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NON LINEAR ANALYSIS ON HIGHRISE STRUCTURES USING INDIAN EARTHQUAKE DATA

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Abstract: Tuned mass dampers are machines which are widely used in mechanical systems to reduce the vibrations in the machines. Now a days they are even used in buildings and bridges to reduce the dynamic response of the building. Tuned mass dampers prevent discomfort, damage and structural failure. They increase the lifespan of the structure. In this report tuned mass dampers are attached to the single degree of freedom and multi degree of freedom for the rectangular and L-Shaped building. The damping ratio for the buildings is considered as 5%.

Tuned mass dampers are used to control the displacements, accelerations and internal stress variables of a structure in case of earthquakes. Depending upon the application these devices are sized from few grams to many tons.

Keywords: Tuned mass dampers, earthquake, linear analysis, dynamic analysis, degrees of freedom, base shear, displacement, etabs.

I. Introduction

Tuned mass dampers has been mostly used for vibration control in mechanical engineering systems. In recent times, Tuned Mass Dampers theory has been adopted to minimise vibrations of tall buildings and other civil engineering structures also. Dynamic absorbers or tuned mass dampers are the realizations of tuned absorbers and tuned dampers for controlling the structural vibrations. Generally the vibrations in buildings is due to earthquakes. The inertial, resilient, and dissipative elements in such devices are: mass, spring and dashpot for linear applications and their rotary counterparts in rotational applications. Depending on the use, these devices are sized from a few grams to many tons. Other configurations such as pendulum dampers, and liquid dampers have also been realized for vibration reduction applications in tall structures.

Tuned Mass Dampers is attached to a structure or a machine in order to reduce the dynamic response or vibration of the structure or machine. The frequency of the damper is set to a particular structural frequency so that when that frequency is excited, the damper will resonate out of phase with the structural motion. The mass is usually attached to the building with a spring-dashpot system and energy is accumulated by the dashpot as relative motion develops between the mass and the structure. Usually 5% of critical damping can be assumed or considered for buildings, and as an increase of the damping ratio there will be a reduction of the stress or acceleration.

A tuned mass damper is a device consisting of a mass, spring and a damper that is attached to a structure in order to reduce or minimise the amplitude or extent of undesirable motion. Tuned mass control systems can be used to control the displacements, accelerations and internal stress developed in a structure in case of earthquakes or vibrations. The location on the structure where the Tuned Mass Dampers are attached is vital and different. There are different types of methods to control the vibrations in large and modern structure.

II. Literature Review

Den Hartog**.** The TMD concept was first introduced by frahm in the year1909 to reduce the rolling motion of ships as well as ship hull vibrations. A theory for the TMD was presented later in the paper by Ormondroyd and followed by a detailed discussion of optimal tuning and damping parameters in Den Hartog's book on mechanical vibrations**.** Sinusoidal force excitation initial theory for an undamped SDOF is applicable. Extension of the theory to damped SDOF systems has been investigated by numerous researchers.

Hrovat *et al***.** Active control devices will be operated by using an external power supply. Therefore, they are more workable than passive control devices which are so far considered and taken into account. However the problems in the vibrations of the structure due to the earthquake are unavoided but can be controlled. Recently a new control approach-semi-active control device, which combines the best properties of both passive and active control devices, is very much attractive due to their low power demand and inherent stability. The earlier papers involving SATMDs may trace to 1983.presented SATMD, a TMD with time varying controllable damping. Under identical conditions, the behavior of a structure equipped with SATMD instead of TMD is significantly improved. The control design of SATMD depends very less on related parameters like mass ratios, frequency ratios and so on, so that there greater choices in selecting them and uswing them effectively.

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Clark**.** The concept of multiple tuned mass dampers (MTMDs) together with an optimization procedure was proposed by Clark. The first mode response of a structure with TMD tuned to the normal frequency of the structure can be reduced at starting but, in general, the higher modal responses may only be marginally suppressed or even amplified to the required values. The frequency-related limitations of TMDs, more than one TMD in a given structure, each tuned to a different dominant frequency, can be used to over come the situation, then, many studies have been conducted for studying the behavior of multiple tuned mass dampers MTMDs a doubly tuned mass damper (DTMD), which consists of two masses connected in series to the structure was proposed (Setareh 1994). In such case, two different loading conditions were considered: harmonic excitation and zero-mean white-noise random excitation, and the efficiency of DTMDs on response reduction was evaluated and taken into consideration. Results show that DTMDs are more efficient and effective than the conventional single mass TMDs over the whole range of total mass ratios, but are only slightly more efficient than TMDs over the practical range of mass ratios (0.01-0.05).

