PalArch's Journal of Archaeology of Egypt / Egyptology

IMPACT OF TUNED MASS DAMPER ON THE STRENGTH OF CONCRETE AND STEEL STRUCTURES UNDER EARTHQUAKE LOAD GIVEN NONLINEAR EFFECTS

Mahdiyeh Salehi[1*]
[1] Master of Civil Engineering
*(Corresponding author)

Mahdiyeh Salehi Impact of Tuned Mass Damper on the Strength of Concrete and Steel Structures under Earthquake Load given Nonlinear Effects -- Palarch's Journal Of Archaeology Of Egypt/Egyptology 18(10), 1979-2012. ISSN 1567-214x

Keywords: Damper - Structure - Structural strength - Earthquake - Reinforcement - Mass damper

ABSTRACT

Application of dampers in the reinforcement of structures is one of the most practical and effective methods of controlling the applied forces and increasing the resulting energy loss. A tuned mass attenuator is a passive energy absorption device. The main purpose of using the separation system is based on reducing the horizontal movement of the earthquake entering the structure, which can provide a good performance for the protection and safety of the structure in combination with the tuned mass damping system. One of the objectives of this study is the optimal design of dampers and evaluation of the performance of structures with and without soil-structure interaction and identification of classes in need of dampers. During the life of structures, various forces are applied to the structure, one of the most important of which is the force caused by the movement of the structure or earthquake. Dampers reduce the energy input to the structure by 2 to 5 times and the displacement by 2 to 3 times. In other words, dampers reduce the force of the members of the structure and deform due to the absorption of input energy into the structure and change the distribution of force in the structure, so this method can be used as a suitable option to modify the distribution of forces. The use of adjustable mass dampers significantly reduces the acceleration responses of classes, which increases with the non-linear hardness of adjustable mass dampers. The use of adjustable mass dampers increases the ductility of the structure. Also, the use of adjustable mass dampers reduces the sections in the structure by reducing the displacement of the floors. The use of adjustable mass dampers improves the vibrational performance of the structure and also improves the seismic performance of the structure by the stiffness of the damper.

INTRODUCTION

One of the new ideas for dealing with wind or earthquake stimuli is the idea of controlling structures. One of the most practical and effective methods of controlling the forces applied and increasing the resulting energy loss is the use of dampers in the reinforcement of structures. Spatial and geographical distance of the structure, its distance from the fault or the center of the earthquake and other influencing factors are selected. A tuned mass attenuator is a passive energy absorption device. This device includes a mass, a spring and a viscous damper. This damper is usually installed on the upper floor of the structure and improves its response by changing the dynamic behavior of the structure. In this paper, the effect of using tuned mass dampers in improving the response of structures has been investigated (Bayani, 2018).

The main purpose of using the separation system is based on reducing the horizontal movement of the earthquake entering the structure, which can provide a good performance for the protection and safety of the structure in combination with the tuned mass damping system. The practical implementation of a mass attenuator set in a building isolated from the foundation obviously includes additional considerations, such as space limitation for relocating the mass attenuator and the cost of construction, and so on. Therefore, another goal of this study is the optimal design of dampers and evaluation of the performance of structures with and without soil-structure interaction and identification of classes in need of dampers. Nowadays, regardless of the design of structures, the need to use advanced technologies due to economic considerations, the need to reduce the execution time of reinforcement projects and improve the performance of various structures at the level of selected risk and its easy implementation in cases where there is limited implementation. Or the need for continuous use of the structure is more felt. Therefore, due to this fact, the main idea of this study was formed to answer the question of what will be the performance of these dampers in the event of earthquake stimulation (Nav, 2017).

During the life of structures, various forces are applied to the structure, one of the most important of which is the force caused by the movement of the structure or earthquake. In the design of structures, various goals are considered, such as increasing the safety of the structure, reducing costs and increasing the speed of construction, increasing the efficiency of the structure, and so on. One of the most important goals is to eliminate possible casualties during and after the earthquake. Today, in addition to this main goal, reducing damage and financial damage to the structure and reducing the cost of repair or reconstruction after the earthquake is an important goal. Various methods have been developed over the past decades to achieve these goals. Reducing the forces on the structure by using base separators and damping the seismic force in limited parts of the structure known as dampers has been very popular in recent decades. Due to this issue, different types of base separators and dampers have been proposed and tested by different researchers. The proposed dampers and separators have a great variety and each of these tools and the method of using it have their own advantages and disadvantages. In general, the use of dampers and separators and other tools that are used to reduce and deplete the seismic force are known as vibration control system in the structure (Darabi, 2018).

At all times, modern control systems have been installed in earthquake-prone structures. Some of them are passive control systems that reduce seismic vibrations without the need for any external energy source and only by using the movement of the structure. In these control methods, with the onset of excitation (eg earthquake), the control system is activated and performs its control function (whether change in hardness, period, attenuation or mass) during excitation, which is deactivated again after the excitation is over. Be. Such systems are sensitive to the frequency and amplitude of the input stimulation of the structure due to the stability of dynamic properties such as stiffness, damping, mass (and therefore natural frequency) and may reduce their efficiency for excitations such as earthquakes that accurately vibrate the input. Unpredictable, be. A mass damper (TMD) with a Tuned Mass Damper is an example of inactive dampers. This damper is installed on the floor of one or more floors of the building. Therefore, it can be used as a tool for retrofitting (Moradi, 2018)

Literature review:

Types of energy dampers

The basis of dampers in the structure is based on the energy dissipation, flowing metal dampers by concentrating the damage in themselves, keep other structural components in the elastic range and reduce the dynamic response of the structure. They are also suitable tools for improving buildings and retrofitting, and with low cost and high execution speed, improve the seismic behavior of the structure (Arzaghi, 2005).

The type of dampers and its capacity are selected according to the conditions and type of structure. The purpose of using dampers is to add elements to the structure to control the input energy and thus reduce the force applied to the structure, the amplitude of vibrations and displacements. There are different types of dampers, the most important of which are:

- A mass attenuator that is of two types: transitional and pendulum
- Viscous fluid damper (viscous)
- Friction damper, which is also of 2 types: pulse and rotary
- Metal damper (surrenders)
- Alloy dampers (SMA)

A criminal extinguisher

An active mass damping system (TMD) is a device consisting of a mass, a spring and a damper that is attached to it to reduce the dynamic response of the structure and begins to vibrate under the side movements of the structure to limit the movement of the structure. The damping frequency is tuned so that it is in phase opposite to the vibrational frequency of the structure. The vibrational energy of the structure is also lost by the damping inertial force applied to the structure. In this method, only by adding 2% to the initial mass of the structure, an effective damping of 10% can be achieved. Of course, the negative aspect is the relatively large motion of the damping mass, which is 10 times the displacement of the original mass, and must be considered in the design. These types of dampers are in fact a system of one degree of freedom, which includes internal mass, internal spring and internal dampers and are installed in the upper floors of the structure. The mentioned object has a horizontal displacement without rotation, the model of this type of damper and also a schematic view of its performance can be seen in the following figure. (Arzaghi, 2005)

Tuned mass attenuator is one of the inactive means of energy dissipation. This device reduces the demand for energy consumption in the main structure by absorbing some of the energy input from the dynamic load to the structure.

Because the natural frequencies of these systems are equal to or close to the frequencies of the structures, they are called tuned systems. In this seismic damper, the structure and the damper play the role of a two-part system. The damper mass is placed on the structure, but the damper can move freely in the horizontal direction by rollers. During an earthquake, a new force is applied to the system by the damper to quench the earthquake energy. An tuned mass attenuator is a device consisting of a mass, a spring, and an attenuator attached to a structure that also aims to reduce the dynamic response of the structure. The frequency of the attenuator is set to a frequency of specific structures so that when this frequency is activated, the attenuator moves with a fuzzy difference with respect to the movement of the structure. At that time, the use of tuned mass dampers was limited to the dynamic absorbers of mechanical systems. But later their use in structures was considered (Kenarangi, 2009).

Importance and Behavioral Characteristics of a Regulated Mass Damper (TMD)

By studying the behavior of the structure, it is observed that the damping ratio of the controlled structure is affected by the TMD adjustment ratio controlled by the seismic damping system.

1) In far-field earthquakes, increasing the number of dampers is better because due to the uncertainty in earthquake prediction and also the dynamic characteristics of the structure such as natural frequencies.

2) Depreciation of different vibration modes, it is more useful to use more dampers so that these dampers have vibrations with little difference to each other to cover a wider range of frequencies, which is called MTMD.

3) By increasing the damping mass ratio in all earthquakes, both far and near, it reduces the acceleration of the floors.

4) Tuned mass dampers have a wide range of applications in reducing the seismic response of high-rise structures to the effects of wind and earthquake due to the need for no special maintenance, no need for external energy source and permanent usability.

5) By increasing the number of structural floors, the effectiveness of the TMD system increases and further reduces the displacement of the maximum floors.

6) The efficiency of TMD in structures with bracing or dual system is much better than single bending frame (Kanarangi, 2009).

Displacement Mass Transfer (Transfer)

In these dampers, the mass is placed on roller bearings, which allow the mass to move transversely to the floor. The springs and dampers are also placed between the mass and the vertical fixed supports and transfer the lateral force in the opposite phase to the floor surface and then to the level of the floor and frame of the structure. Two-way transfer dampers are also made in the form of springs-dampers in two vertical directions and provide the possibility of controlling the movement of the structure in two vertical planes. The following figure shows the general structure of a unidirectionally tuned mass transfer damper (Nasiri, 2018).

