The Significance of the Use of Viscoelastic Dampers in the Seismic Retrofitting

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Abstract: Using the viscoelastic dampers has been considered as one of the seismic retrofitting techniques of the available structures as well as the seismic design of new buildings, for the past two decades. The studies done all indicate that these dampers are effective in reducing the structural response as well as reducing damages to the structures due to the earthquake. In this article, the effect of these dampers on the response of structures and other seismic needs created in them were studied by performing field tests on the steel structure models.

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1. Introduction

Dynamics of structure was shaped in the 19th century, and the earthquake engineering was born at the beginning of the twentieth century. The earthquake is one of the destructive phenomena in the world, which has won the scientists' attention so much that many studies have been done on it so far. One of the main specifications of the earthquake that has separated this phenomenon from other phenomena is the unpredictable nature of it. Although many specialists are studying on it, no positive result has been achieved yet. Of course, through improving the science it is expected to be able to predict the exact time and place of the earthquake in the future.

1.1. The Studies of Earthquake Can Be Divided Into Several Categories

1. The genesis reasons of the earthquake
2. Strategies for dealing with this natural phenomenon

However, due to the extent of these strategies, the dampers, the aim of the present study, are only considered in this article.

2.1. The Aim of This Study

1. To verify the role of dampers against the earthquake
2. To choose the safe, affordable, and executable way

3.1. Summary of the Research Content

1. The structural design with a laboratory scale, manually and through a computerized method
2. Adding the dampers in primary structure of design and in the difference of the structural strength
3. The test of the structure
   a. To build the required machine
   b. To perform the considered
4. Conclusion and presenting a practical model

4.1. The Dampers and Their Effects on the Earthquake

Iran is regarded as one of the earthquake-prone countries. Getting familiar with the recent changes about the technological advances in reducing the seismic intensity and new structural systems is considered as a significant issue. Regarding this issue, the researchers can take the advantage of the FEMA-547 instruction. The seismic improvement methods include increasing the resistance, the hardness, the strength of the sections, and improving the loading of the structure. In this regard, three ways of reducing the effective seismic weight, seismic separators, and inactive dampers can be used to reduce the seismic force in buildings. Each of these three parameters is one of the factors shaping the structural vibration differential equation, i.e., (mx+cx+kx=pt) by which vibration is affected.

5.1. Inactive Dampers or Energy Wasting

Adding such dampers as the seismic separators is regarded as a rather unusual strategy for the seismic improvement. Adding the dampers causes the overall displacement of the structure to be reduced and the lateral place of the internal floors to be changed. The dampers include solid and liquid parts of viscous. Other equipment such as sphere-like alloys, frictional spring, and fluid reversible power reduction equipment are installed in them. Some ample of these dampers is shown in the following. Many engineers believe that adding the dampers are mostly related to the increasing of the building formation in the bending steel and concrete frame. The dampers should have been adapted for large displacements.

6.1. Constructing the Laboratory Model of the Earthquake Table

1. **The Earthquake Table**

Different parts of the earthquake table include: base, deck, engine, and inverter. The earthquake table, with the fluctuating source, and a 70 * 80 cm deck has been constructed (fig. 1). The propulsion of the deck is provided by a single phase electrical engine, which is situated under the deck (fig. 2). To provide the possibility of bringing continuous changes in the vibratory frequency of the deck, an inverter is used to provide the connection between the engine and the electricity supplier (fig. 3). The rotational frequency of the engine or the vibratory frequency of the deck is able to be seen on the screen of the inverter. To provide the possibility of the experimental study of the dynamic behavior of the steel frames, a model of the five-floor metal shear frame has been made (fig. 4). The shear model frame is composed of five 25* 30 cm ceilings, and five 92 cm columns.


Fig 1


Fig2

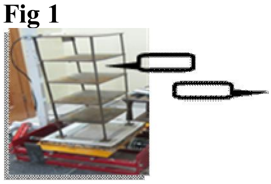
Fig3


Fig4

2. The Machine of Acceleration Registration

This machine has been designed and built for measuring the rate of acceleration of a vibrating object (fig. 5). To study the behavior of the structure against dynamic loads, the acceleration sensors can be installed in the five points of the structure. If the sensor is connected to the vibrating object, the machine can measure the rates of the momentary acceleration of each of the sensors with the sampling frequency 5ks/sec simultaneously, and save in a file (fig. 6).


Fig 5


Fig 6

3. Field Tests and Conclusion

1.3. The Analysis of the Tests

To perform the field researches, the test is done in different situations and then the structure is compared and analyzed in the above-mentioned mode. The structure is tested in two general modes with and without dampers.

2.3. The First Step: Doing Tests on the Undammed Structure

First, the undammed structure is placed on the seismic table. The structure is tested in the following three modes. It should be noted that in order to achieve better and more accurate results and in order to see the difference rate of the floor displacement more clearly, one weight, which is placed on different floors is used.

