PARAMETRIC STUDYON OPTIMUM DETERMINATIONOF DOUBLETUNNED MASS DAMPER (DTMD)CHARACTERISTICSFOR MOMENT–RESISTING STEEL FRAMESUNDERSEISMIC LOADING

AmirhosseinMIRKOOSHESH
MS.,University of Science and Culture,Tehran,Iran
amirhmirkooshesh@yahoo.com

Ali NIKKHOO
AssistantProfessor,University of Science and Culture, Tehran, Iran
nikkhoo@usc.ac.ir

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ABSTRACT

In this study, in order to reduce undesirable vibrations which is caused by seismic loads in structure a special type oftuned mass damper(TMD) named doubletuned mass damper (DTMD) has been surveyed to find optimal characteristics of thisdamper and it's efficiency in comparosion withtuned mass damper.Doubletuned mass damperconsists of one large and one smaller tuned mass damper for achieving more effective and more capable system to reduce undesirable vibrations resulting from seismic loads. Therefore the damper was located in roof storey of 5 and 10-storey structures with steel frames and about 850time history analyses have been done by considering nonlinear behavior of the structure. The criteria of this study is displacement of storeys and the trial and error method has been used for obtaining the specifications of damper.The result shows that double tuned mass damper is more effective than tuned mass damper in order to reduce the displacement responses of these structures and in additionsome tables has been presented for extracting the optimal characteristics of two types of dampers.

INTRODUCTION

In recent years, energy disipation and reducing responses of the structure against dynamic loads such as wind and earthquake have been interested byresearchers. Passive control method is one of the most common methods for this purpose, as well as useful which some of it's advantages in comparison with other methods are low cost of maintenance and operation and it's capability of permanent exploit. Tuned mass damper is oneof the passive control methods.

The basic ideaof double tuned mass damper has been proposed by Li and Han (2006) which was raised for the first time using several DTMD which simultaneously forms MDTMD that creates a system with more effectiveness and robustnessagainst the seismic loads. Then Li (2006) in other research on the MDTMDnamed DTMD which is composed of a big damper and a smaller damper in terms of simplicity of construction and practical application as a system that requires more research .Li and Zhu (2006) dedicated to research on numerical method for finding the optimal DTMD indicated that it has effective and robust fuctioninorder to reduceundesirablevibrations of structures against seismic loads.

Other important tips iswhen structure enter nonlinear area that so far few studies in this field has been done.in this case the optimum specification of damper that was calculated by considering linear behavior of structure,is not optimum any more in non-linear behavior of the structure and can even increase the responses as well.

The aim of this study is approaching to find the optimal characteristics of both types of DTMD and TMD and their performance comparison for reducingdisplacement responsesby considering the non-linear behavior of structures.

DAMPER SPECIFICATIONS

The three main features in the performance of both types of dampers are as follows: Mass ratio, damping ratio and frequency ratio.These specifications along with the shape of both types of dampers are shown in Figure 1 and Figure 2:

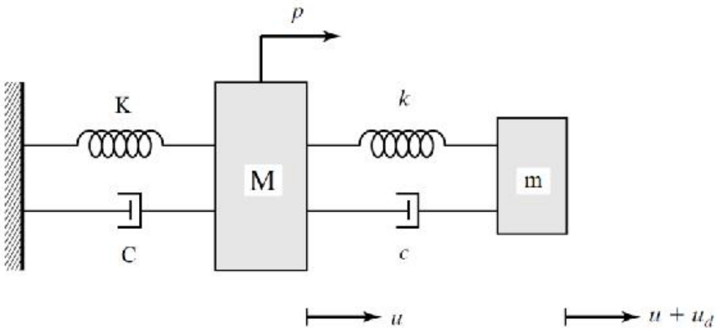

Figure 1: Tuned MassDamper (TMD) (Connor,2002)

$\mu = m/M$ Mass ratio (1)

$\zeta = c/(2m\omega)$ Damping ratio (2)

$f = \omega/\omega 0$ Frequency ratio (3)

where m is the mass of damper,M is the mass of first moodstructure,c is damping coefficient, ω_0 is thevibration angular frequency ofdamper,and ω is the vibration angular frequency of first mood of thestructure.
The double mass tuned damper is a simple model of dual layer tuned mass damper that is in figure below.

