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Reviewing the performance of tuned mass dampers (TMD), in the near-fault earthquakes

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ABSTRACT

Using of tuned mass damper is a common way for reducing responses of structures as a result of wind and earthquake. This damper is consisted of concentrated mass which is connected to the point of structure by a damper and spring. In this paper frame of last floor is used for placing tuned mass damper. For this reason, four models of 4, 8, 12, 20 floor buildings with moment resistance frame are studied under effect of earthquakes of near field Leandros, Northrdig, Kube and Tabas faults. So, mass damper which is suggested on the base of improved values in scientific resources is calculated. On the base of these results, it is possible to found appropriate behavior of tuned mass damper in 12 and 20 buildings.

Introduction

Design of structures against seismic vibrations, is one of the main challenges for engineers. In the conventional methods, building using a combination of stiffness, ductility, energy dissipation and inertia, the dynamic forces, show their strength. In such a structure was very low attenuation value, and thus the energy dissipated in the elastic behavior of the structure is negligible. The building, under the influence of powerful dynamic forces, such as earthquakes through the elastic range, a lot of places are changing, and only by way of non-shift feature their elastic, remained stable. The non-elastic displacements, causing plastic joints, are topically in the areas of structure, which increases ductility, and the seismic energy dissipation is increased. As a result, much of the energy of the earthquake, local devastation caused by lateral resistant system construction, to be amortized.

problem statement

Iran is the world's seismically active zone, and the Certificate scientific evidence and observations of the twentieth century, the most dangerous regions of the world, is caused by a powerful earthquake. In recent years, on average, every five years, an earthquake with a very high financial loss, occurred in part of the country, and now Iran leads the countries that, an earthquake of high casualties is. Although fully prevent the damage caused by earthquakes is extremely difficult, but with the increase of information, in relation to seismicity of the country, educating and promoting a culture of safety, identification and detailed study of the vulnerability of constructions, buildings, infrastructure and artery of life, and the retrofit of immunization and correct it may be desirable to limit the losses and damages caused by future earthquakes, respectively.

The experience of past earthquakes, especially the recent earthquakes show that, in the near-fault ground motion has special characteristics which, with far-fault ground motion in different areas. In areas near fault ground motion is strongly influenced by the failure mechanism to develop the fault, the permanent displacement of the site and the land is located.

So these two phenomena have caused a total failure, and permanent displacement (step mutational displacement) that, for motion estimation land near active faults, is used.

Movements of earth, near pulsed nature's fault, and studies show that this movement demand shift, energy and high formability, to impose the system. Special properties near-fault earthquakes, including the impact of lower damping than in ordinary earthquakes behavior, lack of enough time to perform cyclic movements, and energy loss as a result of this move, because of the nature of their pulse, and demand a lot of energy in time short time, and also impose high velocity and displacement demand system requires based design approach requires, have the possibility to consider this demand. As a result, today, one of the main challenges to achieve this objective, the use of dampers in the structure, and the integration of these new techniques, concepts seismic design of structures, and improving the seismic performance of structures in areas near fault.

Review of past research

The main idea of the mass dampers, as a damper system, first in 1909 by Mr. frahm for ship motion was coined. (1) The concept of TMD, goes back to about 1974. The system includes an auxiliary mass, About one to four percent of the total mass of the building is, which are usually placed on the top floors of the building, and by a passive spring and damper, connected to the building. The success of such a structure, the vibrational excitation wind, proven today.

For example, villaverde, in 1994, it examined on three different structures, the first 10-storey two-dimensional structures, which, for the building were cut. The second structure, a three-dimensional structure of a class, and the third was a three-dimensional structure of a suspension bridge, the 9 different types of earthquake records, it used to get answers. Numerical and experimental results showed that, in the performance of TMD, the same reduction in the structural response, during different earthquakes, as well as in reducing the different structures, over the same earthquake, there is a huge difference. (2)

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Seismic first strong evidence for the phenomenon of near-field momentum by beniof, in 1955, according to the California Earthquake kern county, have been reported. He has shown that the development of fault fracture, as the supplier can, to land with a variety of impulses, at the end of the fault fracture zone, the waves can lead, as waves of high intensity and high frequency, in order to with low emissions, and lower frequency content, or to be released. hall in December 1995, a lengthy report entitled ((the response parameter steel moment frames, close to the earthquake fault)), with investments Emergency management agency America (fema), provided.

