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ENERGY DISSIPATION ANALYSIS ON REAL APPLICATION BY USING VISCOELASTIC DAMPERS

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ABSTRACT :

Design and study on petrol hotel in Xi'an city in China using viscoelastic energy dissipation braces in seismic regions of intensity 8 are carried out. First, dynamic responses of the structure under normal earthquake design level are calculated by the time history method. Considering the structure does not satisfied aseismic requirement, viscoelastic energy dissipation braces are used for reinforcement. Then, the position optimization and design of viscoelastic dampers and connected braces are provided. The results proved that viscoelastic dampers can reduce the earthquake responses of the structure effectively through the comparison with and without viscoelastic dampers, and viscoelastic dampers are high-performance energy dissipation devices.

KEYWORDS: viscoelastic damper; energy dissipation; aseismic reinforcement; time history analysis

1. INTRODUCTION

Viscoelastic damper has been long used in vibration control of structures. After first utilized in the Twin World Trade Center Towers in New York in 1969 for wind induced vibration [1, 2], the function of the viscoelastic damper has been acknowledged by most of people. With low cost and minimal maintenance requirements, viscoelastic damper has been widely adopted to reduce the dynamic response of structures and was followed by a number of other similar applications [3-5].

2. MATHEMATICAL MODEL

One of the most important topics for analysis on structures with viscoelastic dampers is choice of mathematical model of viscoelastic dampers. Energy dissipation properties of viscoelastic dampers are affected by frequency and temperature. In order to simulate the properties of viscoelastic dampers, some models are proposed. The main models are as follow: Kelvin model, Maxwell model, Standard Linear Solid model, Complex Stiffness model, Four Parameter model, Finite Element model, Equivalent Standard Solid model.
Among the mathematical models mentioned above, the typical model is Kelvin model. Kelvin model[6] considers viscoelastic dampers as a combination of linear spring and dashpot. The relation between shear stress and strain in viscoelastic materials can be described as

$$\tau = q_0\gamma + q_1\dot{\gamma} \tag{2.1}$$

Where q_0 and q_1 are coefficients determined by the property of viscoelastic materials. After a series of derivation under sinusoid loads, the following equations will be obtained.

$$\left.\begin{aligned} G_1 &= q_0 \\ \eta &= q_1\omega / q_0 \end{aligned}\right\} \tag{2.2}$$

3. TEST ON VE DAMPERS

In order to acquire the energy dissipation behavior and performance parameters changing with temperature and frequency of the viscoelastic damper, property tests are carried out in RC&PC Key Laboratory of Education Ministry, China. Tests are carried out under the environmental temperature 7^0C and each test consists of twenty cycles of sinusoidal displacement. The tested damper is a single layer viscoelastic damper with ameliorated ZN22 viscoelastic material. The other data under different temperatures are provided by manufactured company.