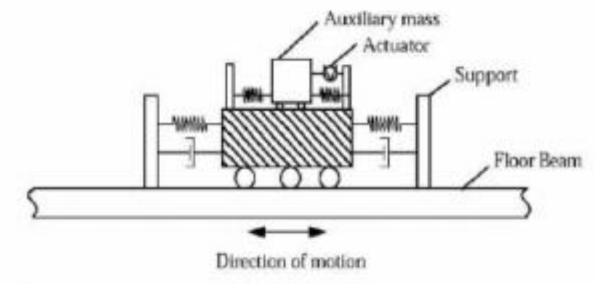


Figure 1: General structure of unidirectionally tuned mass-suppressed mass damper

Pendulum tuned mass damper

The use of rollers, as well as problems and issues related to them, made designers think about correcting this idea and not being dependent on it.

This problem can be solved with the help of mass cable amplifiers, which allow the system to behave similar to a pendulum, and its model can be seen in the figure below. Of course, in practice, these types of dampers have serious limitations. Because the period depends on L, the length required for a large Td may be greater than the floor height. For example, the length required for a 5-second period is 2.6 meters. To solve this problem, I use a rigid internal connection so that the effective length of the pendulum increases to 2L.

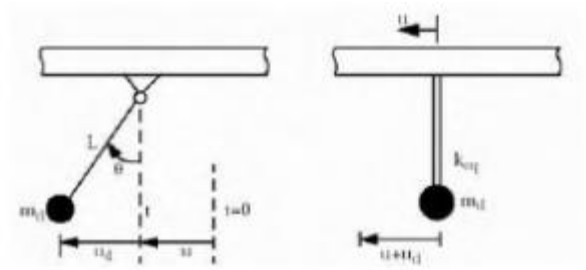


Figure 2: Pendulum tuned mass damper

conclusion of dampers

Dampers reduce the energy input to the structure by 2 to 5 times and the displacement by 2 to 3 times. In other words, due to the absorption of input energy into the structure, dampers reduce the force of structural members and deform and change the distribution of force in the structure, so this method can be used as a suitable option to modify the distribution of forces. It is noteworthy that the dampers and all its connections are designed for 130% of the displacement caused by the MCE earthquake (an earthquake that occurs with a probability of 2% in fifty years (Nasiri, 2018).

1) Adding damping fluid to a structure can also increase the depreciation property of the structure to something more than 30% of its final and critical limit, which in some cases has been more than this amount. As a result, this action significantly reduces seismic movements. Increasing the damping fluid to a structure reduces the horizontal acceleration of the floor and changes the lateral shapes by up to 50% and sometimes more. In general, mass dampers and dampers containing damping fluid have the ability to absorb the energy of lateral forces and the performance of structures reinforced in this way, against several large earthquakes, has been evaluated as appropriate and satisfactory. Using dampers is a better and less expensive alternative to other methods in this field. Of course, it should also be taken into account that dampers are easier to install in the structure and its efficiency is higher. Also, this system can be used in both new and new structures and in built and old structures (Lin et al., 2014)

The relationship between attenuation and time

Typical earthquakes often have time intervals in the range of 0.10 to 1 second. Structures with a rotation time of 0 to 1 second are more vulnerable to these earthquakes, as they may be subject to resonance. The most important feature of seismic separation is the creation of flexibility that increases the natural rotation time of the structure. Increasing the natural periodicity reduces the probability of occurrence of the resonance phenomenon, and also reduces the acceleration in the structure, and this also affects the horizontal displacements. In strong earthquakes it can reach about one meter, and damping can increase this amount to about 50 to 400 millimeters. This amount of displacement must be provided by the seismic joint. The actual responses of the structure depend on various factors such as mass distribution, seismic separation parameters and ((Daker, 2017).

Analysis and evaluation of reinforcement methods of concrete and steel buildings

Concrete structures as a large part of structures, if designed and executed according to accurate calculations and ductility relationships, will be very desirable buildings, but the quality of construction in some structures is very poor for various reasons.

Poor quality of concrete, improper reinforcement, poor execution of concreting, substandard materials, design errors, execution errors, increase in structural load, the impact of destructive environmental conditions and earthquake risk in most parts of Iran are among the factors that weaken concrete structures and the need They strengthen the building.

Many existing reinforced concrete structures, designed and implemented in accordance with pre-1970 regulations, have poor reinforcement details that cause problems such as low lateral displacement capacity, low energy desirability, deterioration of the mechanism and the occurrence of unreacted mechanisms in the mechanism. All of these cases lead to the collapse and destruction of the structure. Deformable details in a reinforced concrete structure in the form of such things as poor shear strength of the joint due to lack of transverse reinforcement in the joint, low shear capacity of the column leading to the joint, short overlap length of the column longitudinal reinforcement, non-observance of compression fitting Beam reinforcements are present in the connection area. Weakness in the area of joining the beam to the column together with the undesirable factor of the weak column-strong beam endangers the stability of the structure. The occurrence of the mechanism in the beam is preferable in comparison with the column and the column mechanism is more non-critical in comparison with the connection area. The emergence of the mechanism and the formation of the joint in the area of joining the beam to the column, has led to increasing periods in the beam and column, which causes a loss of bearing capacity of the column and affects the safety of the structure (kaner, 2016).

In order to study the reinforcement of concrete structures, it is undoubtedly important and unavoidable to identify different types of damage in concrete buildings. Therefore, the different types of weaknesses of concrete structures are as follows:

- Creating diagonal cracks in the concrete core

- Laminating of the central core of concrete in most oblique reciprocating cracks caused by earthquakes

- Detachment of concrete cover

- Tightening the straits and straits and leaving their places

- Shear failure of short elements or members that are connected to the surrounding and their effective free length is short.

- Buckling phenomenon in longitudinal reinforcements

- Reinforcement coming out of the initial areas and going to areas of high intermittent stress

- Rupture of reinforced concrete slabs on non-continuous sides

- Diagonal cracks in the shear wall, especially concentrated around the openings

- Creating shear cracks at the joints and the junction of the column beam

Concrete is a building material with relatively good compressive strength and low tensile strength, and if a concrete member without a reinforcement is considered, a crack is created by applying a load to the member, and this cracking proceeds to the final destruction of the member (concrete rupture only Face is brittle and sudden). In reinforced concrete, this problem is solved by using tensile reinforcement reinforcements. This is one of the weaknesses of reinforced concrete structures and its complexity in strengthening, repairing and strengthening it. Evaluation and selection of existing repair materials is a difficult step in concrete repair and reconstruction of concrete. The need for countless new repair and reinforcement materials in recent years, has led to the development of various methods of strengthening concrete structures (Rames, 2017)

Explanation of building retrofitting

The growing and growing need of the society for buildings and housing and the necessity of using new methods and materials in order to increase the speed of construction, lightening, increase the useful life and also make buildings and structures of concrete and steel earthquake resistant. This has led to a large number of reinforcement companies today working on seismic improvement of structures and strengthening structures against earthquakes.

The purpose of seismic improvement and strengthening of buildings is to improve the performance of structural components. Reinforcement is a set of measures that create the ability to perform a task or tasks in the structure that the structure was not able to perform completely before the reinforcement.

Building reinforcement in civil engineering means to increase the resistance of a structure against the forces. Today, the term is more commonly used to describe seismic force. From a scientific point of view, the term reinforcement is not entirely appropriate for this purpose. Because the term "resistance building" definitely does not mean to increase the resistance to earthquakes, but to improve the performance of components against earthquakes. For this reason, the term "improvement" and in a special case for seismic force, "seismic improvement" is a more accurate term (David, 2017).

The continuous movement of science in the field of structural engineering and earthquake engineering has led to the use of new methods and new materials for the improvement and strengthening of buildings and structures in recent years, including FRP (polymer composite materials) reinforced with (Fiber) has a special place to the extent that according to some experts, FRP should be called the material of the third millennium, which has opened a new way for structural engineers as well as reinforcement companies (Strongtie). Compared to building a new structure, reinforcing an existing structure can be even more complex because the structural conditions have already been proven, and it is not always easy to access areas that need structural reinforcement.

Traditional methods used as building reinforcement techniques against earthquakes and dead and live loads, such as various types of reinforced coatings such as steel and concrete jackets, shotcrete, post-tensioning cables outside the structure and the use of plates and Steel sheets attached to the structure usually require a lot of space and are often vulnerable to environmental conditions.

To strengthen the buildings that are going to change their use or its structural floors are to be increased; It should be noted that the live loads, the coefficient of importance of the building as well as the level of performance of the building change, so there is a need to redesign the structure and determine its level of performance by the retrofitting company (Rames, 2017)

Also, strengthening buildings whose structural members, such as beams, columns and roofs, have been corroded and decayed; Or buildings that are observed due to structural weakness, cracks in concrete structures or cracks and distortion and crushing in the elements and welding of steel structures can be reinforced with the reinforcement methods provided by the reinforcement company.

