International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

IJIEMR Transactions, online available on 20th Jul 2019. Link :http://www.ijiemr.org/downloads.php?vol=Volume-08&issue=ISSUE-07

Title: NON LINEAR SESIMIC PERFORMANCE OF A BUILDING USING BASE ISOLATION DEVICE

Volume 08, Issue 07, Pages: 202–213.

Paper Authors

P. VENKATESWARLU, P.M.B RAJ KIRAN NANDURI

Samskruti College of Engineering and Technology, Kondapur (V), Ghatkesar (M) Medchal Dist (Old R.R. Dist), Hyderabad 501301, TELANGANA, INDIA

International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

NON LINEAR SESIMIC PERFORMANCE OF A BUILDING USING BASE ISOLATION DEVICE

P. VENKATESWARLU[1], P.M.B RAJ KIRAN NANDURI[2]
Mtech Scholar[1], Assistant Professor, Research Scholar[2] Samskruti College of Engineering and Technology, Kondapur (V), Ghatkesar (M) Medchal Dist (Old R.R. Dist), Hyderabad 501301, TELANGANA, INDIA
Rajkiran.n1987@gmail.com

1.0 INTRODUCTION

Tuned mass dampers have been widely used for vibration control in mechanical engineering systems. In recent years, Tuned Mass Dampers theory has been adopted to reduce vibrations of tall buildings and other civil engineering structures. Dynamic absorbers and tuned mass dampers are the realizations of tuned absorbers and tuned dampers for structural vibration control applications. The inertial, resilient, and dissipative elements in such devices are: mass, spring and dashpot (or material damping) for linear applications and their rotary counterparts in rotational applications. Depending on the application, these devices are sized from a few ounces (grams) to many tons. Other configurations such as pendulum absorbers/dampers, and sloshing liquid absorbers/dampers have also been realized for vibration mitigation applications. Tuned Mass Dampers is attached to a structure in order to reduce the dynamic response of the structure. The frequency of the damper is tuned 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 via a spring-dashpot system and energy is dissipated by the dashpot as relative motion develops between the mass and the structure. Usually 5% of critical damping can be assumed for buildings, and an increase of the damping ratio causes 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 the amplitude of undesirable motion. Tuned mass control systems can be used to control the displacements, accelerations and internal stress variables of a structure in case of earthquakes. The location on the structure where the Tuned Mass Dampers are attached is vital. There are different types of methods of control for large modern structures. Tuned mass damper frameworks are generally utilized for the decrease of vibration brought about by wind and traffic like people on foot or railroad trains. Commonplace structures like slim scaffolds, stacks, high and thin structures have low dimensions of damping and may thusly experience inadmissible vibration. Tuned Mass Dampers cause control impacts which are like the expansion of damping.

International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

Contingent upon the mass proportion, the tuning recurrence and the damping capacity the a abundance decrease can be noteworthy and accomplish estimations of around 10 to 20% of the figures without Tuned Mass Dampers. The mass, firmness and damping proportion has picked agreeing various criteria. Here, a multistory structure is furnished with a tuned mass framework on the house top.

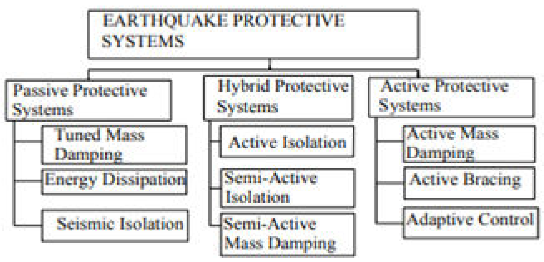

Figure General diagram of Earthquake protective system

Semi-active Control:

Semi-dynamic control frameworks are a class of dynamic control frameworks for which the outer vitality prerequisites are not exactly normal dynamic control frameworks. Normally, semi-dynamic control gadgets don't add mechanical vitality to the basic framework (counting the structure and the control actuators), thusly limited information limited yield dependability is ensured. Semi-dynamic control gadgets are regularly seen as controllable uninvolved gadgets. Dynamic wind load x1 Structure, m k, c Tmd, m1.