In conclusion, it was found that the non-elastic tension, generally in the beams, but significantly, lodged in the column happens. The results relative displacement values, the records intended to the slurry of 6 and 20 floors, stating the need to change the record high places, as near-fault records, compared with the limits is the current seismic regulations. During the study, reached the conclusion that, the impact of earthquakes (near-fault records), the effects of earthquakes, the proposed regulations will be harder. In order to consider the impact of near-fault records, the seismic regulations, have the force of regulations, for near-fault earthquakes increased. (4)

Near earthquake faults, especially on the road leading to rupture, causing serious damage to structures, constructions and survivor particularly high frequency, due to the long period of the pulse movements. Experimental also Northridge earthquake in Kobe, Chi Chi was observed, and this was the important factor as one of the determining factors in science enter the city. So that Mr. Rauch, and Smolka, in a paper presented in 1996, the Northridge, California earthquake study, research, the response of structures against earthquakes near the fault, indicate that, based Analysis the time history, response spectrum analysis should, because the frequency domain characteristics of earthquakes (during the whole call), the process states that have relatively uniform distribution of energy, the duration of the movement is, so long as the energy in a few pulse, the movement is concentrated, a phenomenon believed to be aggravated, the whole answer should offer not enough time for the formation. (6)

In 2001 Kazuto and colleagues explores the tuned mass damper the pendulum, did. In this study, the tuned mass damper pendulum, applied in buildings that were due to traffic flow volatility and vibration. (8)

In 2001 Yao-ting and his colleagues set to work on a new type of mass damper, Drawing up by rubber layer, is attached to the main structure, to act as a structural joint suspension. This damper, was on the top floor. According to the findings of the researchers, if the design parameters of the damper, the right to be elected, this system can reduce more than 25 percent of structures against earthquake. In other words, if the structure is elastic behavior, and this structure is under harmonic forces, and the main mode of structural adjustment, it can reduce the structural response. (9)

In 2002 Johnson, to study, TMD, and the location of its properties, on the top floor have frames. The structure is made of 6, under certain time history, analytically studied, and found that the damper attached to the frame softness, its mass increases the period of construction.

This increase reduces the earthquake acceleration response, for the same time history, and records the response spectrum. It also proved that, in a building should be non-linear analysis methods, the stability of the tuned mass damper template, on which it is located should be considered. (10)

In the year 2004 Ambrosini, the effect of fluctuations in the rotational machine control systems, in order to substitute for their transmission control systems for cases where the installation of transmission systems, not possible. In this paper, an experimental and numerical analysis, to such systems are discussed, and presented formulas that must be used for dynamic analysis.

Kamrani and his colleagues in 2006, to study the performance of TMD, the response of structures under earthquake right away, and went right approach. In this paper, Building 3, 9 and 20 floors, examined. First time history analysis, no damper on these structures under earthquake right away and right near the stage was done then, the model has been adjusted with the mass damper was studied, and the results indicate positive effect of the tuned mass damper, the seismic response of structures respectively. (12)

In 2004wong and chee, The effect of the tuned mass damper frame, the capability of energy dissipation earthquake arrival, the buildings and of building examined, and concluded that TMD, in reducing responses energy buildings a period of medium and long term, to building a short period, is more effective . (13)

In 2005 Nawrotzki, to improve the seismic behavior of buildings suggestions for increasing the damping has to offer, to achieve this goal, the tuned mass damper has been adjusted, research and found that the system TMD, usually against seismic forces, good behavior not show, but could be accelerated to reduce the displacement, and internal stresses caused by the quake Search, in addition to seismic retrofit of structures built as well, can be effective. In this paper, TMD mass ratio of the mass of the structure about 5 to 15 percent, were present.

In the year 2007 Tulei, to evaluate the effect on seismic behavior of structures have 5 floors. The 5-storey building seismic analysis, concluded that, to reduce the level of injury, and retrofitting of the building, without changing the nature of TMD use it, but found that the loss of the seismic response of structures 5 floors, is not effective, and compared with reinforced concrete frame, the better the result. The researchers showed that, TMD in reducing shift, and internal forces caused by the earthquake, the frame is not effective. (15)

Shariatmadar and Akbarzadeh in 2010, the effect of the variation frequency of the tuned mass damper, the performance of structures under seismic evaluation and performance indicators, evaluated, and strategies to determine the optimum settings were introduced. In this project, the far-field and near field earthquakes, tuned mass damper has been adjusted performance also was evaluated. (16)

Shariatmadar and Meshkat Razavi in 2010, to evaluate the effect of several TMD, the deceleration of the structure's floor and high class. In this study, two 16 and 32-storey buildings, the earthquake in Zarand and Bam were studied. It results in a maximum 32-storey structure uncontrolled acceleration under earthquake near Zarand right and Taft, have exhibited.