Villaverde. Recently, numerical and experimental studies have been carried out on the effectiveness of TMDs in reducing seismic response of structures [for instance, Villaverde(1994)]. In three different structures were studied, in which the first one is a 2D two storey shear building the second is a three-dimensional (3D) one-storey frame building, and the third is a 3D cable-stayed bridge, using nine different kinds of earthquake record. Experimental and numerical results show that the usage of TMDs on reducing the response of the same structure during different earthquakes, or of different structures during the same earthquake is truly not similar; some cases give good performance and some have little or even no effect during the taken earthquake. This implies that there is a dependency of the attained reduction in response on the characteristics of the ground motion that excites the structure with its vibration. This response reduction is large for resonant ground motions and diminishes as the dominant frequency of the ground motion gets further away from the structure's natural frequency to which the TMD is tuned. Also, TMDs are of limited effectiveness under pulse-like seismic loading

III. Methodology

The non linear dynamic analysis method used in the present study to control the structural vibrations due to earthquakes. The computational details of the dynamic analysis, the mass and damping idealization of the structure are clearly discussed.

The proposed nonlinear analysis method is applicable to both the static and dynamic nonlinear analysis of tall structures. Where as the nonlinear static analysis of frames is just a special case of the dynamic analysis with no damping or inertia forces and with lateral forces applied as concentrated static forces at each floor, details related to the calculation of unbalanced forces and to the process of static determination of individual frame elements of the structure.

The dynamic models representing a building has the number of mode shapes is equal to the number of degrees-of-freedom of the model which has been taken into consideration. Mode shapes have the property of orthogonality, which means that no given mode shape can be constructed as a combination of others, and any deformation of the dynamic model can be described as a combination of its mode shapes, each multiplied by a scale factor. Each mode shape has a natural frequency of vibration. The mode shapes and frequencies are determined by solving for the Eigen values which are obtained.

Mechanics as a branch of physics is sub divided into both statics and dynamics. Statics studies systems in static equilibrium, i.e., rest..i.e., in a state where the system internal forces counterbalance the external forces acting on the system. Static refers to the fact that the state of the system and the applied forces do not vary with time; they are time-independent that means they do not depend on time variation. Dynamics is the study of systems subject to time-varying applied forces. As a consequence of the time variability of the applied forces, the system's internal forces and its state (defined in terms of displacement and deformation) also vary with time and the values will change — the system's response involves motion. While a static problem has a single time-independent solution, the solution of a dynamic problem involves a description of the system's state at every time point within the period of study because it is time dependent. The appearance of inertia effects associated with mass in motion is another key distinction of dynamic related problems.

Degrees of Freedom:

The number of independent displacements required to define the displaced position of all masses relative to their original equilibrium position is called the number of degrees of freedom in other words we can say that how far the mass has been displaced from its original postion.

IV. Results and Discussion

Non linear Dynamic Time History Cases studied on 10 storied R.C.C. framed structure by applying TMD at top of the building with a damping ratio of 5% by using the software ETABS.

Description of the Building: In the present study two R.C framed models with ten stories i.e., rectangular in plan and the other is having L-shape in plan. The tuned mass damper was placed at the centre of the grid in plan.

Rectangular Plan Building: Placing of Damper in Columns at top of the Building.

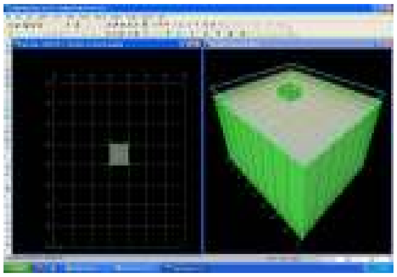

Fig:1 Plan showing the TMD placed at top floor for symmetrical section.

Without TMD & With TMD: Time Period Vs Base Shear x results of the building are tabulated as follow.

Table1. Time Vs Base shear in X-direction (without & with TMD).