Advantages and limitations

The best favorable position of semi-dynamic frameworks is their capacity to give improved control powers a low interest for power. As the power can be provided by a battery, which guarantees 6 proceeded with usefulness even at power disappointment, adding dependability to any semi-dynamic control strategy. As a result of these advantages that excitement towards the semi-dynamic basic control plans has expanded as of late, making it a practical option in contrast to demonstrated inactive gadgets. While these preferences are for some situation really critical, semi-dynamic control still has its depreciators. Most applicable is the requirement for sensors innovation and PC controlled input, which is as vital to semi-dynamic controls to dynamic control.

2.0 LITERATURE REVIEW

Lair Hartog [7]. The TMD idea was first presented by frahm in the year1909 to diminish the moving movement of boats just as ship structure vibrations. A hypothesis for the TMD was introduced later in the paper by Ormondroyd and pursued by a point by point talk of ideal tuning and damping parameters in Den Hartog's book on mechanical vibrations [8]. The underlying hypothesis was appropriate for an un-damped SDOF framework exposed to a sinusoidal power excitation. Augmentation of the hypothesis to damped SDOF frameworks has been explored by various specialists.

Hrovat et al.[11]. Dynamic control gadgets work by utilizing an outside power supply. In this manner, they are more effective than latent control gadgets. Anyway the issues, for example, inadequate control-power limit and exorbitant power requests experienced by current innovation with regards to auxiliary control against seismic tremors are unavoidable and should be survived. As of late another control approach-semi-dynamic control gadget, which consolidates the best highlights of both detached and dynamic control gadgets, is alluring because of their low power request and inalienable solidness. The prior papers including SATMDs may follow to 1983. exhibited SATMD, a TMD with time differing controllable damping. Under indistinguishable conditions, the conduct of a structure furnished with SATMD rather than TMD is fundamentally improved. The control structure of SATMD is less reliant on related parameters (e.g, mass proportions, recurrence proportions, etc), so that there more noteworthy decisions in choosing them. Clark [2]. The idea of various tuned mass dampers (MTMDs) together with an advancement system was proposed by Clark. The principal mode reaction of a structure with TMD tuned to the major recurrence of the structure can be considerably diminished at the same time, when all is said in done, the higher modular reactions may just be insignificantly smothered or even enhanced. To defeat the recurrence related restrictions of TMDs, more than one TMD in a given structure, each tuned to an alternate prevailing recurrence, can be utilized., at that point, various examinations have been led on the conduct of MTMDs a doubly tuned mass damper (DTMD), comprising of two masses associated in arrangement to the structure was proposed (Setareh 1994). For this situation, two diverse stacking conditions were considered: consonant excitation and zero-mean background noise excitation, and the proficiency of DTMDs on reaction decrease was assessed. Logical outcomes demonstrate that DTMDs are more proficient than the ordinary single mass TMDs over the entire scope of complete mass proportions, yet are just somewhat more productive than TMDs over the down to earth scope of mass proportions (0.01-0.05). Villaverde. As of late, numerical and trial thinks about have been completed on the viability of TMDs in decreasing seismic reaction of structures [for example, Villaverde(1994)].