Buildings that have structural weaknesses during construction, such as poor quality and execution of concreting, inaccurate installation of reinforcement in structural components in concrete buildings, low strength of concrete and the use of substandard materials in concrete structures Reinforcement and lack of inappropriate and unacceptable welding in steel structures can also be reinforced by various methods (Bayani, 2018).

METHODS AND STRATEGIES FOR RETROFITTING

Reinforcement using classical methods

Traditional methods of strengthening and improving steel structures and reinforced concrete can include external reinforcement of a structural member with ordinary or prestressed steel, increasing the cross section of the concrete member by spraying concrete and shotcrete, and connecting prefabricated parts and gluing steel sheets.

Increase the dimensions of beams, columns and foundations (concrete or metal jacket)

One of the basic ideas and techniques of improving and strengthening concrete structures and strengthening structures has been to split the concrete cover of the structural member and put additional steel reinforcements in the element and then cover that part with high-strength adhesives and resins. This idea, while improving the capacity of the structure somewhat, still leaves the problem of corrosion of steel reinforcements unanswered; Another technique used to reinforce concrete structures is the use of steel sheets or the steel jacket technique in which steel sheets are glued to concrete components from the outside. The method of connecting steel sheets is a simple and economical method; But it is problematic in the following ways: (Jayson, 2015)

High weight of steel sheets and manufacturing problems of these components

Hard access to components and need for scaffolding

Weakness in the adhesion between steel and concrete due to corrosion of steel

Having a longitudinal limit in the transfer of steel sheets to the workshop due to the fact that in reinforcement projects of concrete structures, beam lengths are generally long.

Another traditional method of reinforcing concrete structures is the use of concrete jackets or reinforced concrete coatings. The use of this method increases the hardness and ductility and in general strengthens concrete structures; One of the weaknesses of this method is the increase in the dimensions of the sections and the dead load of the concrete structure. The use of this method also requires the evacuation of the building and a lot of destruction of the concrete structure and causes an undesirable increase in the stiffness of the concrete members.

Stretching or pre-tensioning

Retraction or prestressing technique is one of the traditional reinforcement methods used to prestress reinforced concrete structures. The tensile action immediately increases the active load-bearing capacity of the member and strengthens the present structure.

Shear wall

In recent years, steel shear walls have been frequently used as a lateral load-resistant system in the design and reinforcement of structures. Low construction cost, fast installation, high energy absorption potential and steel shear wall make it a very suitable system for strengthening existing structures and this system is currently widely used in building reinforcement in countries such as USA, Japan and Canada. Has found. Steel shear wall can be easily added to existing metal frames, but seismic reinforcement of concrete frames by steel shear wall is in its early stages of development.

Comparing the behavior of concrete frames with and without steel shear wall, it has been determined that the effect of concrete compressive strength parameter on the capacity of concrete frames with steel sheet shear wall is more, which can be attributed to the effect of steel sheet on boundary elements.

Windbreak

Adding steel bracing to strengthen the concrete structure will increase the stiffness, reduce the need for ductility and increase the shear strength of the system. Generally, the use of divergent bracing systems (EBF) in the reinforcement and reinforcement of concrete buildings is not common due to its high cost and problems in the implementation and provision of beam details, but a variety of convergent bracing systems can be used in this type of structural improvement and reinforcement. Of concrete and steel (Jayson, 2015)

Investigation of some different parts of the building that can be reinforced using the new FRP method:

Concrete beams

Reinforcement of concrete beams with FRP materials and fibers reach 3 times the tensile strength of steel in 3-4 days, therefore, due to the fact that FRP fibers have a very high tensile strength compared to steel sheets, FRP connection to the tensile zone Concrete in concrete beams will increase the bending capacity of the section.

Numerous factors such as the cross-sectional dimensions of the concrete beam, the area and mechanical characteristics of the existing reinforcements and FRP reinforcements used, as well as the strength of the existing concrete, are involved in increasing the flexural strength of concrete structures using FRP systems. In the technical literature, this increase in resistance has been reported from 10 to 160 percent (Jack, 2016)

Advantages of FRP concrete beam reinforcement method

-Increase the flexural strength of the beam

- Increased shear strength of the beam

- Increase the ductility of the beam

- Increase corrosion resistance

- Increase durability and life

-Crack width control

-Low thickness of FRP sheets and no significant change in beam dimensions

- Ease of implementation

-Low cost compared to other conventional methods

-Corrosion repair

Steel arrow

In steel structures, the beams are responsible for bearing the loads coming from the floor of the structure and transferring them to the columns. If the steel beam does not have sufficient bending capacity to withstand loads for any reason, it needs to be reinforced.

Like reinforcing concrete beams, steel beams can be reinforced by attaching FRP to the part of the section to be stretched. Thus, by strengthening the lower wing of the steel beam, the two joint ends can be strengthened according to the figure below. Also, for beam beams or beams used in multi-span frames, it is possible to strengthen the lower wing by FRP in the middle of the length of the limb and also the upper wing in the areas near the abutment (Mivan, 2017).

Advantages of FRP steel beam reinforcement method

Minimize performance problems due to the very low weight of FRP fibers

• High flexibility of FRP fibers

• Increase the bending capacity of steel beams

• Delay the local buckling of the beam wing

• Low thickness of FRP sheets and no significant change in beam dimensions

• Low cost compared to other conventional methods

Concrete columns

When the column is subjected to seismic loads, the issue of energy absorption capacity and ductility of the column becomes important. The use of FRP fibers, while increasing the shear capacity of the column, changes its breaking mode from shear to flexural mode and increases the ductility significantly increases. As the load on the column increases, the concrete tends to open in a direction perpendicular to the direction of the load. Transverse enclosing of concrete with FRP coating (screwing) by adding layers of glass and carbon fibers increases the final strength of the column up to 2 times, and of course the more important effect of these fibers is to increase the deformation capacity of concrete 5 times.

In this method, the placement of fibers along the perpendicular to the longitudinal axis of the limb in a complete twist, causes passive confinement in the limb. Therefore, FRP is passive until loading and transverse deformation occurs in the existing concrete column and is not stressed and has no effect on member load. Therefore, the implementation and installation of standards and ensuring complete adhesion between concrete and FRP in this method of reinforcement is very important (Jason, 2015).

Advantages and characteristics of reinforcing concrete columns with FRP

 Increase the flexural strength of the column

 Increase the shear strength of the column

 Increase the compressive strength of the column

 Increase corrosion resistance

 Increase durability and life

 Control crack and crack width

Low thickness of FRP sheets and no significant change in beam dimensions

 Ease of implementation

 Low cost compared to other conventional methods

 Increase ductility

Steel column

Columns are components of steel buildings that are subjected to most of the compressive force and are often perpendicular to the ground. Major failures in steel columns include local buckling, general buckling and rupture at the joints and patches.

The use of FRP coating in closed sections is similar to the reinforcement of concrete columns in which the fibers encircle the steel columns and increase their compressive strength. It also increases the ductility of the limbs under a combination of axial and flexural forces (Danes et al., 2016).

Advantages of steel column reinforcement with FRP

 Ability to increase the axial, shear and flexural strength of the column

 Increased ductility and ultimate relative mobility

 Minimal increase in base dimensions among similar methods

 High speed of reinforcement without stopping the operation of the structure

Concrete slab

Reinforcement of concrete slab with FRP is done locally to increase the bearing capacity of the slab, increase the slab resistance to corrosion, lack of compressive strength of concrete, increase flexural strength, shear and.. Slabs are practically responsible for withstanding vertical loads, but because they also have the function of horizontal diaphragm, they must be connected to the strong lateral members of the structure and have sufficient rigidity and strength.

To reinforce concrete slabs with FRP, FRP composite materials can be applied in the form of strips or plates on tensile surfaces to increase flexural strength. One-way slab with simple support can be reinforced by gluing FRP strips or plates on their lower surfaces and in the longitudinal direction. In the two-sided slab, reinforcement should be done with FRP tapes in both directions.

Of course, if the slab has a retaining support, FRP strips should be applied to the upper part of the slab as well. Also, reinforcing and improving the concrete slab with FRP is done in order to increase the shear capacity of the concrete slab punch around the columns, and to strengthen the areas around the openings.

The use of CFRP sheets in the tensile area of the slab joint can delay the formation and rupture of shear cracks by increasing the flexural strength of the slab adjacent to the column and thus improve the two-way shear strength of the joint. In FRP slab reinforcement, due to the low thickness of FRP sheets (about 0.05) inches or 1.3 mm), the sheets can be easily hidden under the floor, and also the reduction of costs and economy of this method makes the advantage. It is compared to other common methods (Derek, 2017)

Advantages and properties of reinforcing concrete slab with FRP

 increasing the flexural strength of one-way slabs

 increasing the flexural strength of double-sided slabs

 Strengthen and increase the shear strength

 Increases stiffness and decreases in service loads

 Increase ductility

. Repair and reinforcement due to corrosion

 Increase corrosion resistance

 Economical compared to conventional methods

 Ease of implementation

Concrete wall

Layers of FRP polymer composite materials made of glass or carbon fibers are an ideal solution for repairing and strengthening concrete walls, unreinforced buildings, bricks and shelters. Among the structural elements that can be reinforced building with the help of FRP polymer composite materials, the following can be mentioned: (Derek, 2017)

Reinforced concrete shear walls

. Reinforced concrete walls

Building walls

Advantages and characteristics of concrete wall reinforcement with FRP

 Increase the flexural and shear strength of walls

Maximum increase in wall thickness by 5 mm

 Lightness and minimal increase in wall weight

 Increase the strength of the entire wall even if it covers a small area

Sealing function

Extremely reduced wall corrosion rate

 Ability to connect properly to all types of walls, including concrete, brick and…

 No need for too much overlap and therefore cheaper method

Concrete fittings

By strengthening and strengthening concrete joints with frp, the bending capacity as well as the shear capacity of the building connection can be increased. Due to the distance, using this method also increases the ductility of the connection. By using frp, its resistance can be increased without increasing the connection dimensions. The use of FRP concrete bond reinforcement is preferable to that of steel cladding, as FRP bond reinforcement does not corrode unlike steel and can withstand the corrosion of similar acids, bases and attacking materials over a wide range of temperatures.