The researchers from three different control structures, were used. First, a TMD top floor, has been planted. Second, set two objects, one on the top floor and the other on the floor 15 and 31, 16 and 32-storey buildings, have been used. Uniform distribution of TMD, is in the middle and upper classes.

The results show that, using more than one TMD, the acceleration of the middle class in the amount of 10 to 15%, more than one can reduce TMD.

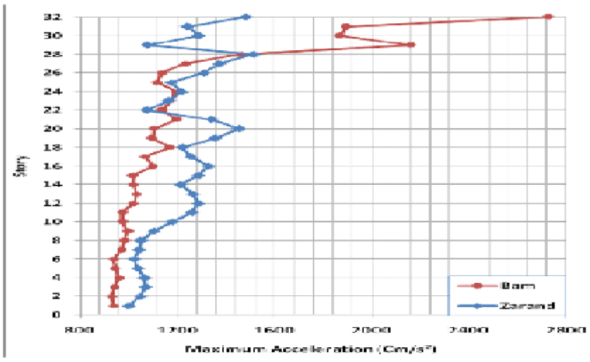

Figure 1. The maximum acceleration for class 32 uncontrolled structures under earthquake in Zarand and Taft.

The time-history analysis indicated that if the mass of TMD 6 to 8 percent of the total mass of the structure, and their distribution among the classes be uniform, acceleration response of 15 to 30 percent, compared to uncontrolled structures, respectively.

Research findings

The nature of earthquakes used in areas near fault

In this study, we have tried that, a near-field earthquakes in Iran and the world. One of the selection criteria of near-fault earthquake could be distance, but as the only selection criterion cannot be accepted, and should be in addition to that, the mapping of velocity and displacement response spectrum, and near-field spectra used. According to the definition established in the near earthquake faults, and according to the above parameters, a near-field earthquake ground motions were selected based .Data Iran, Housing and Urban Research Organization, is provided. To complete record of earthquakes, seismic Tabas, 1995 Kobe, Japan, in 1992 Landers, 1994 Northridge and used, which, from the website of PEER, has been prepared earthquakes. In this, the whole call using the software Seismosignal, calculated and in Figure (1) is drawn.

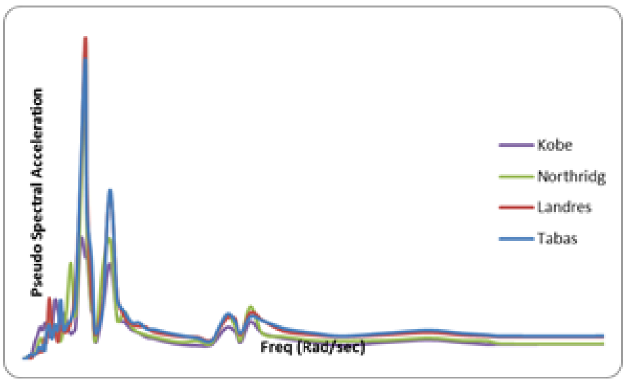

Figure 2. earthquake response spectrum near fault.

2) The results of nonlinear dynamic analysis, using the software SAP2000-V15.The selected models, using Iran's bylaws loading, loading, and then Etabs, modeling and was designed. With specific sections, other analysis in SAP2000, version 15 was carried out. In all constructions, extensions TMD, the existence of a mass damper.

5.2.1) four-storey building

Figure (2), the effect of the earthquake on the four-storey building, the Kobe earthquake in Japan is shown. In the Kobe earthquake, at times unfavorable effect of TMD, and increases the shift. While the earthquake Northrdig, almost all the time of the earthquake, the mass damper increases the lateral displacement, the structures.