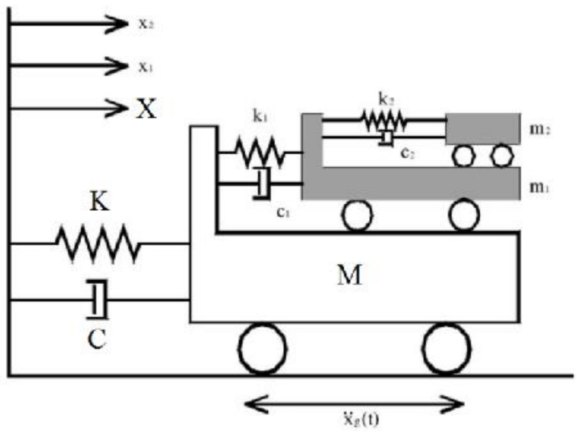

Figure 2: double tuned mass damper (Li C. and Zhu B., 2006)

$\mu_1 = m_1/M$mass ratio ofthelargerdamper (4)

$\mu_2 = m_2/m_1$ mass ratio ofthe smaller damper (5)

$\zeta_1 = C_1/(2m_1\omega_1)$damping ratio of the larger damper (6)

$\zeta_2 = C_2/(2m_2\omega_2)$ damping ratio of the smaller damper (7)

$f_1 = \omega_1/\omega_0$frequency ratio of the larger damper (8)

$f_2 = \omega_2/\omega_0$ frequency ratio of the smaller damper (9)

In whichindex 1 corresponds to the largerdamper andindex 2 to the smaller one.

TRIAL AND ERROR METHOD

As was expressed in order to find the optimum specification of the TMD and DTMD, trial and error has been done on two 5 and 10 storeystructurewith steel moment resisting frame which is two-dimensional by locating damper on the roof.sevenfar field records have been used to apply over 850 time history analysis on the structures byOpenSEES software.The criteria which is taken into consideration is displacement of the storeysthat is expressed by damper efficiency percentage index, I, indicates the extent of damper effectiveness with the specified specificatoins.The relationship between the performance damper efficiency is:

$$I = \frac{\text{Max uncontrolled response - Max controlled response}}{\text{Max uncontrolled response}} \times 100 \tag{10}$$

In the end the average of damper efficiency percentage of seven recordsconsidered as a criterion to determine the amount of the damper efficiency.

In this study by choosing mass ratio the operation of trial and error is applied on damping ratio and frequency ratio as presented in figure 3 and 4 for both TMD and DTMD. It should be noted thevalue of mass ratio and the specifications of the smaller damper in DTMD was selected as accordingSadek et al. (1997) and Connor (2002).

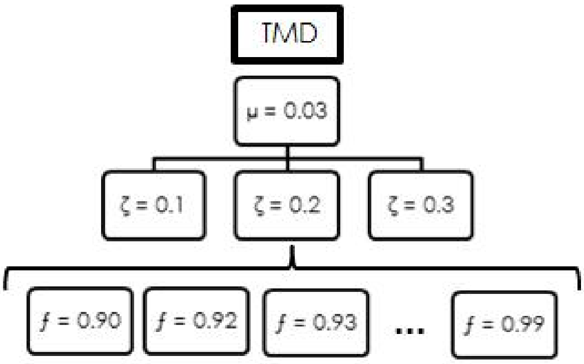

Figure 3: The selected specifications in trial and error for TMD

According to figure 3 in the case of TMD mass ratiois 0.03 and damping ratio was considered 0.1, 0.2 and 0.3, As well as the frequency ratio the ten values of 0.9, 0.91,... , 0.99 was checked out.

