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An Experiment Research on Different Damping Distributions of Isolation Bearings of Lateral-torsional Coupling Isolated System

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Abstract: The purpose of this research is to study the isolation effect of damping distribution of the lead rubber isolation bearings on lateral-torsional coupling isolated system. A series of shaking table tests of the lateral-torsional coupling isolated system under different eccentricity situations are carried out for a 3-storey, 2-span steel frame, with changing the locations of upper loads and the isolation bearings. Torsional displacement time-history curves and torsional acceleration time-history curves are obtained under different eccentricity conditions and different damping distribution. The experiment shows that making the damping center of the isolation layer closed to the stiffness center of the superstructure or increasing damping radius of the isolation layer can further reduce the torsion reaction of the superstructure.

Key words: Isolation bearings, lateral-torsional coupling, isolated system, damping distribution

INTRODUCTION

Studies have shown that the torsional deformation of the eccentric structures can be suppressed by reasonable adjustment of the distribution of the isolated device (Hisaichi, 1997). But it has a further research on the damping distribution of the isolated layer on the influence of isolated effect. In order to obtain the influence law of isolated effect of the structures on different damping distribution and find out the method of reasonable layout of the damping, in this study using the lead rubber bearing and lead-free rubber bearing, had a test study on the different eccentricity working situations and the damping distribution.

TEST PROFILE

Plane size of the test model framework are1.6×0.8 m, storey high 0.8 m, a total of three layers, the total height of 2.4 m. Framework is made of all kinds of steel, steel are all of Q235, corner column post ⌊110×8, middle column ⌊110×70×7, the middle layer beam [100×48×5.3, bottom and top layer beams [140×58×5.3. Each layer are all placed concrete weight block, including the basic load and additional load and the thickness are all of 10 cm. Isolated bearing (Japanese Seismic Structure Association, 1998) of a lead rubber bearings with diameter D = 100 mm (GZY100G4), the performance parameters of the rubber bearing as follows, stiffness K_{eq} = 0.197 KN mm^{-1}, equivalent damping ratio H_{eq} = 0.109, post-yield stiffness K_d = 0.175 KN mm^{-1}, yield load Q_d = 0.073 t.

The test select of three real record seismic waves (the El-Centro wave, Taft wave, Tianjin wave), according to the need, the acceleration amplitude is adjusted as 250 cm sec^{-2}, time compression ratio for 1/6.

The test consists of three kinds of mass distribution cases, no eccentricity, little eccentricity and large eccentricity (Fig. 1), the specific layout program is shown in Fig. 2.

Rubber bearings isolation cases (Fig. 3): (1) lead rubber bearings placed in position 1, 3, 4, 6 and no eccentricity of the underlying stiffness, the upper quality in three cases, no eccentricity, small eccentricity and large eccentricity; (2) lead rubber bearings placed in position 2, 3, 4, 5 and no eccentricity of the underlying stiffness, the upper quality in three cases, no eccentricity, small eccentricity and large eccentricity; (3) lead rubber bearings placed in position 1, 2, 5, 6 and no eccentricity of the underlying stiffness, the upper quality in three cases, no eccentricity, small eccentricity and large eccentricity.

According to the different mass distribution of the superstructure and the different layout of the lead rubber bearing, it design of the nine test cases, show as Table 1.

TEST RESULTS AND ANALYSIS

In this study, we study the isolation effect in the case of different distribution of the rubber bearings mainly from two aspects of the displacement and acceleration of the structure.

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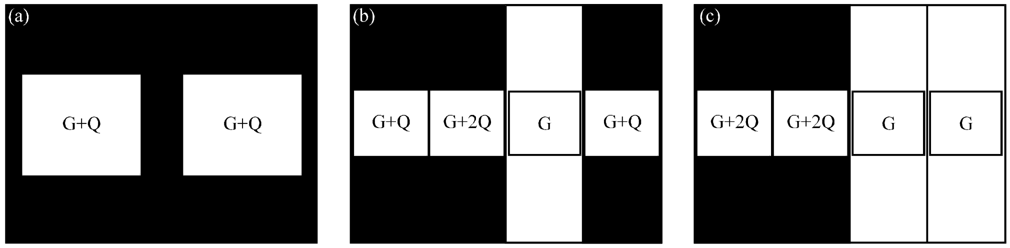