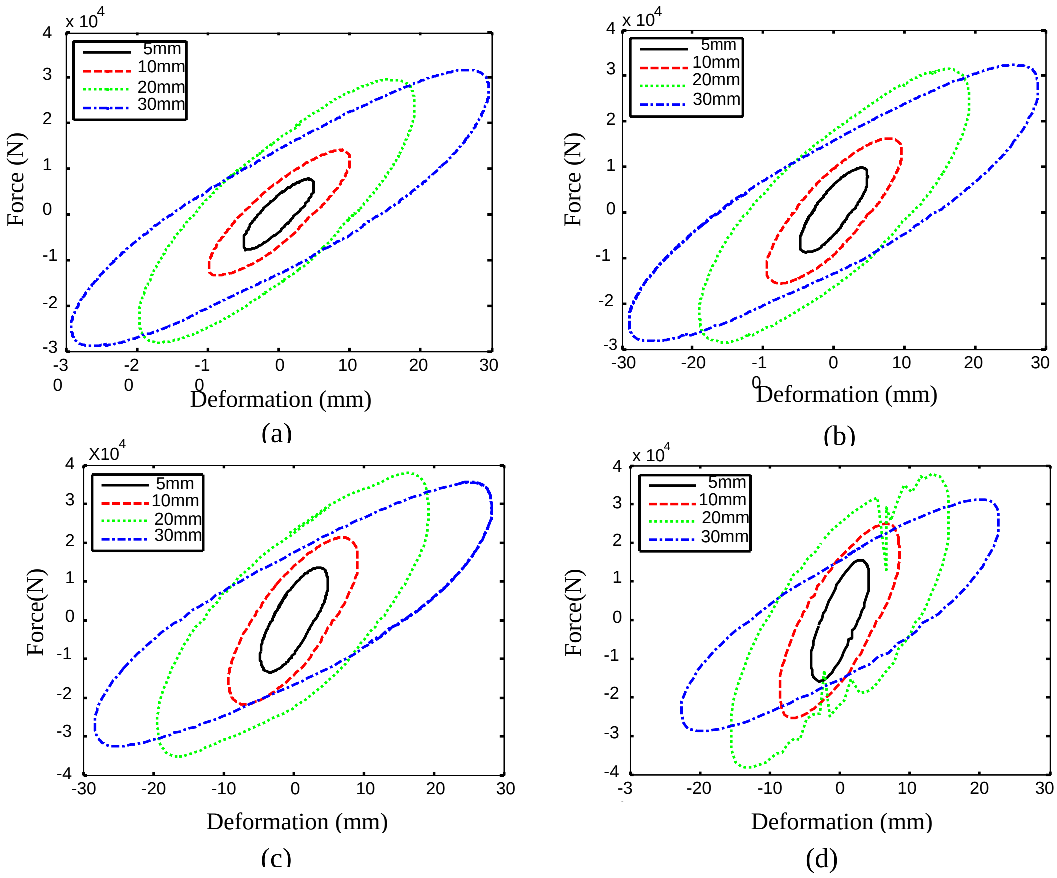


Figure 1 Hysteretic curve (a) 0.1HZ (b) 0.2HZ (3)0.5HZ (4)1.0HZ

3.1 Test results and analysis

It can be know that the slope and plump degree of these hysteretic curves are different obviously with different excitation frequencies and amplitudes. The slope and plump degree of force-displacement hysteretic curves are correlative with stiffness and energy dissipation of the device, respectively.

It is difficult to analyze the raw data because of the overlapping cycles, so one cycle is taken out while the hysteretic curve becomes Fig.1.

Through the analysis of the test, some regularity can be summed up: in the case of equal frequency, the hysteresis loops are stable if the damper strain is within 20%, this findings consistent with results from other Literature; in the case of equal amplitudes, the slop of hysteresis curve increase and the area enclosed by hysteresis curve tended to increase with increasing frequency; the slop of hysteresis curve decrease with increasing amplitude under same frequency.

3.2 Excitation frequency effect

It was suggested that the storage modulus G_1 increases as frequency increases but the increase amplitudes slowdown as the frequency increases. These results show that the characteristic factors G_1, G_2, η and E_d increase with the increasing frequencies at all displacement amplitudes. It can be also know from test that the characteristic factors G_1, G_2, η and E_d increase more fast in lower frequency than in higher frequency. The results show that increasing magnitudes of the characteristic

4. SEISMIC DESIGN AND ANALYSIS ON REAL APPLICATION

4.1 The engineering survey and design

The petrol hotel in Xi'an city is a seven-story reinforced concrete frame structure with local eight-story. Overall dimensions of the frame are 47.4m×10.8 m in plan and with story height of 23.8m. The story height of each layer is 5.7 m 、2.8m、2.8m、2.8m、2.8m、3.0m and 3.9m respectively. The structure is in seismic regions of intensity 8 with design basic acceleration of ground motion 0.2g and soil type II. The detection results showed that: the side column section size is 400mm×500mm and middle column is 450mm×550mm; concrete strength grade of the column is C23 and the beam is C22. Original structure did not consider the ant seismic design, and the structures under earthquake excitation can not meet the demand of current code, so ant-seismic strengthening of the structure must be conducted. Design and study on earthquake absorption using viscoelastic damper in this hotel have been carried out. Figure 2 shows the plane schematic of the structure.