As a result, corrosion protection systems are not required and it is easier to prepare member surfaces before reinforcing the concrete joint with FRP and to maintain them after installation than steel sheet. It should be noted that in the use of FRP, unlike the method of reinforcement with concrete coating, there is no need to increase the dimensions of the connection and high-volume construction operations.

Due to the presence of internal reinforcement at the junction, this type of bracing can only be used if the width of the sheet or FRP strip is small so that it can be placed in the holes created between the two reinforcement's inside the wall. Most conventional methods focus on methods that similarly harness the end of the FRP.

Results and experiments have shown that this type of bracing works well and the holes created should be refilled with epoxy mortar after FRP. Cement mortar is not suitable for filling these holes because cement drop has a negative effect on FRP bracing resistance (Shanner, 2017)

Foundation and pedestal

Extremely unfavorable environmental conditions in mines, refineries, and coastal and marine areas cause corrosion of the reinforcement and cracks in the foundation concrete. In some cases, even improper design that does not include the amount of reinforcing elements should be added to these problems. In all these cases, FRP polymer composite products are the ideal solution for strengthening the foundation and pedestal. The newly introduced PileLaminateTM polymer composite product can solve all these problems in a short time without disrupting operation.

Advantages and features of foundation, pedestal reinforcement using FRP

 Increase the axial and shear strength of the foundation

 Function as a barrier to the penetration of moisture and oxygen into the foundation and pedestal and thus reduce corrosion

 Change the dimensions of the foundation close to zero

 Quick implementation without disrupting operation

The low thickness of FRP fibers makes FRP composite sheets thin (in millimeters) and prevents them from taking up extra space.

The reasonable price of FRP polymer composite materials has led to its high sales in Iran and other countries in recent years.

FR FRP polymer composite materials have low weight and the density of FRP materials and sheets is low.

Tensile strength and high modulus of elasticity of FRP polymer composite materials

 The connection of FRP sheet to different levels of concrete and iron is good and its overlap is not high. Which reduces the price of FRP polymer composite materials (Anton, 2017).

Disadvantages of traditional retrofitting methods

 High cost

Hard to use

 Risk of corrosion and decay in steel sheets

 Inflexibility

 Change in the weight of structural components and thus change the natural frequency of the structural member

 Change the overall stiffness of the structure

 Heavy material problems and installation and transportation of materials

. Researchers are constantly looking for new methods to strengthen concrete and steel buildings against earthquakes and natural disasters, and this science is developing and expanding day by day.

Design, implementation and features of active mass dampers

An active mass attenuator (TM) system is a device consisting of a mass, a spring and an attenuator that is attached to it to reduce the dynamic response of the structure. The frequency of the attenuator is tuned to the frequency of the particular instrument so that when this frequency is excited, the attenuator vibrates in the opposite phase of the movement of the structure. Energy is wasted by the damping inertial force applied to the structure. In this type of dampers, the mass is placed on the roller supports and can move relative to the floor. The springs and dampers are placed between the mass and the fixed supports, the force of the opposite phase of the damper is level with the floor and in the result is transferred to the instrument frame. Usually, this type of mass dampers are used in the upper floors of the structure, and if the structure is subjected to a load, by defining a specific acceleration depending on the damping design, the system automatically starts operating and eliminates the effect of seismic vibration. Takes. Usually the mass of this system is made of concrete, lead with steel and in a square or rectangular shape and in a single set with dimensions of 5 to 10 meters and is installed in the upper floors of the structure. This type of damping system has a large mass, large and costly space allocation and complex mechanism, and in some cases can only be used in one direction. By modifying these cases, a more advanced type of tuned mass dampers was designed. By changing rubber rollers instead of mechanical rollers due to performance in different directions (such as shear springs) and using bituminous rubber materials (BRC) instead of dampers that are easy to install and small in size, the ability of viscoelastic dampers also They have caused a more complete system to be designed and built (Anton, 2017).

In designing mass damping systems for calculations, by determining the mass, hardness and damping coefficient, the most suitable damping system should be designed according to the weight of the whole structure so that the effect of the designed damping system can be understood with a simple ratio. Assuming the frequency of the structure is equal to the optimal value for the damping frequency, this equates the damping period with the dominant period of the structure. The 90-degree mass response is fuzzy different from the initial mass response. This phase difference cause's energy loss by the damping inertia force, increasing the mass ratio leads to an increase in damping, but it should be noted that there is a practical limit to increase the mass, also by reducing the damping coefficient can be damped Added that there is a limit to this parameter as well. The final design is due to the combination of these two values with respect to the application of restrictions. Also, the location of the damper and spring on a fixed support in the structure and the two-way mechanism of the system should be considered.

Early TMDs had a complex mechanism for supports and damping elements, were also relatively heavy, took up considerable space, and were somewhat expensive. Recent versions are designed to minimize these limitations. The design has several stacked elastomeric rubber supports that act as a shear spring and have "bituminous" (BRC) rubber material elements that provide viscoelastic damping capability. The device is small and compact and does not require complex control. It is multi-directional and easily mounted on top of each other and can be easily repaired and repaired (Driss, 2017)

Reasons for assessing the reliability of existing buildings

Assessing the reliability of existing buildings can be done for a number of reasons, including:

1. Use of the structure that requires increasing the load.

2. Concerns about design errors with construction

3. Concerns about the quality of building materials

4. Evaluation of depreciation effects in structures

5. Assessing the damage caused by natural and unforeseen events (such as storms or earthquakes)

6. Concerns about the usability of the structural change structure are probably the main reason for assessing the reliability of existing buildings.

General introduction of reliability method

The category of structural safety can be dealt with in a much more logical way in the form of probabilistic methods. It is quite clear that the main effort in creating safety for structures is to create a suitable platform for its performance during its useful life. In this way, a number of parameters involved in the problem are not fixed and ambiguous in principle and can be an example of the types of values that are possible. This means that these parameters are random variables. As mentioned before, the variable nature of these parameters was not unknown to engineers, but they prescribed the use of safety coefficients to cover the range of changes in these parameters. Reliability analysis of structures claims to perform this function. The purpose of this analysis is to evaluate and quantify structural safety. Because before the details of the above assessment are explained, the category of risk and its acceptable amount for structures will be explored (Anton, 2017).

Risk and its acceptable amount in structures

Risk can be defined as the potential for loss and damage caused by a system failure. Thus, what is effective in this sense is the probability of an event occurring as well as the consequences and consequences of that event. Therefore, risk can be measured as follows:

Consequences of the occurrence of Robes failure It is clear by this definition that a high probability of failure can be acceptable provided that the failure is low and vice versa, the consequences of a high failure should be the lowest probability of failure with a low probability of occurrence. Acceptable risk Communities and governments dictate different combinations of the probability of failure and its consequences in different industries. In the case of structures, although their probability of failure is very low compared to other activities, but because a significant amount of human time is inside the buildings. (About 70 times per person) So the current risk in society for structural damage is about 10 per year (Anton, 2017).

Impact of ductility of building structures on earthquake resistant design

One of the important points during earthquake resistant design of buildings and structures; . This post discusses ductility and its importance in design. To understand the importance of ductility and its effect on building performance, we must first know what ductility is. Ductility is generally defined in materials engineering as the ratio of the final strain to the flow strain of materials.

Ductility should be understood as the ability of a structure to withstand larger deformations without collapsing. An engineer must consider such a factor in the design and make sure that the designed structure can withstand these loads without causing major deformations or collapses. For this purpose, ductility in the building should be considered and increased with it (Zatar, 2017)

Ductility of structural materials

Ductility of bricks one of the most widely used materials for construction are bricks made of clay and cement mortar. In lowland areas, due to the availability of cement mortar ingredients, mud mortar is used. In terms of structural characteristics, these materials have high compressive strength but will have poor tensile performance as shown in the figure below.

Here compression means pressing the two ends of the wall together. Building materials resist this pressure. These materials cannot withstand tensile force.

Ductility of concrete

Concrete is another material that has been widely used in the last four decades. As you know, concrete is made of cement, aggregate and water. Concrete aggregates are composed of fine and coarse aggregates that are mixed with water with good intentions.

Concrete is both strong in pressure and weak in tension. Concrete has a higher compressive strength compared to building materials but has a weak tensile strength.

However, the strength of concrete depends on water ratios and the amount of water, more or less, affects the strength of the concrete mix. Concrete and building materials are brittle and break down suddenly.

Need for ductile reinforcement for building structures

If we want the structure to remain elastic during the largest earthquake expected in the area, we must use ductile reinforcement; But increasing the elasticity is not a cost-effective method of construction.