Fig. 1(a-c): Mass distribution cases, (a) Mass distribution case 1, (b) Mass distribution case 2 and (c) Mass distribution case 3

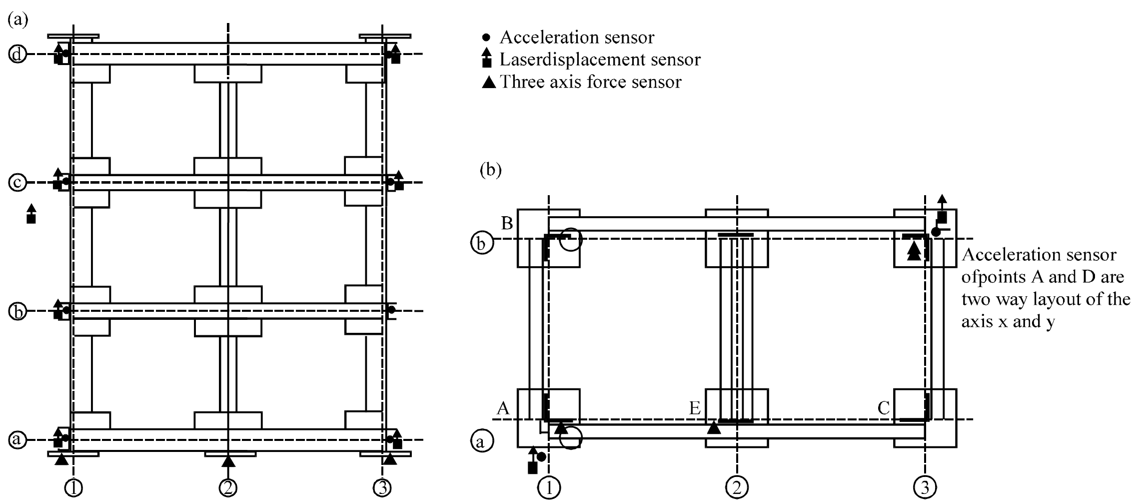

Fig. 2(a-b): Structure model

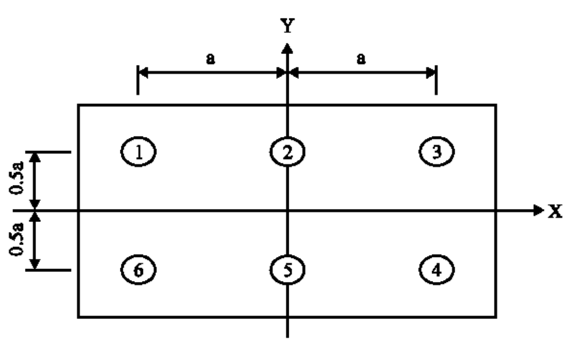

Fig. 3: The distribution of rubber bearings

Response analysis of the torsional displacement of the large eccentricity working situation. In order to study the change low of the seismic response of the superstructure under different damping distribution, from the test data, we drawn the torsional displacement and acceleration time-history curves of the top floor under

Table 1: Test case

Serial No.	Mass distribution case	Rubber bearings isolation case
1	1	1
2		2
3		3
4	2	1
5		2
6		3
7	3	1
8		2
9		3

displacement time-history curves of the top floor under large eccentricity working situation, Fig. 4d-f are the torsional acceleration time-history curves of the top floor under large eccentricity working situation.

From Fig. 4a-c we know, the maximum of the torsional displacement of the top floor are all 2.5×10^{-3} m under the first, second and third working situations, the displacement range of about 1.0×10^{-3} m after four second under the second working situation, while about 5.0×10^{-3} m under the first and third working situations, the peak of the displacement time-history curve of back

