608.8979	608.8979
Story7	21.7	466.1875	466.1875
Story6	18.6	342.5051	342.5051
Story5	15.5	237.8507	237.8507
Story4	12.4	152.2245	152.2245
Story3	9.3	85.6263	85.6263
Story2	6.2	38.0561	38.0561
Story1	3.1	9.514	9.514
Base	0	0	0

Fig.4.4: Applied Story Forces on model **M4**

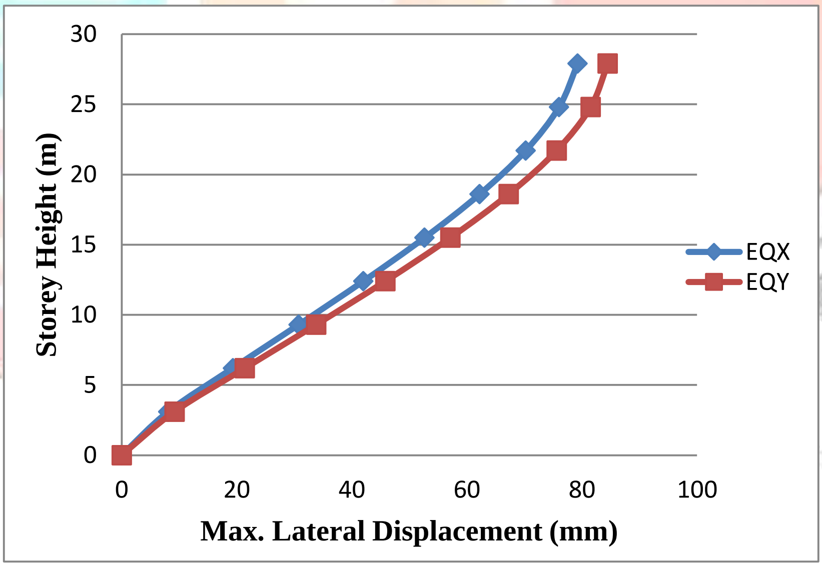
Maximum Lateral Displacement:

Table4.5: Maximum displacement of model M1			
Storey No.	**Storey Height**	**EQX Max**	**EQY Max**
	(m)	**(mm)**	**(mm)**
9	27.9	88.335	94.18
8	24.8	84.715	90.839
7	21.7	78.256	84.264
6	18.6	69.356	74.978
5	15.5	58.681	63.708
4	12.4	46.825	51.092
3	9.3	34.298	37.667
2	6.2	21.529	23.875
1	3.1	9.029	10.224
Base	0	0	0



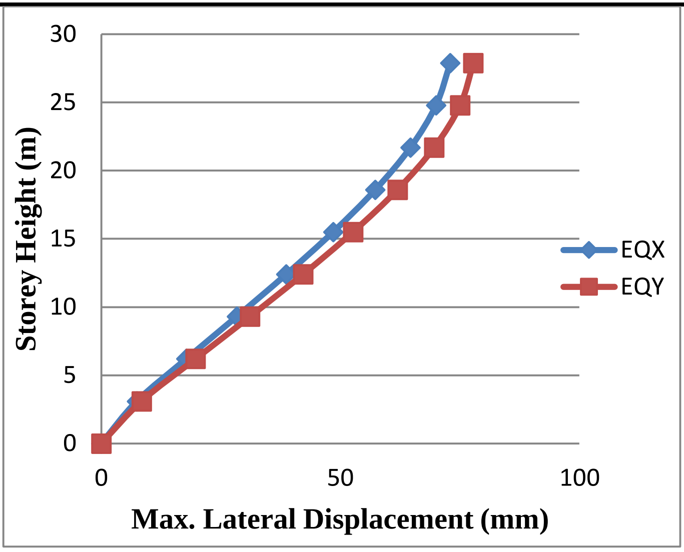
Graph 4.5: Maximum displacement of model M1 with respect to height.

Table4.6: Maximum displacement of model M 2 (with TMD having 10 % load of total seismic load generated from model M 1)			
Storey No.	**Storey Height**	**EQX Max**	**EQY Max**
	(m)	**(mm)**	**(mm)**
9	27.9	79.255	84.498
8	24.8	76.006	81.501
7	21.7	70.212	75.602
6	18.6	62.226	67.271
5	15.5	52.648	57.159
4	12.4	42.012	45.84
3	9.3	30.772	33.795
2	6.2	19.316	21.42
1	3.1	8.101	9.173
Base	0	0	0



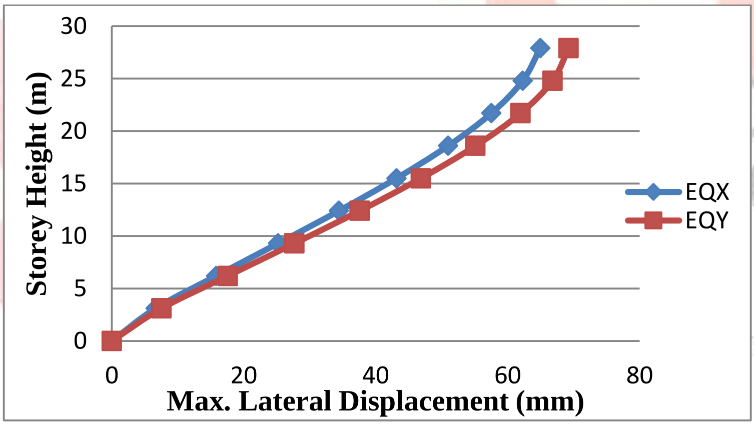
Graph 4.6: Maximum displacement of model M2 with respect to height.