To save money and ensure safety in structures that experience unforeseen earthquakes, the best way is to allow the structure to suffer damage in the form of plasticity, failure, crushing, etc., but its resistance to maintain the vertical load due to deformation during an earthquake. For example, consider columns that need to be designed to be malleable. For this purpose, concrete can be limited with reinforcing reinforcement and buckling of longitudinal reinforcement can be prevented. This helps the column to withstand vertical loads even after cracking, crushing of concrete or flow of reinforcing reinforcement; bear. In this method, the amount of stiffness in the structure and related components is reduced. If the structure remains elastic, there will be larger internal forces and more total shear base.

The total base shear can be defined as the sum of the internal shear forces in all members of a vertical load-bearing structure; So ductility in materials means that the structure will be damaged, but we will have less internal forces. This is a dynamic response.

Modification coefficient or ductility coefficient is also present in building codes all over the world. The ductility coefficient depends on the peripheral system. For systems that have to withstand larger deformations without collapsing, the ductility coefficient will also be higher. Therefore, for a structural system that must withstand small deformations before collapsing, we will have a lower ductility coefficient (Zetr, 2017).

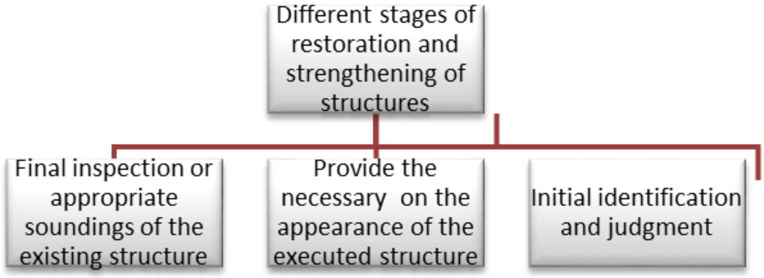


Figure 3: chart diving the steps of repairing and strengthening the structure

First stage: initial identification and judgment:

In the first stage, the history and specifications of the project, such as the geotechnical report of the soil, the technical specifications map, how to transfer the lateral load of the structure, calculation book, etc. are prepared.

Step 2: Prepare the necessary information about the appearance of the executed structure:

- Frequent visits to the structure

- Measurement of structural members (strength of reinforcements, concrete, etc.)

- Checking the quality of execution of beams and columns, shear wall, roof system, concrete cover on reinforcements, cutting and joining reinforcements.

Step 3: Final review in restoration:

The main factors in strengthening the structures are economic and executive and the speed of project implementation.

When it is concluded that all structural elements are weak, there are several solutions, such as:

Lateral load system change (assistance from bracing or shear wall)

Increased cross section and concrete

Planting reinforcement in weak areas

Use of PRF reinforced fibers (carbon, glass ...) and ...

By using a shear wall or brace, the concentration of tension is created in these points and other points are relieved of stress, and certainly the previous elements in these places will not be responsive.

If it is not possible to use a shear wall or bracing inside the structure (plan), special boxes can be used outside the plan of the structure, but proper structural connections must be provided at this point.

High torsion of the structure due to the mismatch between the center of gravity and the center of mass

 Lack of proper operation of the discontinuous seam

 Columns are not in the same direction and they are not busy

 Existence of large panels and the need to strengthen the beams

 Lack of columns at the junction of beams due to the long length of the main beams and the impossibility of placing the side beam on it

 Need to strengthen the columns around the beams

MODELING

So far, various methods have been used to analyze structures that are affected by various factors such as the effects of earthquakes and wind. With the advancement of knowledge and especially the extensive changes that have taken place in the computing power of computers have led to more sophisticated and accurate methods of analyzing and examining structures, which make it possible to make a more accurate assessment of performance. We have structures during earthquakes and other factors. In this section, we will recount the formation and development of these methods of analysis, and a brief explanation is given in relation to each. These methods are: 1- Static analysis 2- Dynamic analysis 3- Nonlinear static analysis ¬4- Nonlinear dynamic analysis (Anmi, 2013)

Linear static method

In this method, by converting the seismic force into static loads, they are equalized and then distributed in the height of the structure, but the disadvantage of this method is that the dynamic effects of the earthquake on the structure can not be observed and the structure behavior does not enter the nonlinear phase. ¬ becomes and remains in the linear range.

Linear dynamic method

This method, like the linear static method, keeps the behavior of the structure and materials in the linear range, but the difference with the static method is that it considers its dynamic properties by applying an earthquake directly to the structure. The problem with this method is that it does not consider the nonlinear behavior of the structure like the linear static method (Farhadi, 2018).

Nonlinear static method

In this method, the behavior of the structure can be nonlinear and the structure is allowed to exhibit nonlinear behavior. In this method, how the seismic load is applied is proportional to the deformation of the structure, which allows the behavior of the structure and the materials used to enter the nonlinear phase. In this method, the shape of the lateral load distribution is important and its value is important in that the behavior of the structure enters the nonlinear range. In this method, because the behavior of the structure is considered statically, so the dynamic properties of the structure are not considered, and as a result, an error occurs in the calculation of nonlinear forces and paste deformations, resulting in a method that can also Incorporating nonlinear effects as well as dynamic properties is a method called nonlinear dynamic analysis, which is introduced in the next section.

Nonlinear dynamic method

In this method, in addition to the nonlinear behavior of the structural members, the dynamic properties of the loads are also considered and the earthquake loads can be applied directly to the structure using the recorded earthquake record itself and the behavior. He also considered materials in the nonlinear range. In the common design of structures, which is currently widely used and considers the nonlinear behavior of structures, the design is based on performance, which can be based on the amount of performance expected by the employer. Did. Due to the many facilities that are provided in the field of nonlinear analysis using computers with high processing power, it is possible to perform these analyzes (Farhadi, 2018).

How to scale records

To measure the seismic intensity, there are various algorithms that must be selected according to the type of structure and characteristics of the earthquake, including their frequency content, time, maximum acceleration and other factors to select the number of times for each record. Optimized the scale done and in addition achieved sufficient accuracy and speed to the end of scaling, which is to reach the level of dynamic instability of the structure. In this study, due to the high accuracy of the analysis, many steps have been used to scale each record. According to the regulations, 2800 pairs of selected accelerometers must be scaled in the following way: (Anmi, 2013)

A. Each accelerometer pair should be scaled to its maximum value. This means that the maximum acceleration in the component with the largest maximum is equal to the acceleration of gravity g (use a scale coefficient for both components of an accelerometer pair)

B- The acceleration response spectrum of each of the scaled accelerations is determined by considering the damping ratio of 5%.

C- The response spectra of each acceleration mapping pair are combined using the square root of the squares method to form a single composite spectrum for each pair. Each accelerometer pair should be scaled so that for each period in the range of 0.2 to 1.5 T1, the average value of the SRSS spectrum for all component pairs is not less than 10% of 1.3 times the corresponding value of the standard design spectrum.

Earthquake acceleration maps:

To perform nonlinear dynamic analysis of time history, seven accelerometers with different frequency content, duration and dominant periods have been used. According to Code 2800, accelerometers used in the dynamic analysis of time history must have at least three accelerometers belonging to earthquakes that meet the seismic conditions of the project and in terms of geological characteristics and In particular, the characteristics of the soil layers should be as similar as possible to the ground of the building, and also the duration of intense ground movement in accelerometers should be at least 10 seconds or three times the main rotation time of the structure, whichever is longer. In this dissertation, earthquakes: Mangil, Kobe, Elcentro, Tabas, Loma, Northridge, Superstition¬Hills have been used (Opera, 2017).

Modeling and design process:

The structures used in this dissertation are two-dimensional with a medium steel bending frame system, which includes a 10-story structure with 5 openings of 5 meters in the x direction. Each of these structures is modeled with a 15% mass ratio of adjustable mass damper with linear and nonlinear stiffness. The height of all floors is 3 meters. All design criteria related to this type of system have been observed according to the 2800 standard of the fourth edition. In calculating the mass of the floors, the dead load is DL = 600kg / m ^ 2, LL = 200kg / m ^ 2, each multiplied by the load level, which is equal to 5 meters. All systems are designed in accordance with the sixth topic, loads on the building, edition 2013, 2800 loading regulations, version 4, American steel regulations, AISC360-10, and topic 10 of the national building regulations, 2013 edition, by LRFD method. In the design of structures, the soil of the construction site, type 3 soil, high risk area and the type of residential use with a moderate degree of importance are considered (Opera, 2017).

Adjustable mass damper modeling process:

Tuned mass attenuator is one of the inactive means of energy dissipation. This device reduces the demand for energy consumption in the main structure by absorbing some of the energy input from the dynamic load to the structure.