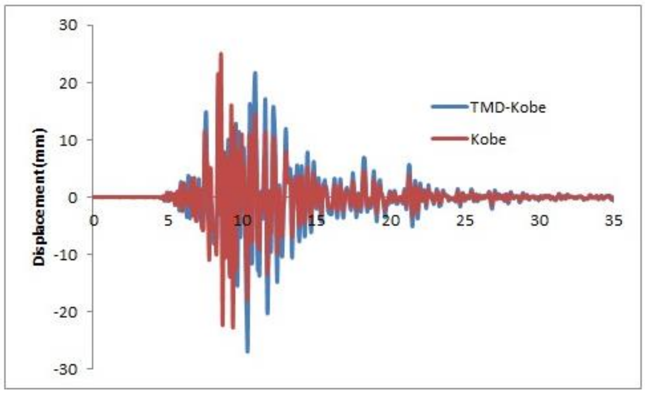

Figure 3. call shift in the Kobe earthquake.

Until four seconds, almost non-existent or non-mass damper, has no effect on the structural response, but then its effect is significant.

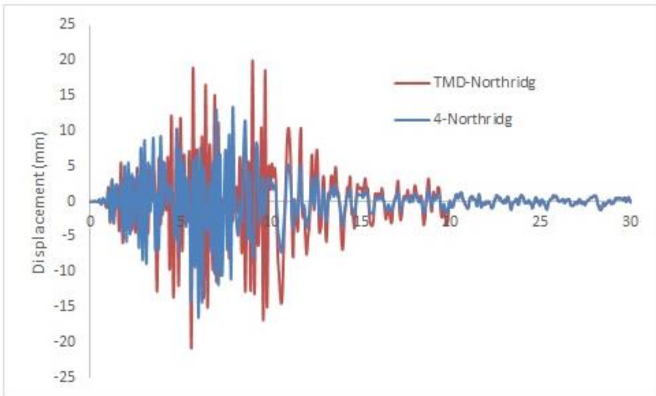

Figure 4. call shift in the earthquake Northrdig.

Landrs earthquake, the earthquake Northrdig show similar behavior. First, despite the structural mass damper, and conventional structures, have mutually beneficial manner, but gradually the mass damper, increase the structural displacement. Around the time of five seconds, change the location of the structure has a damper mass, much more than the conventional structure, and becomes more visible adverse effect damper.

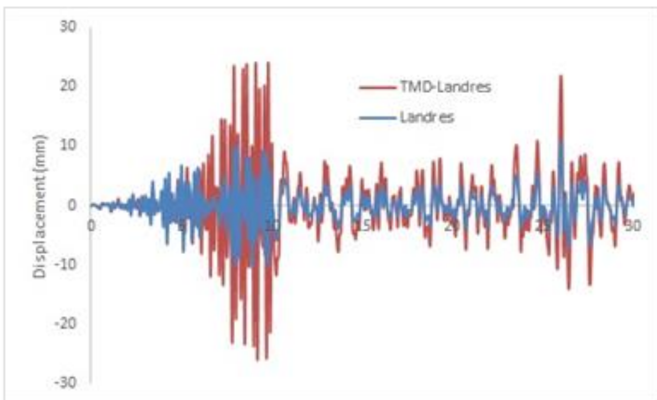

Figure 5. call shift in the Lenders Earthquake.

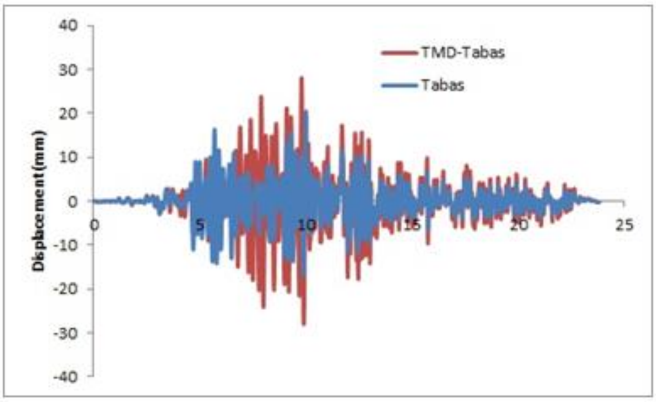

Figure 6. call shift to Tabas earthquake

5.2.2) eight-story building

Figured (5) to (8), the structure has a mass damper and damper crime under four areas of near-fault earthquake, have been compared. The results show that, in the presence or absence of the mass damper, affected by the Kobe earthquake, the structure shows the same treatment. But Landrs earthquake, the damper mass decreased in the first shift, but it is gradually increased, and the total amount to little more than structures, without the damper. This behavior also Northrdig earthquake, is true. Tabas earthquake damper on the effects and influences, and closing cycles associated with it, are without force.

In general it can be concluded that, in the eight-storey structures damper, is better than a four-story structures.