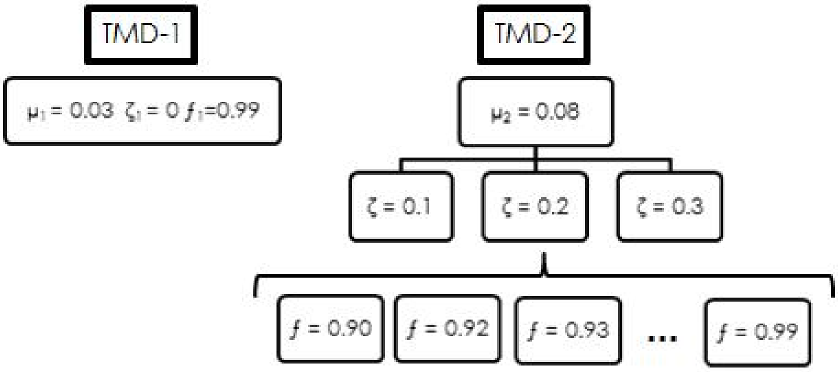

Figure 4: the selected specifications in trial and error for DTMD

The first and larger damper specifications with mass ratio of 0.03,frequency ratio of 0.0 and damping ratio of 0.99 was considered. The second and smaller one mass ratio equal to 0.08 and damping ratio in three modes of 0.1, 0.2 and 0.3 was considered and finally frequency ratio in the ten values of 0.9, 0.91,..., 0.99 was checked out.

TABLES AND GRAPHS

As previously mentioned, the result of trial and error on various specifications of dampers and time history analysis are tables that optimal damper specifications can be extracted, which in summery is presented the most efficient for reducing the responses.As was mentioned the criteria reviews was displacement ofstoreys which have been specified in the left of table and in the top part of the table frequency ratio are intended for specified damper and finally the numbers specified in table isdamper efficiency percentage index that optimal amount of each storey represent the greatest percentage reduction of response displacement which has been specified byunderlined and red text.

Table 1 : TMD with mass ratio of 0.03 and damping ratio of 0.1 in 5-storey structure

	FREQUENCY RATIO	0.90	0.91	0.92	0.93	0.94	0.95	0.96	0.97	0.98	0.99
DISPLACEMENT	5th STORY	14.826	15.346	15.860	16.395	17.002	17.389	17.107	16.729	16.287	15.741
	4th STORY	15.436	16.044	16.613	17.221	17.815	17.963	18.037	17.901	17.876	17.625
	3rd STORY	13.572	14.611	15.121	15.261	15.503	15.686	15.786	15.959	15.868	15.913
	2nd STORY	13.615	14.406	15.057	15.496	15.727	15.672	15.480	15.415	15.180	14.969
	1st STORY	13.099	13.612	13.999	14.417	14.780	14.635	14.481	14.551	14.516	14.448

As can be observed, the best performance of TMD with these specificationsin the 5-storey structure with frequency range between 0.94 to 0.97 and on the roof with a 17.4 percent decrease in the frequency ratio of 0.95 is occured.

Table 2 : TMD with mass ratio of 0.03 and damping ratio of 0.1 in 10-storey structure

	FREQUENCY RATIO	0.90	0.91	0.92	0.93	0.94	0.95	0.96	0.97	0.98	0.99
DISPLACEMENT	10th STORY	17.214	17.144	17.074	17.043	16.905	16.781	16.492	16.072	15.647	15.167
	9th STORY	18.707	18.658	18.561	18.396	18.228	18.006	17.685	17.317	16.860	16.341
	8th STORY	20.262	20.132	19.972	19.826	19.677	19.583	19.261	18.858	18.459	18.003
	7th STORY	21.412	21.423	21.383	21.288	21.149	21.063	20.972	20.853	20.760	20.381
	6th STORY	20.773	20.741	20.679	20.664	20.605	20.615	20.546	20.241	19.958	19.352
	5th STORY	19.764	19.621	19.444	19.288	19.033	18.839	18.652	18.415	18.162	17.601
	4th STORY	18.666	18.593	18.497	18.364	18.220	17.997	17.785	17.537	17.260	16.987
	3rd STORY	15.482	15.904	16.280	16.584	16.586	16.396	16.223	16.006	15.770	15.515
	2nd STORY	12.318	12.730	13.105	13.397	13.671	13.799	13.958	14.090	13.795	13.294
	1st STORY	7.954	8.335	8.702	8.976	9.270	9.432	9.656	9.854	10.053	9.731

According to this table, the best performance of this TMD would be in the 10-storey structure in higher storeys in the lower frequencies and on the roof in the ratio frequency of 0.9, with 17.2 percent reduction.