Table4.7: Maximum displacement of model M 3 (with TMD having 20 % load of total seismic load generated from model M 1)			
Storey No.	**Storey Height**	**EQX Max**	**EQY Max**
	(m)	**(mm)**	**(mm)**
9	27.9	73.001	77.831
8	24.8	70.009	75.07
7	21.7	64.672	69.636
6	18.6	57.316	61.963
5	15.5	48.494	52.649
4	12.4	38.697	42.223
3	9.3	28.344	31.128
2	6.2	17.791	19.73
1	3.1	7.462	8.449
Base	0	0	0



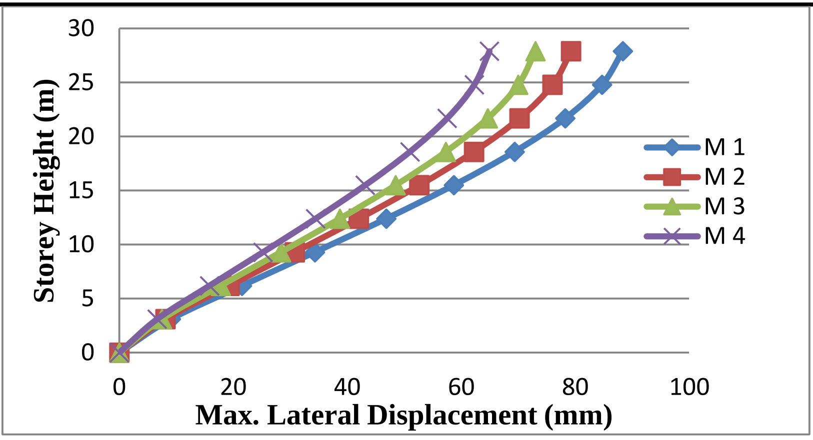
Graph 4.7: Maximum displacement of model M3 with respect to height.

Table4.8: Maximum displacement of model M 4 (with TMD having 40 % load of total seismic load generated from model M 1)			
Storey No.	**Storey Height**	**EQX Max**	**EQY Max**
	(m)	**(mm)**	**(mm)**
9	27.9	64.948	69.245
8	24.8	62.286	66.788
7	21.7	57.537	61.954
6	18.6	50.993	55.127
5	15.5	43.144	46.84
4	12.4	34.428	37.565
3	9.3	25.217	27.694
2	6.2	15.829	17.554
1	3.1	6.638	7.517
Base	0	0	0



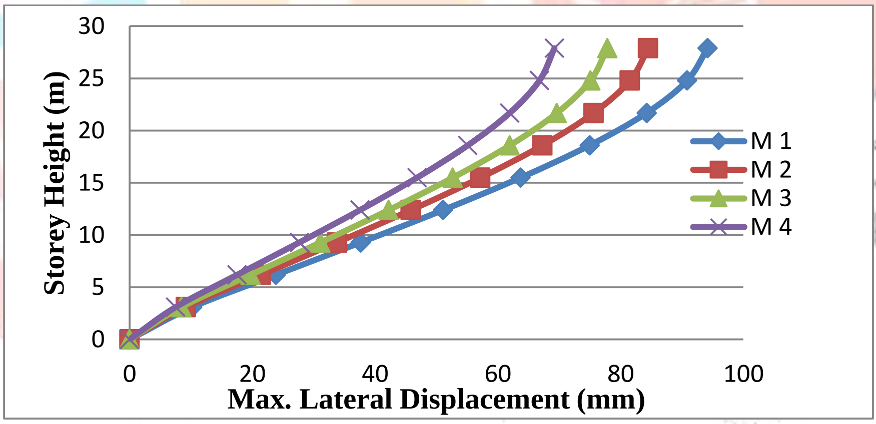
Graph 4.8: Maximum displacement of model M4 with respect to height.

Table4.9: Comparison of models M1, M2, M3 & M4					
Maximum displacement in X-direction					
Storey No	**Storey Height**	**M1**	**M2**	**M3**	**M4**
	(m)	**(mm)**	**(mm)**	**(mm)**	**(mm)**
9	27.9	88.335	79.255	73.001	64.948
8	24.8	84.715	76.006	70.009	62.286
7	21.7	78.256	70.212	64.672	57.537
6	18.6	69.356	62.226	57.316	50.993
5	15.5	58.681	52.648	48.494	43.144
4	12.4	46.825	42.012	38.697	34.428
3	9.3	34.298	30.772	28.344	25.217
2	6.2	21.529	19.316	17.791	15.829
1	3.1	9.029	8.101	7.462	6.638
Base	0	0	0	0	0



Graph 4.9: Comparison of Maximum displacement in X-dir. of Building models M1, M2, M3 & M4 with respect to height.