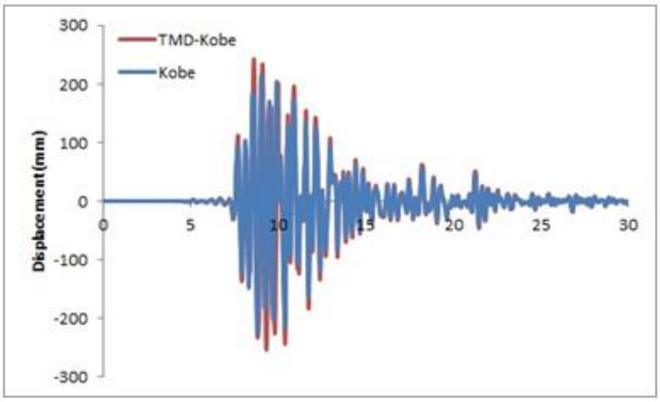

Figure 7. call shift in the Kobe earthquake.

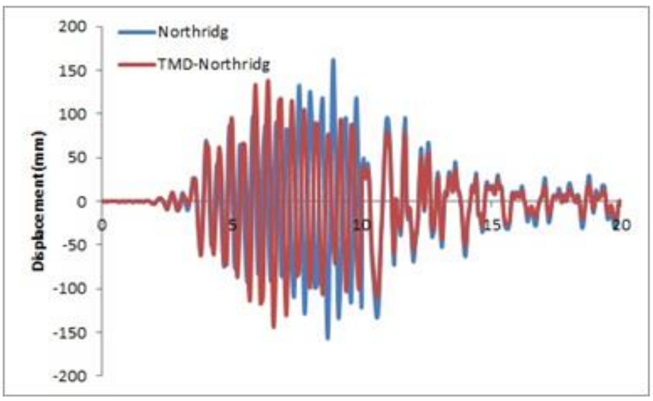

Figure 8. call shift in the Northridge earthquake.

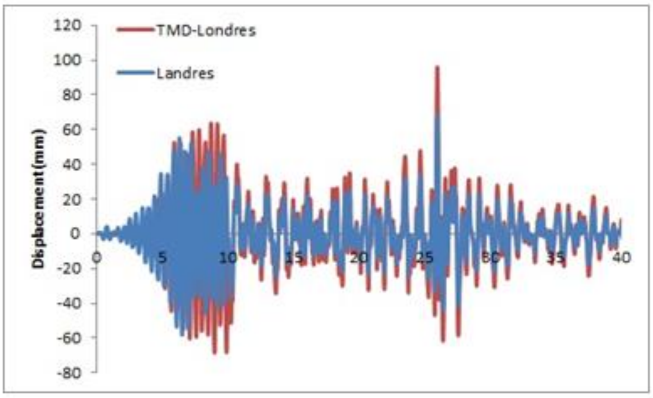

Figure 9. call shift in the earthquake Lenders

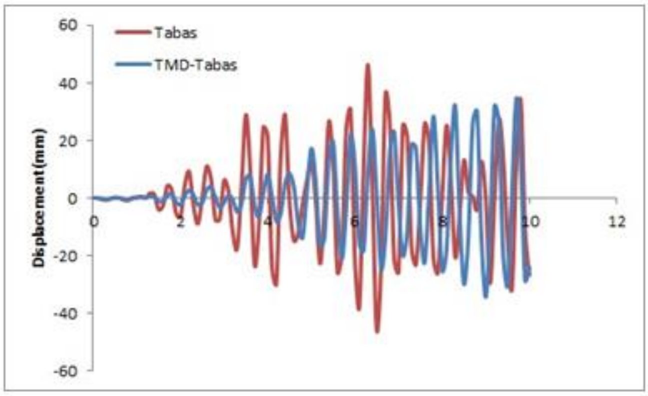

Figure 10. call shift in the Tabas earthquake.

5.2.3) twelve-storey building

Figured (9) to (12), the structure has a damper mass, and no mass damper under four areas of near-fault earthquake, have been compared. The results show that, despite the damper has a positive effect on behavior. Unlike four and eight-storey structures because it reduces the lateral structures. However, in the initial cycle of earthquake acceleration, shift significant structural mass damper, and conventional structures are identical. Generally at this stage it was observed that, by increasing the number of classes and thus increase the height of the structure, as well as increased period of structural mass damper effect, is more favorable.