In three distinct structures were considered, in which the first is a 2D two story shear fabricating the second is a three-dimensional (3D) one-story outline building, and the third is a 3D link stayed connect, utilizing nine various types of seismic tremor records. Numerical and exploratory outcomes demonstrate that the viability of TMDs on decreasing the reaction of a similar structure amid various quakes, or of various structures amid a similar tremor is altogether extraordinary; a few cases give great execution and some have pretty much nothing or even no impact. This suggests there is a reliance of the accomplished decrease accordingly on the qualities of the ground movement that energizes the structure. This reaction decrease is expansive for resounding ground movements and lessens as the predominant recurrence of the ground movement makes tracks in an opposite direction from the structure's characteristic recurrence to which the TMD is tuned. Likewise, TMDs are of constrained viability under heartbeat like

International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

seismic stacking. Allen J. Clark [2]. Different uninvolved TMDs for lessening seismic tremor instigated constructing movement. In this paper a system for structuring numerous tuned mass dampers for decreasing structure reaction movement has been talked about. The method depends on expanding Den Hartog work from a solitary level of opportunity to various degrees of opportunity. Improved straight numerical models were energized by 1940 El Centro tremor and noteworthy movement decrease was accomplished utilizing the structure method.

3.0 METHODOLOGY

A high-rise framed building has been modeled using ETABS package. The confined structure was broke down utilizing dynamic investigation and the timeframe, sizes of relocations at basic areas were recorded. From that point, an appropriate TMD framework was structured. The heaviness of the TMD will be 3% to 5% of the all out weight of the structure. The TMD was first examined independently and its characteristic recurrence was gotten. Keeping the TMD so planned over the structure, the structure was by and by dissected utilizing dynamic examination and the timeframe, relocation at the relating areas was contrasted and the outcomes acquired without TMD to represent the utility of the investigation. The methods of dynamic analysis are as follows:

1. Response spectrum analysis: This technique is appropriate for those structures where modes other than the principal one influence fundamentally the reaction of the structure.

In this strategy the reaction of multi-level of opportunity framework is communicated as the superposition of modular reaction, every modular reaction being resolved from the ghostly investigation of single level of opportunity frameworks, which are joined to process the all out reaction. The strategy utilized is typically utilized related to a reaction spectrum.

2. Pushover analysis: The pushover analysis of a structure is a static non-straight investigation under lasting vertical burdens and step by step expanding parallel burdens. The identical static loads fittingly speak to seismic tremor initiated powers. A plot of absolute base shear and rooftop uprooting in a structure is gotten by the examination that would untimely disappointment and shortcoming. The examination is conveyed up to disappointment, along these lines it empowers assurance of breakdown burden and flexibility limit.

3. Inelastic time history analysis: A seismically deficient building will be subjected to inelastic action during design earthquake motion. The inelastic time history analysis of the building under strong motion earthquake brings out the regions of weakness and ductility demand in the structure. This is the most rational method available for assessing building performance.

International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

Rectangular plan:

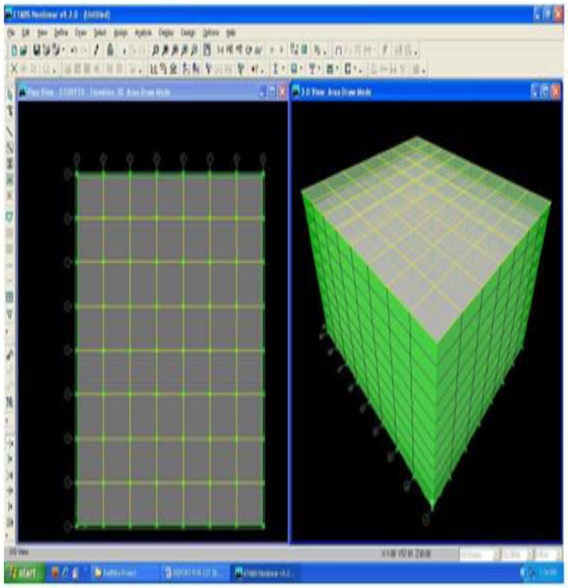

Figure Symmetrical building Plan without TMD.