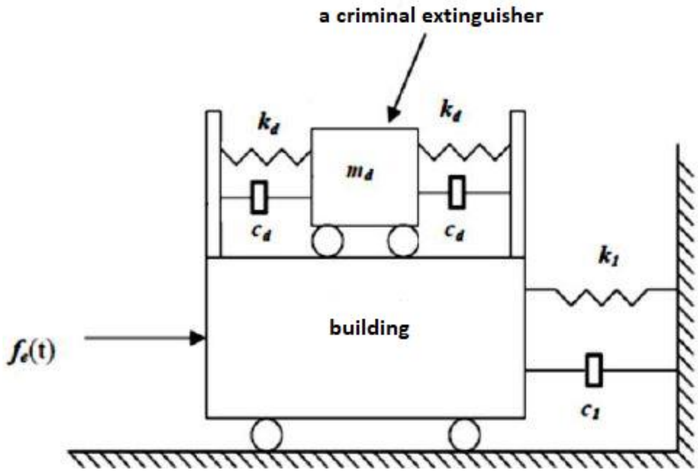


Figure 4 : A simple schematic representation of how a mass damper works

Design, implementation and features

An active mass attenuator (TMD) system is a device consisting of a mass, a spring, and an attenuator attached to it to reduce the dynamic response of the structure. The frequency of the attenuator is tuned to the frequency of the particular instrument so that when this frequency is excited, the attenuator vibrates in the opposite phase of the (opposite) motion of the structure. The energy is lost by the inertial force of the attenuator applied to the structure.

In this type of dampers, the mass is placed on the roller supports and can move relative to the floor. .

Usually, this type of mass dampers are used in the upper floors of the structure, and if the structure is subjected to loads, by defining a specific acceleration depending on the damper design, the system automatically starts operating and eliminates the vibration effect of seismic force. . Usually the mass of this system is made of concrete, lead or steel and is made in a square or rectangular shape and in a single or set with dimensions of 5 to 10 meters and is installed on the upper floors of the structure.

In designing a mass damping system for calculations, by determining the mass, stiffness and damping coefficient, a more suitable damping system should be designed according to the total weight of the structure so that the effect of the designed damping system can be understood with a simple ratio. Assuming the frequency of the structure is close to the optimal value for the damping frequency, this equates the damping period with the dominant period of the structure. The 90 degree tuned mass response is phase different from the initial mass response. This phase difference causes energy loss by the damping inertial force. Increasing the mass ratio increases the attenuation, but it should be noted that there is a practical limit to increase the mass, also by reducing the attenuation coefficient can increase the attenuation that there is a limit for this parameter. The final design is done according to the combination of these two values according to the restrictions. Also, the location of the damper and spring in the fixed support in the structure and the two-way mechanism of the system should be considered (Faran, 2016)

Adjustable mass damper modeling:

For the design of adjustable mass dampers in the structural model, one of the main parameters is the damping mass. Usually, the damping mass is expressed as a percentage of the total mass of the structure:

$$m_d = \mu \times m_s$$

In which the mass, frequency and mass ratio of the whole structure for the present project is 854.75 tons.

The mass ratio varies from 1 to 20%, and the total stiffness of the adjustable mass damping system is obtained from the following equation.

$$k_d = 4\pi^2 \mu f^{\,2} \frac{m_s}{T_s^{\,2}}$$

At that time, the main frequency of the first mode of the structure is 1.663 seconds for the present project and the frequency ratio is TMD. The ratio of the damper frequency to the adjustable mode frequency varies between 0.9 to 1, which in the present project is 0.98 for all models.

The damping coefficient of the whole adjustable mass damping system is obtained from the following equation, which has been proposed by Zahraei and Confectionery for the damping coefficient:

$$c_d = 4\pi \mu f \xi \frac{m_s}{T_s}$$

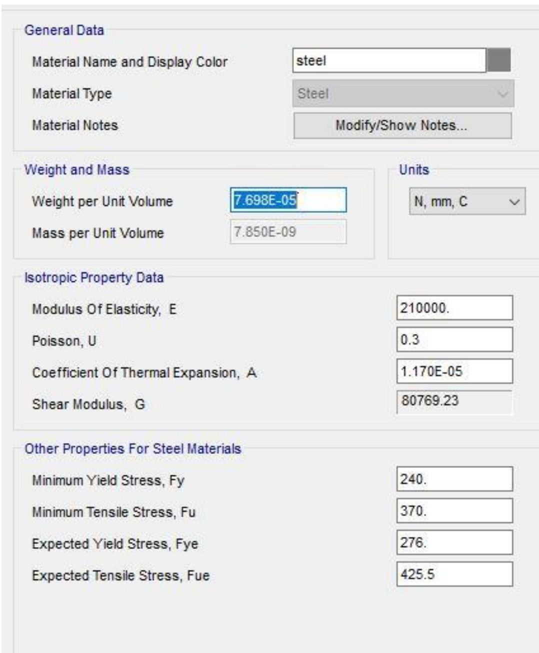
Where the damping ratio is TMD. Most of the validation results indicate that the most suitable damping ratio is between 20 to 30%, which in the present project we consider 30%. The link element is used to model the adjustable mass damper, and due to the action of the spring and damper, the link element is of the Linear type. The linear link is connected to a centralized and transferred mass on one side and to the structure on the other side.

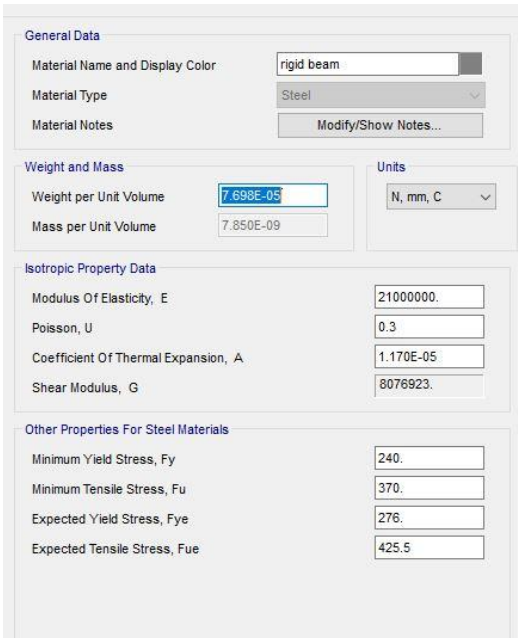
Specifications of adjustable mass dampers

$c_d\ (\frac{kg}{s})$	$K_d\ (\frac{kg}{s^2})$	μ (٪)	**mper placement pos**
285352	1764111.75	15	**floor**

Material specifications:

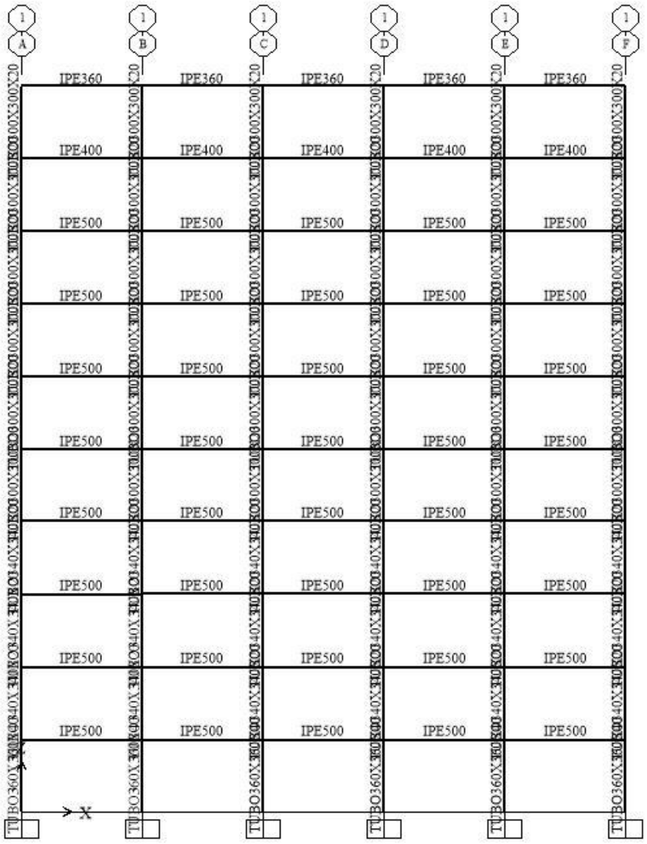
Material specifications	
Poisson's ratio	0.3
Modulus of elasticity	F_y =210000 *Mpa*
Modulus of elasticity of rigid beam	F_y =21000000 *Mpa*
Minimum yield stress of steel	F_y =2400 *Mpa*
Minimum tensile strength of steel	$F_u = 370\text{Mpa}$
Effective yield stress (expected)	$F_{ye} = 1.15\, F_y = 1.15 \times 2400 = 276 Mpa$
Effective tensile strength (expected)	$F_{ue} = 1.15 \times 370 = 425.5\text{Mpa}$