Table 3 : DTMD with a big damper with specifications of mass ratio of 0.03 and damping ratio of 0.0 and frequency ratio of 0.99 along with the smaller damper with mass ratio of 0.08 and damping ratio of 0.3 in the 5-storey structure

	FREQUENCY RATIO	0.90	0.91	0.92	0.93	0.94	0.95	0.96	0.97	0.98	0.99
DISPLACEMENT	5th STORY	19.717	19.694	19.528	19.339	19.160	18.988	18.823	18.665	18.511	18.369
	4th STORY	21.318	21.317	21.326	21.347	21.359	21.222	21.096	20.978	20.842	20.690
	3rd STORY	18.717	18.619	18.531	18.462	18.390	18.324	18.266	18.215	18.185	18.146
	2nd STORY	18.097	18.112	18.001	17.818	17.655	17.512	17.361	17.231	17.116	16.999
	1st STORY	17.321	17.206	17.067	16.927	16.775	16.643	16.511	16.397	16.317	16.212

According to the table the best performance of this DTMD in 5-storey structure except onestorey in the lower frequency ratio and on the roof in frequency ratio of 0.9 the reduction percent is 19.7.

Table 4 : DTMD with a big damper and specifications of mass ratio of 0.03, damping mass of 0.0 and frequency ratio of 0.99 along with the smaller damper with mass ratio of 0.08 and damping ratio of 0.1 in 10-store structure

	FREQUENCY RATIO	0.90	0.91	0.92	0.93	0.94	0.95	0.96	0.97	0.98	0.99
DISPLACEMENT	10th STORY	21.199	21.421	21.650	21.817	21.959	22.075	22.170	22.246	22.310	22.149
	9th STORY	22.152	22.388	22.613	22.826	23.026	23.187	23.304	23.363	23.381	23.396
	8th STORY	23.732	23.955	24.158	24.337	24.500	24.541	24.487	24.455	24.433	24.438
	7th STORY	25.443	25.719	26.009	26.263	26.122	25.948	25.786	25.651	25.540	25.476
	6th STORY	23.891	24.076	24.334	24.595	24.861	24.891	24.817	24.768	24.670	24.564
	5th STORY	21.436	21.806	22.013	22.110	22.236	22.408	22.613	22.843	23.090	23.352
	4th STORY	17.572	17.438	17.355	17.325	17.286	17.288	17.339	17.444	17.611	17.836
	3rd STORY	14.937	14.700	14.507	14.325	14.209	14.133	14.119	14.183	14.296	14.448
	2nd STORY	11.865	11.683	11.570	11.513	11.487	11.474	11.506	11.602	11.746	11.903
	1st STORY	7.250	7.039	6.883	6.780	6.748	6.781	6.864	6.975	7.104	7.325

As can be seen in the structure of the 10-storey,this DTMD with more dispersion than previous cases in higher frequencies is almost the best performance and about the roof in the frequency ratio of 0.98 with 22.3 percent of the reduced response of displacement has the best performance.
The time history Chart when it has been collecting withoutdamper, with the best TMD and DTMD according to the tables for Superstition Hills record in two structures 5 and 10-storey in order to taking into account the criteria for replacement of the roof in Figure 5 and 6 has been presented. In this chartsthe displacement of the roof are based on meters.