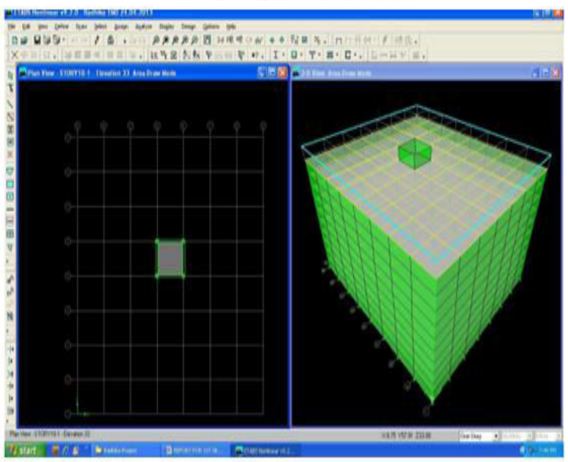

Figure Symmetrical building plan with TMD.

4.0 RESULTS

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% inETABS.

Description of theBuilding:

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

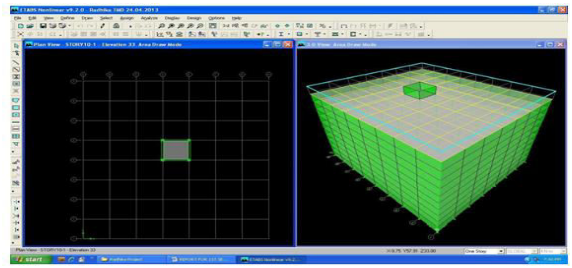

Fig: Plan showing the TMD placed at top floor for symmetrical section.

Case I: Without TMD & With TMD: Time Period Vs Base Shear x:

Table 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	-287.539	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	-11.4005
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

International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

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

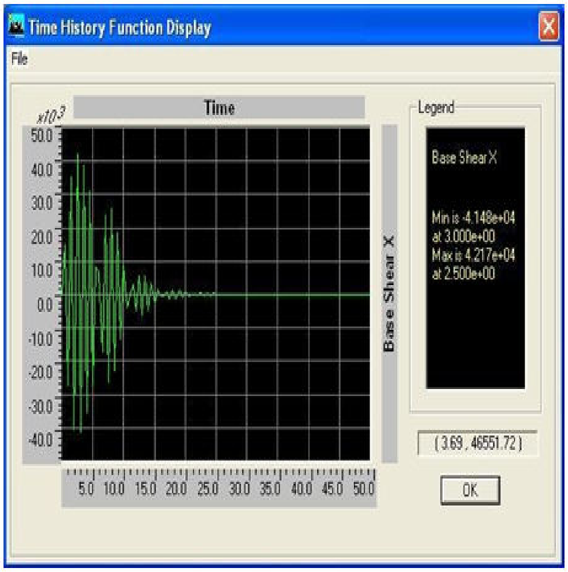

Fig: The Graph Showing between Time Vs Base shear X (Without TMD)

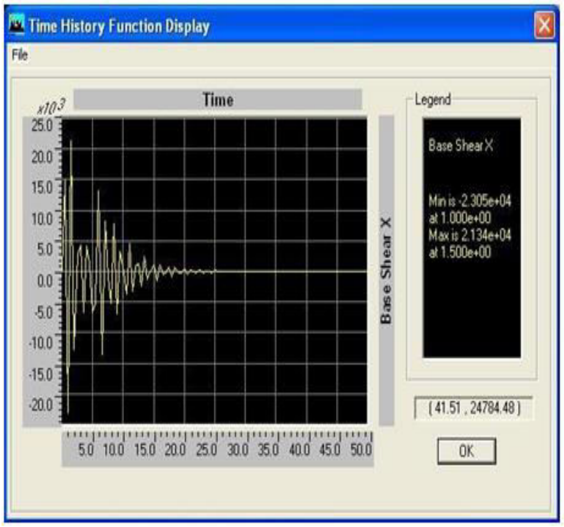

Fig: The Graph Showing between Time Vs Base shear X (With TMD)

Case II: Without TMD & With TMD: Time Period Vs Base Shear y:

Table TimeVs Base shear in Y-direction (without & with TMD).