The viscoelastic dampers (Figure 3) applied in this engineering is developed by Southeast University and Chang Zhou vibration absorber factory. For the construction convenience, only one type of damper is used, of which maximum damping force is 150T, damping coefficient is c_d = 1.6 KN*S/mm, stiffness k_d =11.4KN/mm , maximum stroke is 90 mm. This kind of viscoelastic damper has stable dynamic characteristics, the aging of years exceeding 80years, which can meet the requirement of engineering designs. 52 VE dampers are added in this structure and the dampers arrangement in first story as shown in Figure 2, the pink lines shows the installation position. Three typical brace types are used in this engineering, due to the structural constraint, as shown in Figure 4.

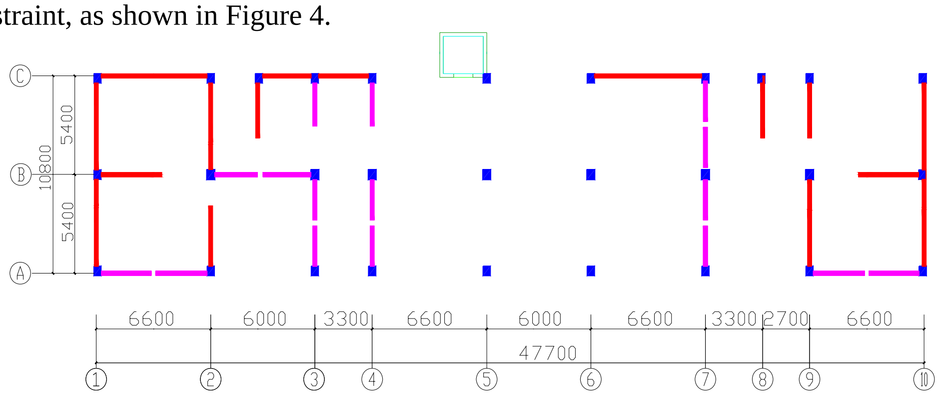


Figure 2 Plane schematic of the structure

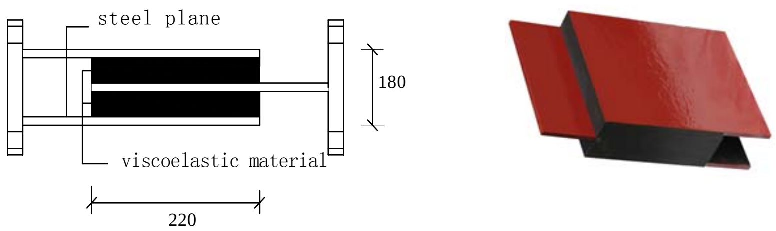


Figure 3 VE dampers

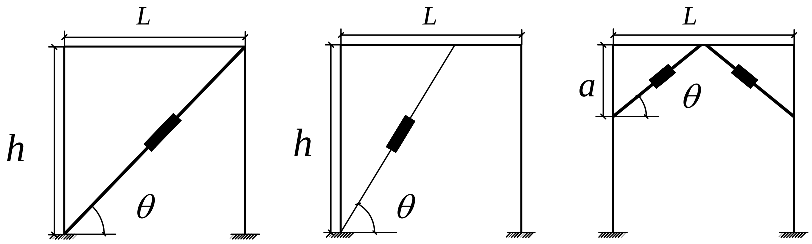


Figure 4 Viscoelastic damper and energy dissipation braces

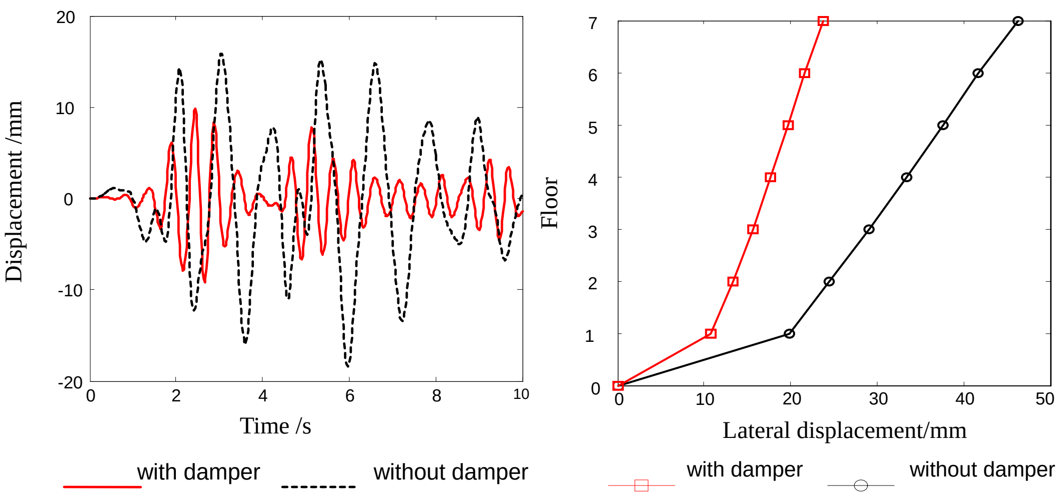
4.2 Results of elasto-plastic time-history analysis