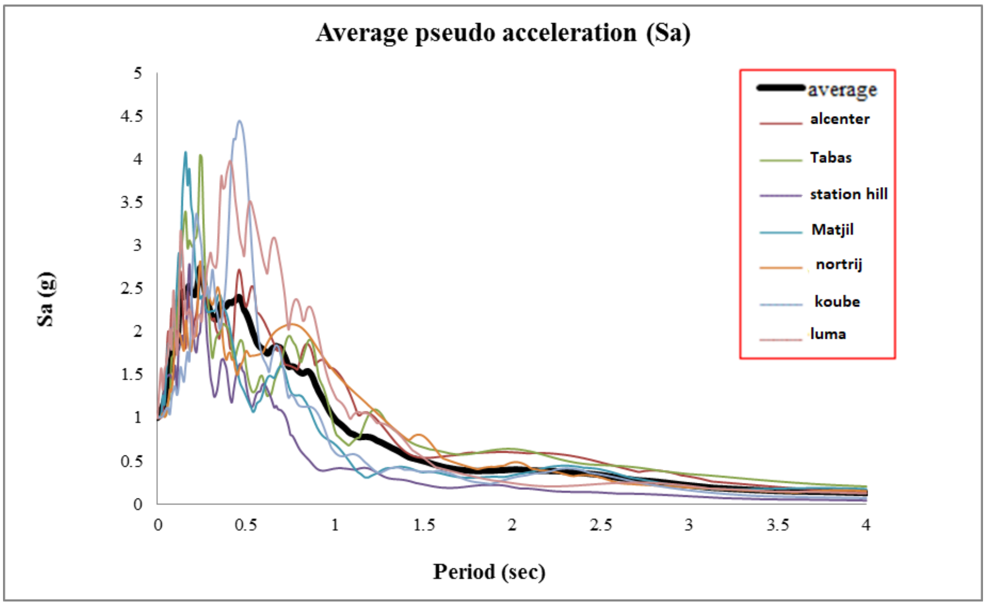


beam	**Cross section**	**column**	**Cross section**
$IPE\,50$	1st to 8th floor	$BOX\ 36 \times 4$	**1st floor**
$IPE\,40$	floor 9	$BOX\ 34 \times 4$	**Floor2-4**
$IPE\,36$	floor 10	$BOX\ 30 \times 2$	**Floor5-10**

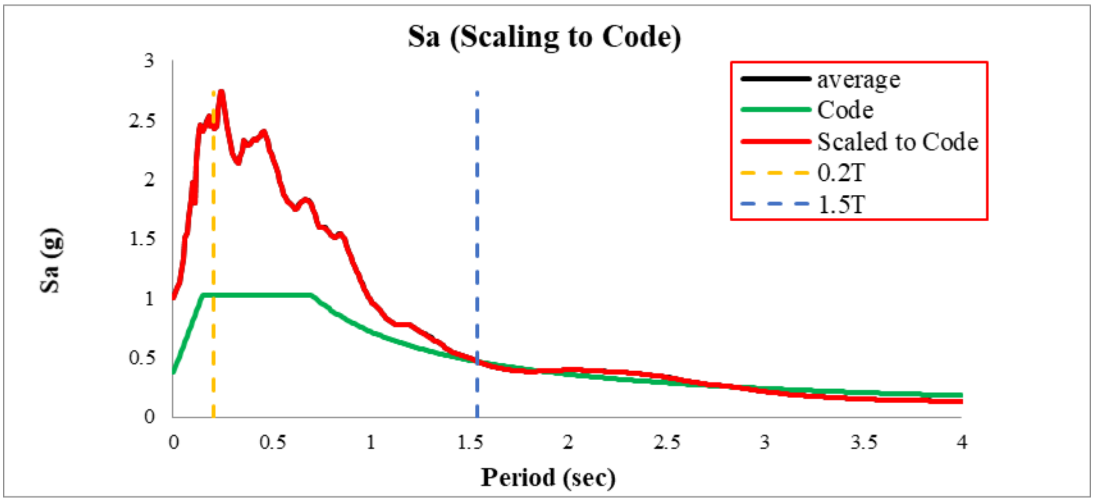
Sections



Average seven acceleration maps:



Calculation of scaling factor:

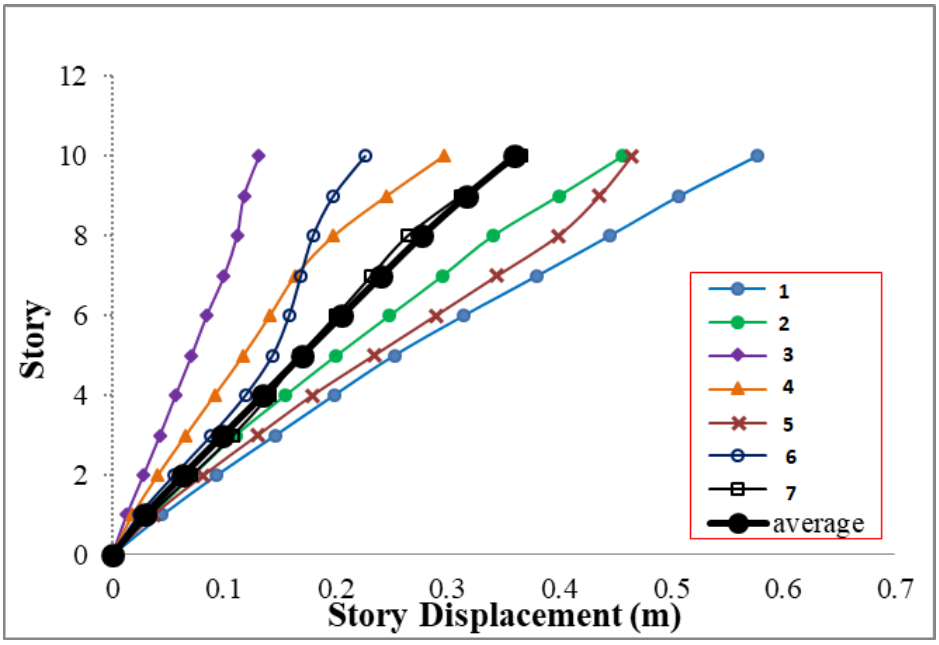


T	0.2T	1.5T	Scaled Factor
1.030	0.206	1.545	0.999

Displacement diagram of the floors of a ten-story structure equipped with an adjustable mass damper with linear stiffness:

Story Displacement (m)								
	R1	R2	R3	R4	R5	R6	R7	Average
Base	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Story01	0.045	0.035	0.013	0.018	0.037	0.024	0.033	0.029
Story02	0.094	0.072	0.028	0.041	0.082	0.055	0.071	0.063
Story03	0.146	0.110	0.043	0.066	0.130	0.089	0.108	0.099
Story04	0.198	0.155	0.057	0.091	0.179	0.119	0.140	0.134
Story05	0.252	0.201	0.071	0.117	0.234	0.143	0.168	0.169
Story06	0.315	0.248	0.085	0.141	0.290	0.158	0.200	0.205
Story07	0.380	0.296	0.100	0.164	0.345	0.169	0.232	0.241
Story08	0.445	0.341	0.112	0.198	0.399	0.180	0.264	0.277
Story09	0.507	0.399	0.118	0.246	0.436	0.198	0.312	0.317
Story10	0.577	0.457	0.131	0.297	0.465	0.226	0.366	0.360

Ten-story structural floor transfer table equipped with adjustable mass damper with linear stiffness

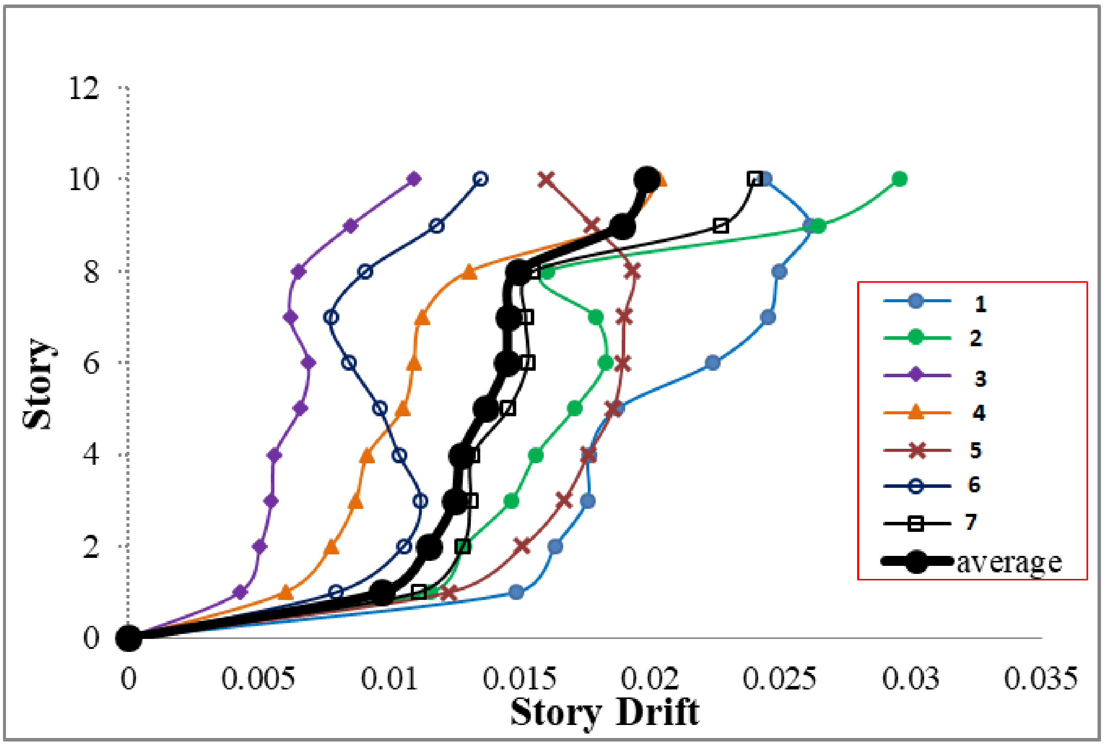


Movement diagram of the floors of a ten-story structure equipped with an adjustable mass damper with linear stiffness