Without TMD		With TMD	
Time Period	Base shear y	Time Period	Base shear y
0.00000	0	0.00000	0
0.50000	0.00133	0.50000	4.73E-05
1.00000	-0.00118	1.00000	1.45E-04

International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

1.50000	7.15E-04	1.50000	-1.01E-04
2.00000	-2.28E-04	2.00000	4.88E-05
2.50000	-1.13E-04	2.50000	-3.52E-05
3.00000	2.74E-04	3.00000	9.61E-06
3.50000	-3.09E-04	3.50000	0
4.00000	2.88E-04	4.00000	1.22E-05
4.50000	-2.56E-04	4.50000	-2.96E-05
5.00000	2.37E-04	5.00000	4.54E-05
5.50000	-0.00136	5.50000	-1.03E-04
6.00000	0.00142	6.00000	-8.95E-05
6.50000	-9.73E-04	6.50000	5.25E-05
7.00000	4.98E-04	7.00000	-1.14E-05
7.50000	-1.64E-04	7.50000	6.45E-06
8.00000	6.92E-06	8.00000	1.60E-05
8.50000	2.94E-05	8.50000	-2.80E-05
9.00000	-1.13E-05	9.00000	2.07E-05
9.50000	-1.55E-05	9.50000	-9.19E-06
10.00000	2.95E-05	10.00000	-2.62E-06
10.50000	-2.72E-05	10.50000	1.22E-05
11.00000	1.39E-05	11.00000	-1.47E-05
11.50000	2.63E-06	11.50000	1.02E-05
12.00000	-1.69E-05	12.00000	-2.77E-06
12.50000	2.60E-05	12.50000	-3.96E-06
13.00000	-2.93E-05	13.00000	7.76E-06

13.50000	2.84E-05	13.50000	-7.67E-06
14.00000	-2.43E-05	14.00000	4.45E-06
14.50000	1.86E-05	14.50000	0
15.00000	-1.25E-05	15.00000	-3.28E-06
15.50000	6.84E-06	15.50000	4.63E-06
16.00000	-2.00E-06	16.00000	-3.84E-06
16.50000	-1.76E-06	16.50000	1.68E-06
17.00000	4.39E-06	17.00000	0
17.50000	-5.94E-06	17.50000	-2.28E-06
18.00000	6.55E-06	18.00000	2.60E-06
18.50000	-6.40E-06	18.50000	-1.81E-06
19.00000	5.69E-06	19.00000	0
19.50000	-4.62E-06	19.50000	0
20.00000	3.38E-06	20.00000	-1.44E-06
20.50000	-2.13E-06	20.50000	1.38E-06
19.00000	5.69E-06	19.00000	0
19.50000	-4.62E-06	19.50000	0
20.00000	3.38E-06	20.00000	-1.44E-06
20.50000	-2.13E-06	20.50000	1.38E-06
21.00000	0	21.00000	0
21.50000	0	21.50000	0
22.00000	0	22.00000	0
22.50000	1.17E-06	22.50000	0
23.00000	-1.42E-06	23.00000	0
23.50000	1.47E-06	23.50000	0
24.00000	-1.37E-06	24.00000	0
24.50000	1.17E-06	24.50000	0
25.00000	0	25.00000	0

25.50000	0	25.50000	0
26.00000	0	26.00000	0
26.50000	0	26.50000	0
27.00000	0	27.00000	0
27.50000	0	27.50000	0
28.00000	0	28.00000	0
28.50000	0	28.50000	0
29.00000	0	29.00000	0
29.50000	0	29.50000	0
30.00000	0	30.00000	0
30.50000	0	30.50000	0
31.00000	0	31.00000	0
31.50000	0	31.50000	0
32.00000	0	32.00000	0
32.50000	0	32.50000	0
33.00000	0	33.00000	0
33.50000	0	33.50000	0
34.00000	0	34.00000	0
34.50000	0	34.50000	0
35.00000	0	35.00000	0
35.50000	0	35.50000	0
36.00000	0	36.00000	0
36.50000	0	36.50000	0
37.00000	0	37.00000	0