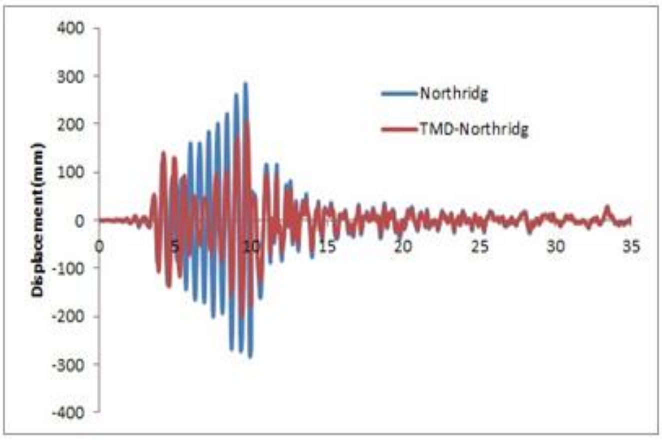

Figure 11. call shift in the Northridge earthquake.

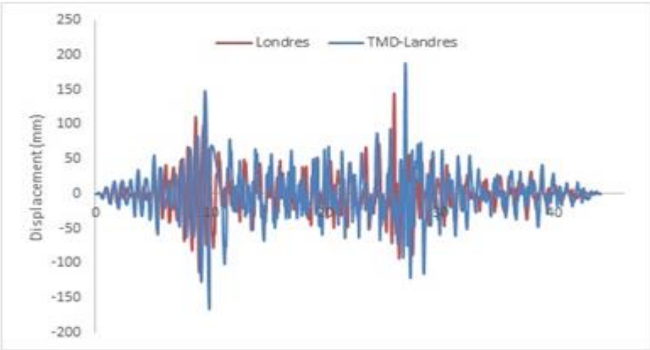

Figure 12. call shift in the earthquake Lenders.

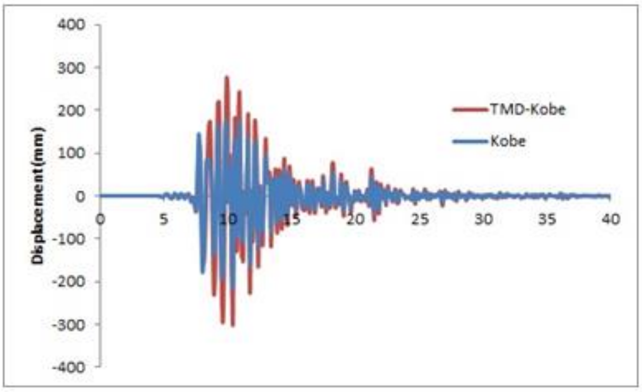

Figure 13. call shift in the Kobe earthquake.

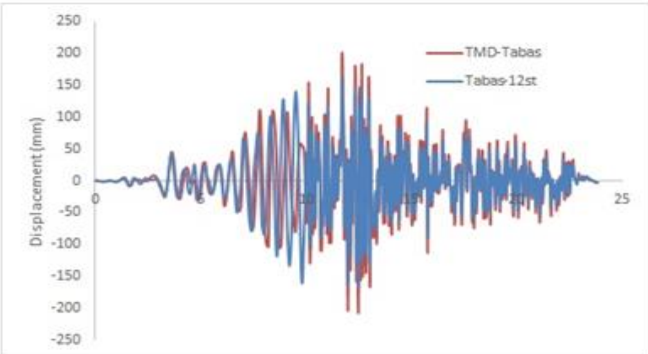

Figure 14. call shift in the Tabas earthquake.

5.2.4) twenty-storey building

Figured (13) to (15), the structure has a damper mass, and no mass damper in twenty-storey buildings, is shown. With reference to these figures can be seen that, damper as twelve-storey structures, structures has a positive effect on behavior, and change places it reduces the side.

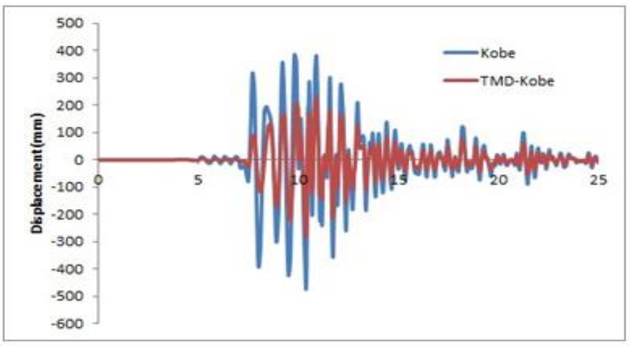

Figure 15. call shift in the Kobe earthquake.