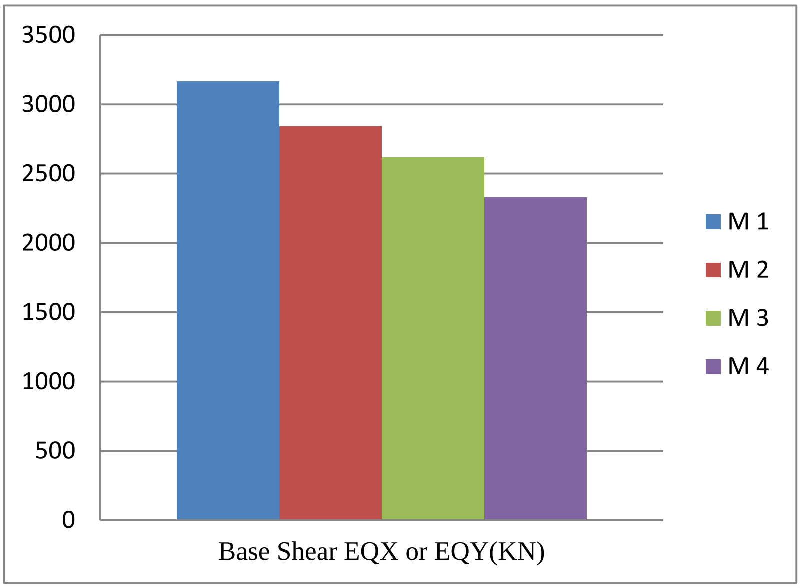
Table4.10: Comparison of models M1, M2, M3 & M4					
Maximum displacement in Y-direction					
Storey No	**Storey Height**	**M1**	**M2**	**M3**	**M4**
	(m)	**(mm)**	**(mm)**	**(mm)**	**(mm)**
9	27.9	94.18	84.498	77.831	69.245
8	24.8	90.839	81.501	75.07	66.788
7	21.7	84.264	75.602	69.636	61.954
6	18.6	74.978	67.271	61.963	55.127
5	15.5	63.708	57.159	52.649	46.84
4	12.4	51.092	45.84	42.223	37.565
3	9.3	37.667	33.795	31.128	27.694
2	6.2	23.875	21.42	19.73	17.554
1	3.1	10.224	9.173	8.449	7.517
Base	0	0	0	0	0



Graph 4.10: Comparison of Maximum displacement in Y-dir. of Building models M1, M2, M3 & M4 with respect to height.

Base Shear:

Maximum Base Shear along X And Y direction		
Model	**EQX (KN)**	**EQY (KN)**
M1	3165.1977	3165.1977
M2	2839.8182	2839.8182
M3	2615.738	2615.738
M4	2327.1778	2327.1778



Graph 4.11: Maximum Base Shear along X and Y direction for all considered Models

Natural Periods:

Natural period of a structure is its time period of undammed free vibration. And it's first (longest) modal time period of vibration is called Fundamental Natural Period.

Table4.12: Fundamental Natural Period (sec)

Models	**X-direction**		**Y-direction**	
	Code	**Analysis**	**Code**	**Analysis**
M1	0.628	1.628	0.628	1.628
M2	0.628	1.672	0.628	1.672
M3	0.628	1.759	0.628	1.759
M4	0.628	1.883	0.628	1.883

Above Table shows the codal (IS 1893-2002) and analytical (by using ETAB2016 software) natural periods of all considered building models. And table shows shorter fundamental periods for without TMD building models from analysis that means to attract higher forces than the with TMD building model.

Modal Load Participation ratios for all Models:

Table4.13: Modal Load Participation ratio

Item Type	**Item**	**Static %**	**Dynamic %**
Acceleration	UX	99.98	97.8
Acceleration	UY	99.98	97.9

As per code IS 1893: 2002 the sum of total of modal masses of all modes considered is at least 90% of total seismic mass

In the present study, the initial modes are found to be in translation for all structural system excites more than 90% of the total mass. All the above considered models are satisfied the clause.

CONCLUSIONS

From the above analysis of the RC frame structure under seismic loads, it has been found that the frame under tuned mass damper building has recorded less frequency of vibration (i.e. f = 1/T) and deflection when compared to the frame without tuned mass damping. The values of displacement are found to be more on structure when structure is acted upon by dynamic conditions without damper But by assigning Tuned Mass Damper to structure the structure is going to more stable as the values of displacement are reduced. Base shear is maximum at the base and by comparing results. It is observed that base shear values for RC building with TMD provided as compared to without damper are minimum. All the consider 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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