37.50000	0	37.50000	0
38.00000	0	38.00000	0
38.50000	0	38.50000	0
39.00000	0	39.00000	0
39.50000	0	39.50000	0
40.00000	0	40.00000	0
40.50000	0	40.50000	0
41.00000	0	41.00000	0
41.50000	0	41.50000	0
42.00000	0	42.00000	0
42.50000	0	42.50000	0
43.00000	0	43.00000	0
43.50000	0	43.50000	0
44.00000	0	44.00000	0
44.50000	0	44.50000	0
45.00000	0	45.00000	0
44.50000	0	44.50000	0
45.00000	0	45.00000	0
45.50000	0	45.50000	0
46.00000	0	46.00000	0
46.50000	0	46.50000	0
47.00000	0	47.00000	0
47.50000	0	47.50000	0
48.00000	0	48.00000	0
48.50000	0	48.50000	0
49.00000	0	49.00000	0
49.50000	0	49.50000	0
50.00000	0	50.00000	0

International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

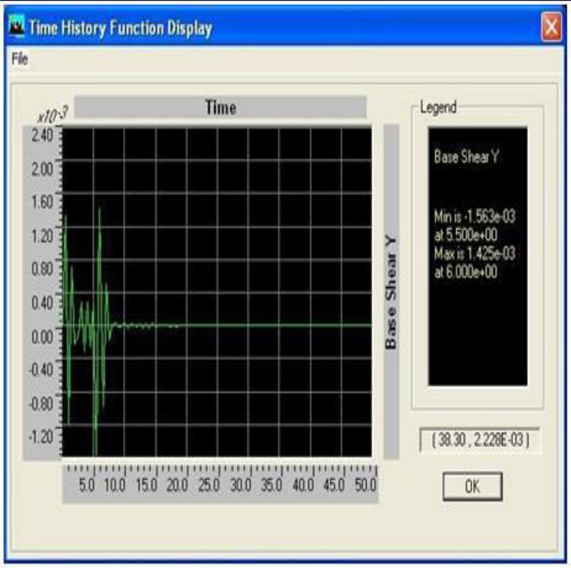

Fig: The Graph Showing between Time Vs Base shear y (With out TMD)

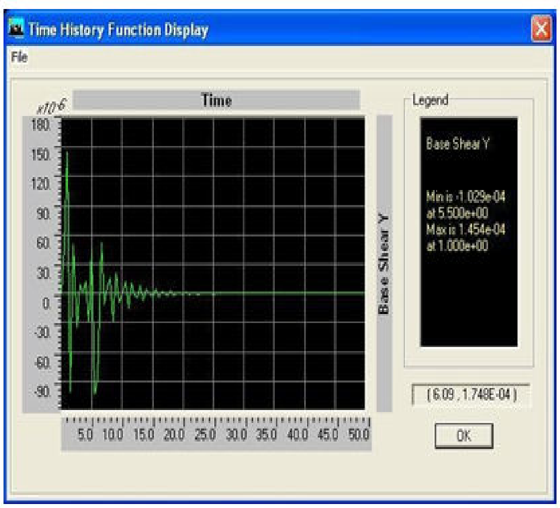

Fig: The Graph Showing between Time Vs Base shear y (With TMD)

5.0 CONCLUSION

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% (page 50).

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% (page 45 & 46) using steel dampers.

5. For un-symmetrical Buildings, the value of the base shear is brought down by 42% (page 54) using steel dampers.

REFERENCES

1. A.K. Chopra, Dynamics of structures: theory and applications to earthquake engineer, 3rd edition, prentice Hall, New Jersey.