In the calculation processes, elasto-plastic time-history analysis is conducted under EL-Centro, TAFT and Rengong earthquake ground motions scaled in time and peak accelerations with peak ground acceleration of 70gal and 400gal. Duration times of the three seismic waves are all 10s. The seismic responses of original structure under moderate earthquake are shown in Table 4.1.

The calculation results show that the lateral displacements of first story can not conform with the code requirements, especially Y direction and Rengong earthquake ground motions have a relatively less influence on the structure. Accordingly, comprehensive analysis is carried out only on calculation results of El-Centro wave and Taft Wave. Table.1 shows that the first floor is the weak-layer of the Structure which has to be mainly reinforced, so more dampers have to be installed in the first story. In this structure 32 dampers are arranged in the first floor and 5 dampers for two to five stories.

Table4.1 Seismic responses of original structure under 70gal earthquake

Floor	maximum values of inter - story displacement (mm)						**Mean values of inter-story displacement (mm)**		**Story drift**	
	EL Centro earthquake		TAFT earthquake		Man-made earthquake					
	X direction	Y direction	X direction	Y direction	X direction	Y direction	**X direction**	**Y direction**	**X direction**	**Y direction**
7	3.06	4.42	3.03	4.56	3.15	4.31	**3.08**	**4.43**	**1/1266**	**1/880**
6	2.51	3.75	2.39	4.01	2.72	3.64	**2.54**	**3.80**	**1/1181**	**1/789**
5	2.74	3.97	2.61	4.20	2.93	3.77	**2.76**	**3.98**	**1/1014**	**1/704**
4	2.87	4.18	2.72	4.39	3.17	4.06	**2.92**	**4.21**	**1/959**	**1/665**
3	3.03	4.39	2.95	4.57	3.32	4.30	**3.10**	**4.42**	**1/903**	**1/633**
2	3.11	4.51	3.07	4.65	3.45	4.52	**3.21**	**4.56**	**1/872**	**1/614**
1	8.71	18.57	8.1	19.83	9.91	17.02	**9.12**	**18.47**	**1/625**	**1/309**