3.3. Analyzing the Structure without a Weight

The undammed structure is placed on the seismic table, and then the table is forced to vibrate. At this stage, the rate of the reciprocating motion of the structure, which is in a sinusoidal form, is registered on every floor separately, by the use of the related software. The rate of the structure displacement on the first floor is more than that of the fifth floor, and the following results have been achieved:

4.3. Analyzing the Structure by Placing the Weight on Each Floor

When the structure is placed on the seismic table, a weight is placed on each floor, and simultaneously, the reciprocal function of the movement is registered. Regarding the achieved results, it is observed that:

Table 1: The weight is placed on each floor

Floor 1	15 mm	Floor 2	17 mm	Floor 3	19 mm
Floor 4	31 mm	Floor 5	47 mm		

Generally, it can be concluded that the displacement of the structure of the first and fifth floors is 32mm.

5.3. Analyzing the Structure with Putting a Weight on the Fifth Floor

On this stage, the weight is placed on the fifth floor and the displacement of each floor is calculated. Regarding the fact that the weight of the structure is increased on the fifth floor, it is expected that the rate of displacement of the structure is increased on the highest floor by increasing the weight of the structure. According to the tests, the following results have been achieved:

Table 2: the weight is placed on the fifth floor and the displacement of each floor

Floor 1	18 mm	Floor 2	21 mm	Floor3	27mm
Floor 4	36 mm	Floor 5	47 mm		

Regarding the above-mentioned data, it can be observed that when weight is increased on the fifth floor (the highest floor); the rate of floor displacement is increased in whole the structure, which results in the drift of the floors. The whole displacement of the floors in the three modes is inserted in the following table for the future analysis

Table 3: The whole displacement of the floors in the three modes

	Floors	1	2	3	4	5
Mode 1	The undamped structure and without any weight/mm	14	16	19	30	40
Mode 2	The undamped structure and a weight on each floor/ mm	15	17	19	31	47
Mode 3	The undamped structure and a weight on the fifth floor/ mm	18	21	27	36	47

6.3. The Second Stage: Performing Tests on the Structure with a Damper

At the previous stage the undamped structure was placed on the table and the necessary tests were performed on it. At this stage, the structure is tested by the use of a rubber damper, which has been placed under and around the foundation. It should be noted that in order to cover the structure with damper, the black silicon tape, which has an elasticity property, thickness 1 cm and has been placed on all the foundation sides, is used. In order to compare the structure with and without dampers, similar to stage 1, the structure with damper is tested in the following three modes.

7.3. Testing the Damped Structure without Placing any Weight

The damped structure is placed on the table and then the displacement of the floors is registered by the use of distance metering sensor. The results are as the following

Table 4: The Damped Structure without Placing any Weight

Floor 1	14 mm	Floor 2	16 mm	Floor 3	19mm
Floor 4	28 mm	Floor 5	30 mm		

8.3. Testing the damped structure and placing a Weight on Each Floor

In this mode, the weight is placed on each floor, and the rate of displacement and the function are registered, and the following results are achieved.

Table 5: the damped structure and placing a Weight on Each Floor

Floor 1	16 mm	Floor 2	17 mm	Floor 3	21 mm
Floor 4	31 mm	Floor 5	36 mm		

9.3. Testing the Damped Structure and Placing the Weight on the Fifth Floor

At this stage of the test and at the outset a weight is placed on the fifth floor (the highest floor) and then the rate of the reciprocal movement of the structure is registered on each floor.

As it was stated earlier, the displacement of the structure is expected to be increased on the highest floor. The results achieved are as the following:

Table 6: the Damped Structure and Placing the Weight on the Fifth Floor

Floor 1	16 mm	Floor 2	20 mm	Floor 3	24 mm
Floor 4	29 mm	Floor 5	35 mm		

Now it is observed that the displacement difference (u) is 21 cm from the lowest floor to the highest floor. On this stage, the general displacement of the floors are analyzed and inserted in the following table in all the three modes.

Table 7: the general displacement of the floors

	Floors	1	2	3	4	5
Mode 1	The undamped structure and without any weight/mm	14	16	19	28	30
Mode 2	The undamped structure and a weight on each floor/ mm	16	17	21	31	36
Mode 3	The undamped structure and a weight on the fifth floor/ mm	16	20	24	29	35

4. Discussions

In the first glance if we look at the all the test, it is generally observed that the displacement is increased by increasing the floors; however, it is interesting to know that the more the weight of the structure on the highest floor, the more displacement it has, and the more it is probable to raze to the ground. The most significant conclusion that is observed is using the damper. Regarding the comparison of the 3-1, and 3-2 tests, it is completely observed that when the damper is used in the structure, its displacement is decreased from 3 to 10 mm on each floor tangibly. It shows that the damper is applicable. Moreover, it can be concluded that if one can use the damper in the residential structures, the displacement of the structure as well as its destruction are reduced significantly by reducing the rate of drift. In the above-mentioned tests, it is observable that when the damper is used, the fifth floor displacement is approximately equal to the displacement of the undamaged structure on the fourth floor. It means that by placing the damper, one can add one more floors to the height of the structure easily; however, it has the same level of displacement, of course the above-mentioned sample is used as an example and the result is achieved in this test. According to the studies done if it is possible to create a 24% displacement reduction on each floor, the design and executive costs are also reduced equally in the buildings.

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