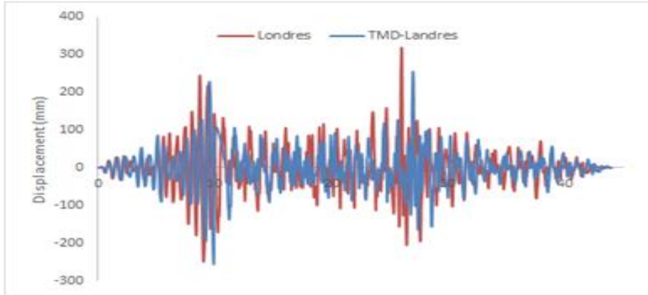

Figure 16. call shift in the earthquake Landrs.

Pushover analysis, the specific spectrum used that site, then explain how it is calculated:

5-2-5) pushover analysis Twenty-class structures

Established using earthquake data in 1989, Loma Prieta, near-fault earthquake ground motion in three areas (less than 20 km distance to fault), the average (between 20 to 50 Kilometer to fault), and the distance (the distance more 50 km) is divided. Anatomy of strong ground motions in the field of near-fault and its effect on structures of important issues in seismology and earthquake engineering is, of course, still many difficulties and uncertainties understand, describe and predict the ground motion, in there is near-fault.

To characterize the whole answer, for different risk levels required acceleration earthquake records (Table 1) is used. This results using the software Matlab, become just Chahar Sotun, so they can be used in SAP2000. Because the momentum mapping, itself just two-column, placed in the hands of users.

Table 1. View near earthquake faults used in this study.

زلزله	سال	ایستگاه	PGA (g)	PGV (cm/s)	PGD (cm)	فاصله (Km)	نوع خاک
Chi-Chi, Taiwan	1999/09/20	TCU128	0.139	73	90.62	9.7	II
Kobe, Japan	1995/01/16	JMA 99999 KJMA	0.7105	77.83	18.87	0.96	II
Kocaeli, Turkey	1999/08/17	Sakarya	0.376	79.5	70.52	3.1	II
Landers	1992/06/28	22170 Joshua Tree	0.284	43.2	14.51	11.6	II
Northridge	1994/01/17	Pacoima Kagel Canyon	0.433	51.5	7.21	8.2	II
Bam, Iran	2003/12/26	Farmandari	0.979	39.63	8.6	<1	II
Golbaf, Iran	1998/03/14	Abaragh	0.269	27.95	5.3	13	III
Silakhor, Iran	2006/03/31	Chalan Choolan	0.52	36.28	12.35	9	II
Tabas, Iran	1978/09/16	9102 Dayhook	0.406	26.5	8.75	14	II
Zanjiran	1994/06/20	Zanjiran	0.98	42.13	10.26	2.65	II

The scale of the earthquake records, they have been divided to its maximum value. Thus, the maximum acceleration of all of them, is equal to the gravitational acceleration g. Each of acceleration response spectrum mapping, by order of 5% attenuation is achieved and in any order, separately combined together. In the figure below, the range of responses to earthquakes x component, averages them, and compare it with the whole 2800, can be seen.

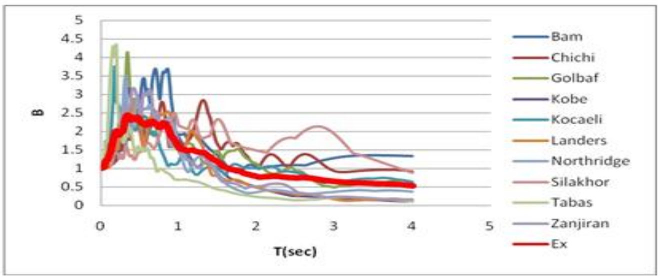

Figure 17. Average of the spectrum, in response, Component x earthquake research.