Without TMD		With TMD	
Time Period	Base shear x	Time Period	Base shear x
0.00000	0	0.00000	0
0.50000	15056	0.50000	14936.57
1.00000	-26986.2	1.00000	-23050.4
1.50000	35406	1.50000	21344.96
2.00000	-40340.9	2.00000	-12778.7
2.50000	42167.01	2.50000	2807.279
3.00000	-41478.7	3.00000	4347.54
3.50000	38967.85	3.50000	-6604.74
4.00000	-35329	4.00000	4039.611
4.50000	31190.24	4.50000	1333.758
5.00000	-27069.3	5.00000	-6678.43
5.50000	8296.232	5.50000	-5127.19
6.00000	6695.808	6.00000	13080.64
6.50000	-17395.6	6.50000	-13591.1
7.00000	23807.02	7.00000	8215.011
7.50000	-26365.9	7.50000	-906.35
8.00000	25781.64	8.00000	-5082.22
8.50000	-22892	8.50000	7814.519
9.00000	18547.01	9.00000	-6811.59
9.50000	-13522.5	9.50000	3218.207
10.00000	8464.324	10.00000	895.1803
10.50000	-3860.05	10.50000	-3722.28
11.00000	32.46118	11.00000	4427.447
11.50000	2849.366	11.50000	-3197.95
12.00000	-4747.63	12.00000	940.3099
12.50000	5726.712	12.50000	1209.04
13.00000	-5921.82	13.00000	-2397.29
13.50000	5508.691	13.50000	2353.852
14.00000	-4677.01	14.00000	-1368.6
14.50000	3609.048	14.50000	45.54885
15.00000	-2464.3	15.00000	1007.399
15.50000	1370.041	15.50000	-1422.72
16.00000	-417.238	16.00000	1171.196
16.50000	-339.03	16.50000	-500.665
17.00000	875.9167	17.00000	-225.735
17.50000	-1196.98	17.50000	702.0137
18.00000	1325.32	18.00000	-790.175
18.50000	-1296.53	18.50000	539.2925
19.00000	1152.249	19.00000	-124.985
19.50000	-934.736	19.50000	-249.326
20.00000	682.6982	20.00000	440.9099
20.50000	-428.524	20.50000	-412.202
21.00000	196.7808	21.00000	222.9691
21.50000	-3.82909	21.50000	15.13195
22.00000	-141.692	22.00000	-195.065
22.50000	237.7674	22.50000	256.7284
23.00000	-287.559	23.00000	-201.023
23.50000	297.8227	23.50000	76.14783
24.00000	-277.378	24.00000	52.24563
24.50000	235.7648	24.50000	-131.432
25.00000	-182.162	25.00000	140.1232
25.50000	124.6087	25.50000	-90.211
26.00000	-69.5264	26.00000	14.70367
26.50000	21.51243	26.50000	50.24866
27.00000	16.64327	27.00000	-80.6693
27.50000	-43.774	27.50000	71.79613
28.00000	60.04476	28.00000	-35.809
28.50000	-66.6067	28.50000	-6.80249
29.00000	65.24413	29.00000	37.34686
29.50000	-58.0487	29.50000	-46.1016
30.00000	47.14571	30.00000	34.28681
30.50000	-34.4846	30.50000	-11.1799
31.00000	21.69829	31.00000	-11.4003
31.50000	-10.027	31.50000	24.43137
32.00000	0.29833	32.00000	-24.7275
32.50000	7.0488	32.50000	14.95243
33.00000	-11.9095	33.00000	-1.26336
33.50000	14.43986	33.50000	-9.94468
34.00000	-14.9779	34.00000	14.6785
34.50000	13.96611	34.50000	-12.4377
35.00000	-11.8841	35.00000	5.65352
35.50000	9.19394	35.50000	1.93547
36.00000	-6.3006	36.00000	-7.08238
36.50000	3.52805	36.50000	8.23823
37.00000	-1.10859	37.00000	-5.80769
37.50000	-0.81643	37.50000	1.55825
38.00000	2.18741	38.00000	2.39288
38.50000	-3.01195	38.50000	-4.51202
39.00000	3.3474	39.00000	4.34208
39.50000	-3.28318	39.50000	-2.45219
40.00000	2.92438	40.00000	-0.01692
40.50000	-2.37788	40.50000	1.93946
41.00000	1.74186	41.00000	-2.65692
41.50000	-1.09865	41.50000	2.14239
42.00000	0.51085	42.00000	-0.87337
42.50000	-0.02034	42.50000	-0.47168
43.00000	-0.3506	43.00000	1.33184
43.50000	0.5965	43.50000	-1.46503

44.00000	-0.72508	44.00000	0.97626
44.50000	0.75324	44.50000	-0.19927
45.00000	-0.70319	45.00000	-0.48852
45.50000	0.59903	45.50000	0.82828
46.00000	-0.46402	46.00000	-0.75859
46.50000	0.31857	46.50000	0.39716
47.00000	-0.17902	47.00000	0.04598
47.50000	0.0571	47.50000	-0.37365
48.00000	0.04002	48.00000	0.47849
48.50000	-0.1093	48.50000	-0.36679
49.00000	0.15108	49.00000	0.13107
49.50000	-0.16822	49.50000	0.10616
50.00000	0.16521	50.00000	-0.24858

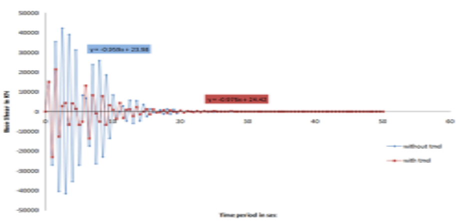

Fig:2. Graph showing the base shear of the building Without TMD & With TMD

Based on the outputs obtained from the ETABS package as per IS: 1893:2002 (part-I) with 5% of structural damping following conclusions are made.

1. With 5% mass of Tuned Mass Dampers the frequency of the Tuned Mass Dampers matches close to the fundamental mode of the structure. Due to this reason mass of the Tuned mass dampers is fixed close to 5% of the structural mass.
2. For Symmetrical Buildings, using of Tuned mass dampers in the form of steel dampers, the amplitude of vibration could be brought down by 51%.
3. Similarly for un-symmetrical buildings, the value of the amplitude of vibration could be brought down by 49% (page 58) using steel dampers.
4. Similarly for symmetrical Buildings, the value of the base shear is brought down by 56% using steel dampers.
5. For un-symmetrical Buildings, the value of the base shear is brought down by 42% using steel dampers.

V. Acknowledgment

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