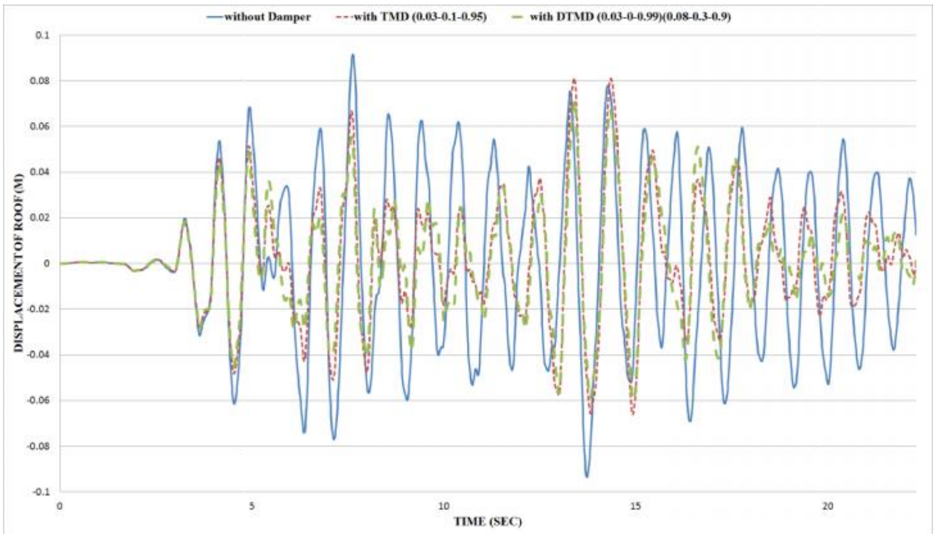

Figure 5: time history comparative chartSuperstition Hills-02 record for 5-storey structure by considering the criteria for replacement of the roof

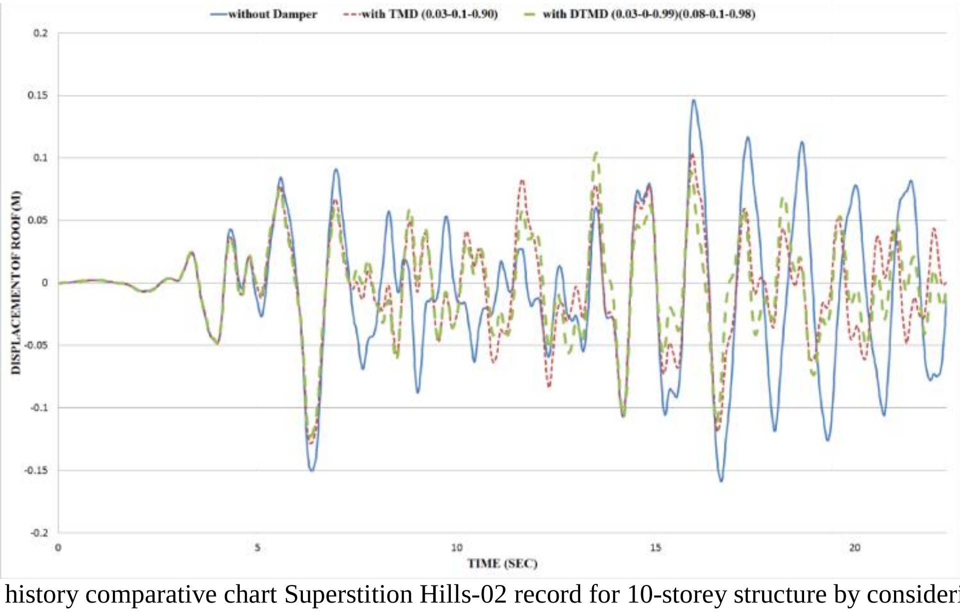

Figure 6: time history comparative chart Superstition Hills-02 record for 10-storey structure by considering the criteria for replacement of the roof

As in these two charts for a particular record the impact of TMD and DTMD compared to the structure without damper observed that overall it can be said the impact would substantially affect the structure.

CONCLUSIONS

In this research it was trying to optimize the specifications is set to doublemasstuned damper and along with mass tuned damper in the nonlinear behavior of structures obtained with the method of trial and error and also the amount of the performance of this damper in reducing the displacement response relative to the mass tuneddamper has reviewed. And finally by taking a percentage of the average performance of the damper efficiency that was the average of seven recordscases was significant that DTMD vs. TMD in the reduction of thedisplacement response has better performance. For example, in 5-stoerys structure the best performance on DTMD damper on performance of displacement response is 19.7, while the same amount for TMD is 17.4. As for structureof 10-storey the best efficiency forDTMD to reduce the response displacement is 22.3 while in the same amount as for TMD is 17.2. The results of the other numbers in the table are listed and can be observed in the 10-storeystructures DTMD for reducing performance of displacement response is better than 5-storey structure.

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