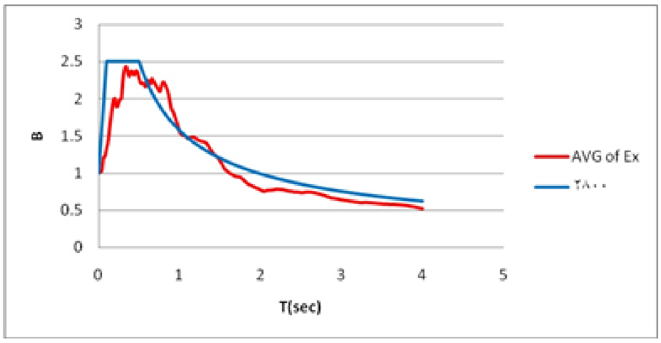

Figure 18. Compare the whole call, the x component averaged, with the whole 2800

5-2-5-1) call pushover analysis

In this section, the results of pushover analysis, are examined, in order to better view the mass damper effect, be evaluated. In dynamic analysis, merely shift were studied, and not effects on behavior damper structure, properly understood. Therefore, the results of pushover, will be discussed.

5-2-5-2) effective period

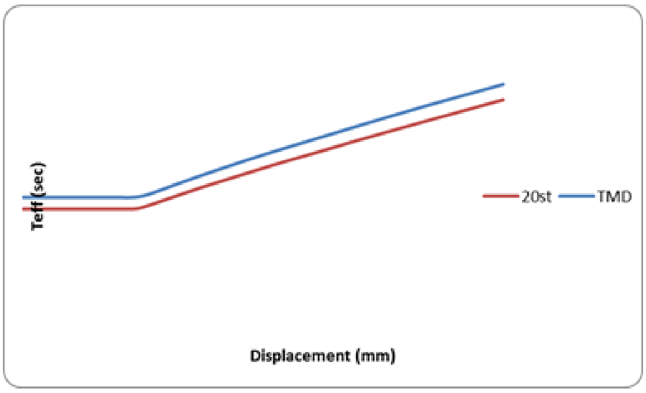

Figure 19. Figure period, the shift twenty-storey structures.

With plastic hinges, the Member structures and structural work period is not fixed, and is ever-changing. Due to the design according to regulations, based on elastic analysis is carried out, so this number is assumed to be constant, although in reality it is not. Figure (19), charts the shift period of twenty-story structures drawn. It can be seen in the same terms, the existence of a mass damper, increase the cycle time for designs. The interesting thing is that the linear equations period of structural change, in both conventional structures and a damper, is almost identical. In other words climb and change the period, compared to a shift in both structures, almost at the same time it happens.

5-2-5-3) structural damping

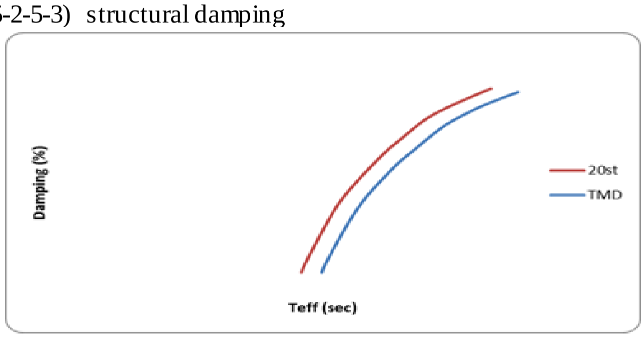

Figure 20. Figure period, the structural damping twenty floors.

There damping in structures, reducing earthquake forces. Figure (20), the period of structural damping is drawn. It can be seen mass damper, the damping and the cycle time increased, so that's why more appropriate behavior, will be.

5-2-5-4) plastic hinges Formation

In addition to the search results of pushover analysis, in the following tables History plastic joints, and their type is specified. It is observed that, mass damper, causing the postponement of structural failure, both the force and change its location. Twenty-class structures without mass damper, the shift 887.34 mm, and the base shear 214.66 kN, Plastic hinge structure, the CP reaches the stage, while the structure has a mass damper, bordering the plastic hinge CP, increased to shift 1173 mm, and cutting base is 217.6 kN.

Conclusion

In this section, the behavior of structures with floors four, eight, twelve and twenty floors under different earthquake, examined, and the effect of their mass damper were evaluated. The investigation led to results that can be summarized as follows.

- - In the short-order structures, mass damper, good effects, no structural behavior.
- Structural response of a mass damper, depending on the nature of earthquakes is investigated.
- With height (period) structures, mass damper effect, is more favorable.
- In the same condition, there is a mass damper, increase the cycle time for designs. The rise and change cycle time, to change places in both structures, almost at the same time it happens.
- Mass damper, the damping and increased cycle time, so that's why more appropriate behavior, will be.
- Mass damper, causing the postponement of structural failure, both the force and change its location.

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