Relative displacement diagram of ten-story structural floors equipped with adjustable mass dampers with linear stiffness

Story Drift								
	R1	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**Average**
Base	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Story01	0.015	0.012	0.004	0.006	0.012	0.008	0.011	0.010
Story02	0.016	0.013	0.005	0.008	0.015	0.011	0.013	0.011
Story03	0.018	0.015	0.005	0.009	0.017	0.011	0.013	0.012
Story04	0.018	0.016	0.006	0.009	0.018	0.010	0.013	0.013
Story05	0.019	0.017	0.007	0.011	0.019	0.010	0.015	0.014
Story06	0.022	0.018	0.007	0.011	0.019	0.008	0.015	0.014
Story07	0.025	0.018	0.006	0.011	0.019	0.008	0.015	0.015
Story08	0.025	0.016	0.007	0.013	0.019	0.009	0.016	0.015
Story09	0.026	0.026	0.009	0.019	0.018	0.012	0.023	0.019
Story10	0.024	0.030	0.011	0.020	0.016	0.013	0.024	0.020

Relative displacement table of ten-story structural floors equipped with adjustable mass dampers with linear stiffness



Relative displacement diagram of ten-story structural floors equipped with adjustable mass dampers with linear stiffness

Acceleration diagram of the floors of a ten-story structure equipped with an adjustable mass damper with linear stiffness

Story Acceleration								
	R1	R2	R3	R4	R5	R6	R7	Average
Base	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Story01	8.608	6.134	6.636	9.201	5.079	4.000	8.733	6.913
Story02	14.386	10.515	10.729	12.759	9.767	7.961	13.174	11.327
Story03	15.936	13.154	13.587	12.696	13.145	11.117	13.695	13.333
Story04	16.694	13.727	14.625	14.409	14.419	12.814	15.095	14.540
Story05	17.444	13.537	14.942	13.221	14.363	14.928	14.119	14.651
Story06	16.804	13.694	14.582	12.437	14.999	15.924	13.079	14.503
Story07	14.119	13.211	13.813	13.201	14.384	15.619	13.452	13.971
Story08	13.132	15.222	12.920	12.960	12.493	15.095	13.277	13.586
Story09	11.478	13.545	11.597	12.244	13.438	13.347	13.235	12.698
Story10	12.801	12.428	9.649	13.219	12.856	13.294	15.336	12.798

Acceleration table of the floors of a ten-story structure equipped with an adjustable mass damper with linear stiffness

RESULTS

The use of adjustable mass dampers significantly reduces the acceleration responses of the classes, which increases with the non-linearity of the hardness of the adjustable mass dampers.

- The use of adjustable mass dampers causes a relative reduction in the displacement responses of classes, which increases with the non-linearity of the hardness of adjustable mass dampers.

- The use of adjustable mass dampers causes the dissipation of energy entering the structure using inertial force, which increases with the non-linearity of the stiffness of adjustable mass dampers.

The use of adjustable mass dampers increases the ductility of the structure.

- The use of adjustable mass dampers reduces the sections in the structure by reducing the displacement of the floors, which with the non-linearity of the damping stiffness, this process reduces further and reduces the cost of construction.

The use of an adjustable mass damper improves the vibration performance of the structure

- Seismic performance of the structure is improved by non-linear damping stiffness.

Offers:

-Comparison of the behavior of steel structures equipped with adjustable mass dampers and fluid

-Evaluation of the behavior of high-rise steel structures equipped with adjustable mass dampers against progressive failure

- Evaluation of the behavior of high-rise concrete structures equipped with adjustable mass dampers against progressive failure

- Comparison of the behavior of steel and concrete structures equipped with adjustable mass dampers.

REFERENCES

Arzaghi, Sh (2005), Evaluation of damping mass performance in controlling seismic behavior of three-dimensional structural models, Master Thesis, Faculty of Civil Engineering, Sharif University of Technology

Bayani, D (2018) Design of steel structures based on Iranian steel regulations. Fifth Edition, Tehran, Iran .., Publishing and Printing Institute, University of Tehran.

International Institute of Seismology and Earthquake Engineering "Guidelines for Seismic Improvement of Existing Buildings (Publication 360)" 2006

Interpretation of Instructions for Seismic Improvement of Existing Buildings (International Institute of Seismology and Earthquake Engineering), Journal No. 2-363 "Practical Guide to Seismic Improvement of Existing Buildings, Concrete Buildings

Darabi, N (2018) Investigation of seismic behavior of a new type of damper-structural separator consisting of a soft first floor frame with elongated columns with frictional rotating joints, Master Thesis, Islamic Azad University, Fars Science and Research Branch

Office for Development and Promotion of National Building Regulations "Ninth Issue of National Building Regulations (Design and Execution of Reinforced Concrete Buildings (2009)" Ministry of Housing and Urban Development

Farhadi, D (2018) Committee. Permanent Review of Building Design Regulations against 2800 Standard Earthquake, Building and Housing Research Center, Third Edition

Konarangi, H. (2009) "Study of the performance of mass dampers tuned in controlling the nonlinear behavior of three-dimensional structural models by considering the effect of soil-structure interaction" Master Thesis, Faculty of Civil Engineering, Sharif University of Technology

Building and Housing Research Center "Building Design Code against Earthquake" Standard 2800 (Fourth Edition) (2015)

Moradi (2017) The effect of liquid viscous dampers in seismic retrofitting of structures, 3rd International Conference on Civil Engineering

Nasiri, M. (2017), "Laboratory studies on a controllable nonlinear viscous damper for isolated base structures in the near field", Master Thesis, Institute of Seismology and Engineering

ACI 318-08 Building Code Requirement for Structural Concrete and Commentary American Concrete Institute, Detroit, 2008

Ahlawat, A.S., (2003), "Multi objective Optimal Absorber for Torsionally Coupled Seismically Excited Structures", Engineering Structures Elsevier ,Vol 25, Issue 7, PP. 941–.95

Anton 2017, "EarthquakeResistance Frames with Combination of Rigid and Semi-Rigid Connections", Journal of Constructional Steel Research,

Aper 2017 Viscous Damper, International Training Programs For Seismic Design Of Building Structure Hosted by National Center For Research on Earthquake Engineering, Sponsored by Department of International Programs National Science Council.

Daker 2016 Pacific Earthquake Engineering Research Center (PEER),Evaluation of Ground Motion Selection and ModificationMethods: Predicting Median Interstory Drift Response of Buildings,

Danso "Performance Based SeismicDesign", Bulletin of the New Zealand Society for EarthquakeEngineering, Vol.

David 2017 Providing a Method to Scale the Accelerograms for Nonlinear Dynamic Analysis and Comparison with Standard 2800 Method, The 4th National Conference on Regulations for Seismic Design of Buildings,

Derek 2017"Characterization of Large Velocity Pulses for Laboratory Testing", Pacific Earthquake Engineering Research Center,

Faran 2016 Passive Energy Dissipation Systems In Structural Engineering. John Wiley & Sons, Press, UK,.

Federal Emergence Management Agency, Prestandard and commentary for the seismic rehabilitation of buildings. Report FEMA-356.Washington (DC); 2005.

Federal Emergence Management Agency. Improvement of nonlinear static seismic analysis procedure. Report FEMA-440. Washington (DC); 2005.

Federal Emergence Management Agency. NEHRP guidelines for the seismic rehabilitation of buildings. Report FEMA-273. Washington (DC); 2008.

Federal Emergency Management Agency, FEMA356 (2008) Prestandard and commentary for the seismic rehabilitation of buildings, building seismic safety council. Washington DC

Jack Intensity of Ground Motion During Strong Earthquakes, Office of Naval Research Report, pp. 1-60, August; http://resolver.caltech.edu/ CaltechEERL:

Jayson (Conditional Mean Spectrum: A Toolfor Ground Motion Selection, Journal of Structural Engineering,

Kane 2017 Structure Specific Scalar IntensityMeasures for Near-source and Ordinary EarthquakeGround Motions, Earthquake Spectra 2007, Vol. 23, No.

Lin, C.C., and Ueng, J.M., (2014), "Seismic Response Reduction of Irregular Building Using Passive Tuned Mass Dampers", Engineering Structures, Elsevier, 513–.524

Mivan2017 "Performance-Based Design in Earthquake Engineering: State of Development", Journal of Engineering structures,

Nav (2017) ''Friction-Dampers Used For Seismic Control Of New And Existing Building in Canada'' , ATC- Proceeding Of A Seminar And Workshop On Base Isolation And Passive Energy Dissipation, Applied Technology Council,

Pinkaew, T., and Lukkunaprasit, P., and Chatupote, P., (2013), "Seismic Effectiveness of Tuned Mass Dampers for Damage Reduction of Structures," Engineering Structures, Vol. 25, N0. 1, PP.46-39

Rames(2017)Structural PerformanceAssessment under Near-source Pulse-like GroundMotions Using Advanced Ground Motion IntensityMeasures, Earthq. Eng. Struct. Dyn..

Shaner(2017) McVerry, G.H."An Introduction to Seismic Isolation", J.Wiley& Sons, London,.

Wang, J.F., (2005), "Seismic Performance of Multiple Tuned Mass Dampers for Soil-Irregular Building Interaction System ", Int. J. Solids and Structures, Vol.42, P.P.5554-5536.