2. Allen J. Clark. "Multiple Passive Mass tuned mass damper for reducing earthquake Induced Building motion".

3. Byung-Wan Jo, (2001) ―Structural vibration of tuned mass installed three span steel box bridge‖ International journal of pressure vessels and piping" 78 pp "667-675.

4. Chen Wai-fah. " Structural Engineering Hand book". CRC Press LLC, 1999.

5. Chi-Chang Lin, Jin-Min Ueng, Teng-Ching Huang, Seismic response reduction of irregular buildings using passive tuned mass dampers, Engineering Structures 22 (1999) 513-524.

6. Chouw Nawawi(2004) ― Behaviour of soil-structure system with tuned mass

dampers during near-source earthquakes‖. Thirteenth world conference on Earthquake Engineering paper no.1353

7. Den Hortog's (1928). – Undamped dynamic vibration absorber- Mechanical Vibrations.

8. Fahim Sadek, (1997) ― A method of estimating the parameters of tuned mass dampers for seismic applications‖. Earthquake Engineering and Structural Dynamics Vol.26 pp 617-635

9. G. W, Housner (1996) ―Structural control: past, present, and future‖ Journal of Engineering Mechanics, Vol.123, No.9, Paper No. 15617.

10. Hartog, D. J. P. (1947). "Mechanical vibrations." McGraw-Hill, New York, N.Y. Anthony C. Webster "Application of Tuned Mass Damper to control vibrations of Composite floor systems.

11. Hrovat. - "Semi active control systems for seismic protection of structures ".

12. I.S. 1893: 2002 (Part I), Criteria for Earthquake Resistant Design of Structures – Part 1: General Provisions and Buildings (Fifth revision); Bureau of Indian standards, New Delhi, 2002.

13. IS. 875-1987, Criteria for Wind loads – Part 1: General Provisions and Buildings (Fifth revision); Bureau of Indian standards, New Delhi, 2002.

14. K.C.S. Kowk (1995) – Performance of Tuned mass dampers under wind loads "Engineering Structures, Vol..17, No. 9, PP. 655-67".

15. K. K. F. Wong, (1999). ― Inelastic dynamic response of structures using force analogy method.‖ Journal of Engineering Mechanics, 125(10), pp1190–1199.

16. Lee Chien-Liang, ChenYung-Tsang(2006) ― Optimal design theories and applications of tuned mass dampers‖. Engineering Structures 28 pp 43–53

17. Mario Paz. "Structural Dynamics Theory and computation".

18. Mehadi Setareh et al, (2007). ―Tuned mass dampers to control floor vibration from humans.". Structural Engineering. ASCE, 118(3),741-762.

19. Pankaj Agarwal, Manish Shrinkhande, Earthquake Resistant Design of Structures, May 2007, Prentice Hall India, New Delhi

20. Peter Nawrotzki "Tuned mass system for the Seismic Retrofit of Buildings".

21. Runlin Yang, Xiyuan Zhou, Xihui Liu(2002) ― Seismic structural control using semiactive tuned mass dampers‖ Earthquake engineering and engineering vibration.

22. Saidi I, Mohammed A.D(2007) ―Optimum design for passive tuned mass dampers using viscoelastic materials‖ Australian Earthquake Engineering Society Conference

23. Singh MP, Moreschi L.M. (2000), Optimal seismic design of building structures with friction dampers. Proceedings of the U.S.–China Millenium Symposium on Earthquake Engineering, Beijing, China, November 8–11.

24. S.K Duggal. - "Earthquake Resistance Design of Structures".

25. S.M. Zahrai. Seismic performance of Tuned mass dampers in Improving the Response of MRF Buldings".

26. Shimazu T, Araki H(1996) ― Survey of actual effectiveness of mass damper systems installed in buildings‖. Eleventh world conference on Earthquake Engineering, Paper no.809
27. Xiudong tang and lei zuo "Simultaneous Energy harvesting and vibration control of structures with tuned mass dampers