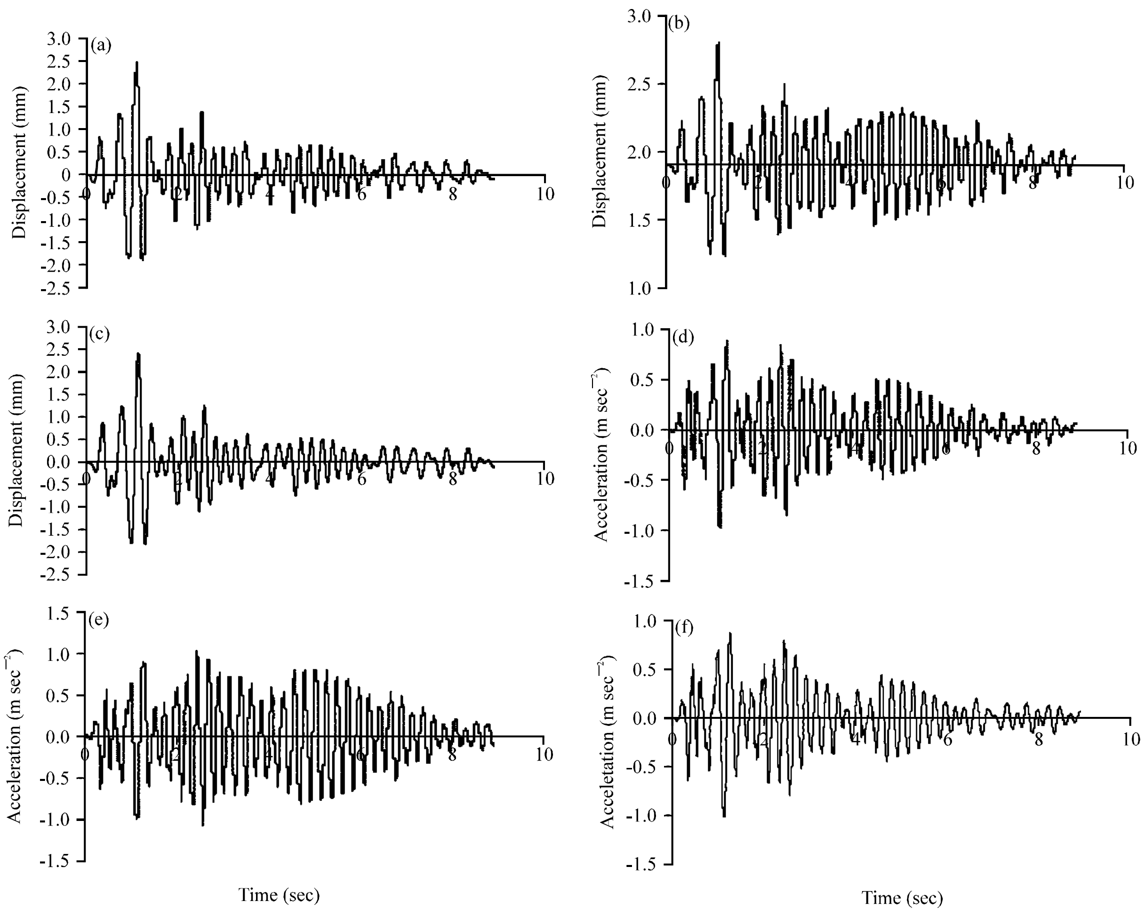

Fig. 4(a-f): Torsional displacement and acceleration time-history curve of the top floor of the large eccentricity under El-Centro wave. (a) The first working situation, (b) The second working situation, (c) The third working situation, (d) The first working situation, (e) The second working situation and (f) The third working situation

half of the second working situation was significantly bigger than the first and third working situation, indicating that the isolation effect of the first and third working situation are better.

From Fig. 4d-f show that, the maximum of the torsional acceleration of the top floor are all 1.0 m sec^{-2} under the second working situation, while 0.8 m sec^{-2} under the first and third working situations, the torsional acceleration change similar with the torsional displacement, indicating that the isolation effect of the first and third working situations are better.

From the analysis of the torsional displacement and acceleration time-history curves of under different large eccentricity working situations we know that increasing damping radius of the isolation layer or making the damping center of the isolation layer closed to the stiffness center of the superstructure can better reduce the torsion reaction of the structure.

Response analysis of the torsional displacement of the small eccentricity working situation. The following analysis of the damping distribution under small eccentricity working situation, take the same of the torsional displacement and acceleration of the top floor for example. Fig. 5a-c are the torsional displacement time-history curves of the top floor under small eccentricity working situation. Figure 5d are the torsional acceleration time-history curves of the top floor of the first small eccentricity working situation under El-Centro wave.