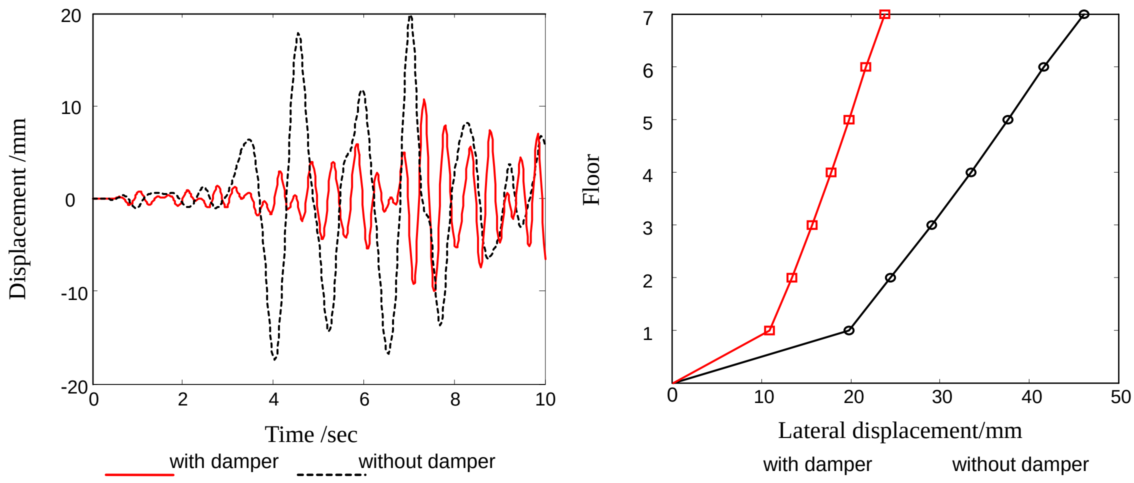


(a) The first floor displacement (b) The maximum values of each floor

Figure 5 Displacement responses under 70 gal EL-Centro earthquake

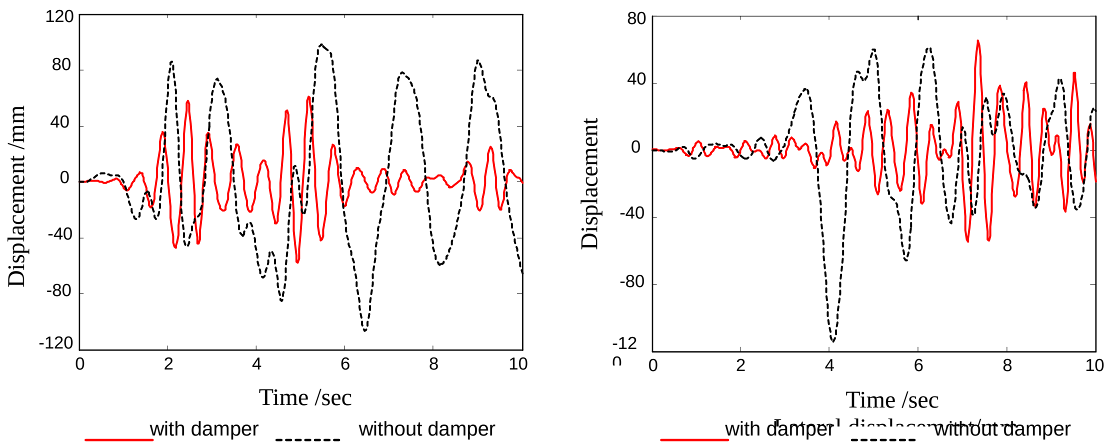
As can be seen from Figure 5, during the ground shaking of 70gal EL-Centro earthquake record, the displacement decreases markedly with dampers, even though the structure remains elastic under this moderate earthquake with and without dampers. In particularly, the maximum displacement decreased from 18.75mm to 9.79mm at the first floor. Similar results are observed under 70gal Taft earthquake ground motion, as shown in Figure 6, the maximum displacement decreased from 19.83mm to 10.81mm at the first floor under 70gal Taft earthquake ground motion.

Figure 7 shows Displacement time history of the first floor with and without dampers under 400gal EL-Centro and Taft earthquake. The results shows that the structure without dampers damaged under this strong earthquake ground motion, but the structure remains elastic with added dampers and the displacement satisfies the code requirement. Figure7 (a) and (b) show that the maximum displacement decreased from 112.4 mm to 61.2 mm at the first floor under 400gal EL-Centro earthquake ground motion and from 114.6 mm to 65.36 mm at the first floor under 400gal Taft earthquake ground motion. The construction torsion has been commendably controlled also.



(a) (b)

Figure 6 Displacement responses of 70 gal Taft earthquake:
(a) the first floor; (b) displacement envelopes



(a) (b)

Figure 7 Displacement responses of first floor: (a) 400gal EL-Centro earthquake
(b) 400gal Taft earthquake

5. CONCLUSION

The results of the current study can be summarized as follows:

(1) The experiments show that the viscoelastic dampers have better energy dissipation capacities and can be used for the Vibration-Reduction Control of Engineering Structures. By the comparison with experimental data of performance test of visoelastic damper, the results showed that the equivalent standard solid model can describe energy dissipation behavior of visoelastic damper under the different temperatures and frequencies precisely.

(2) Calculation results show that, viscoelastic dampers are effective in reducing the seismic response of the structure. It is a kind of velocity-dependent energy dissipation device which has stable dynamic character and

strong ability of energy dissipation.

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