From Fig. 5a-c, we know, the maximum of the torsional displacement of the top floor is 1.4×10^{-3} m under the second small eccentricity working situation, the maximum of the torsional displacement of the top floor is about 1.2×10^{-3} m under the first and third small eccentricity working situations, it about sixteen percent bigger under the second small eccentricity working situation than the first and third small eccentricity working

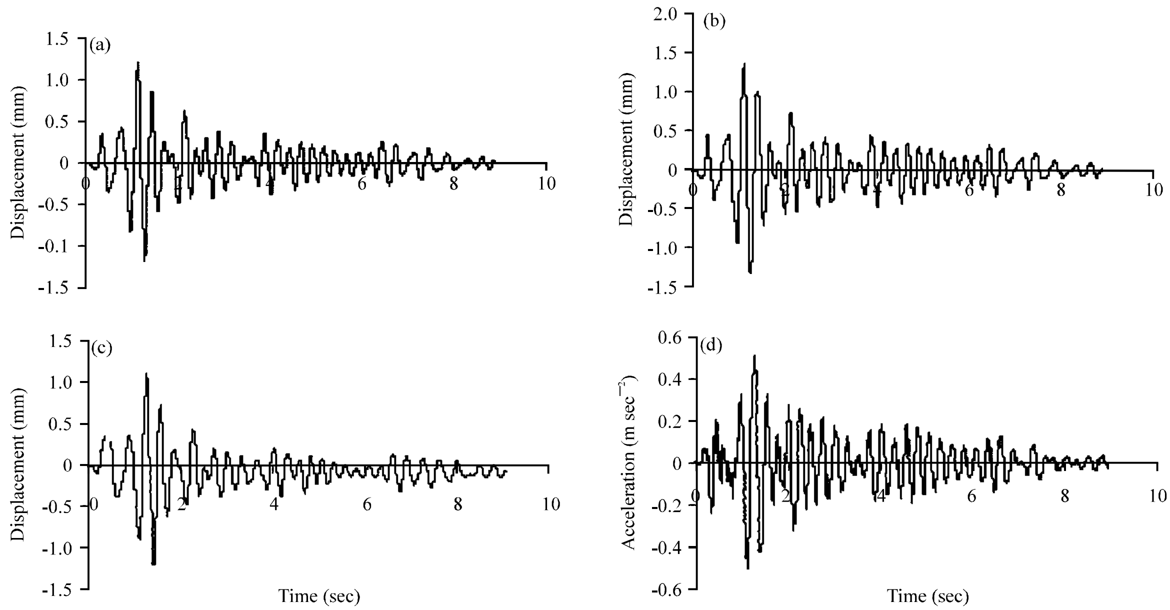

Fig. 5(a-d): Torsional displacement and acceleration time-history curve of the top floor of the small eccentricity under El-Centro wave, (a) The first working situation, (b) The second working situation, (c) The third working situation and (d) The first working situation

situations, so the worst isolation effect of the second working situation, the isolation effect of the first and third working situation are better. The torsional acceleration change similar with the torsional displacement, also indicating that the isolation effect of the first and third small eccentricity working situations are better, here are just give the acceleration time-history curve of the top floor of the first small eccentricity working situation under El-Centro wave (Fig. 5d).

From the analysis of the torsional displacement and acceleration time-history curves of under different small eccentricity working situations we know that increasing damping radius of the isolation layer or making the damping center of the isolation layer closed to the stiffness center of the superstructure can better reduce the torsion reaction of the structure.

For the other seismic waves, the curves law obtained are as the same as El-Centro wave. The influence of different damping distribution is not big while the structure of no eccentricity.

CONCLUSION

In this study, a series of shaking table tests of the lateral-torsional coupling isolated system under different eccentricity situations are carried out for a 3-storey, 2-span steel frame, with changing the locations of upper loads and the lead isolation bearings. According to the tests results we can get the conclusion as follow, we can achieve a better isolation effect when use lead rubber isolation bearings relative to rubber isolation bearings, increasing damping radius of the isolation layer or making the damping center of the isolation layer closed to the stiffness center of the superstructure can better reduce the torsion reaction of the structure and achieve a better isolation effect.

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