The Property Experimental Study of Vertical Seismic Isolation System by Disk Spring

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ABSTRACT :

A kind of vertical seismic isolation system, which is composed of dish spring and damper with viscidity and elasticity by using parallel combination, is proposed in this paper. A series tests under static loads and dynamic loads have been performed in order to study the stiffness and damping permance of this isolation system. Most of experimental results can be drawn its effect in the resolution of difficulty in strong vertical capacity and vertical damper of vertical isolation bearings. It is not only with vertical appropriate stiffness and damper performance, but also with easy stable performance and compact system, easy to manufacture as well. It is an ideal vertical damping device.

KEYWORDS: Disk Spring, viscoelastic damper, vertical Seismic isolation, equivalent stiffness, equivalent damping ratio

1. INTRODUCTION:

The base-isolation technique has been used widely to reduce seismic disaster in different country. But most of these devices are effective just in horizontal earthquake responses and do not work well in vertical earthquake responses. The massive earthquakes disaster and the findings indicated that, the vertical earthquake should not be neglected to the structure. Sometimes the horizontal earthquake responses even been exceeded by the vertical one. Because of the bigger vertical rigidity, the structure may be destroyed when its vertical basic periods is closed with the vertical earthquake wave. Therefore it is necessary to study a device which is able simultaneously to complete horizontal and vertical isolation.

A kind of vertical seismic isolation system, which is composed of disk spring and damper with viscidity and elasticity by using parallel combination, is proposed in this paper. A series tests under static loads and dynamic loads have been performed in order to study the stiffness and damping performance of this isolation system. Most of experimental results can be drawn its effect in the resolution of difficulty in strong vertical capacity and vertical damper of vertical isolation bearings.

2. EXPERIMENTAL PROGRAM

2.1Prototype structure

The Prototype represented a building of RC structure with eight stories which designed by PKPM in order to compare with non-isolated building. The design axle force is 2800kN. The plan is as Fig. 1 shows.

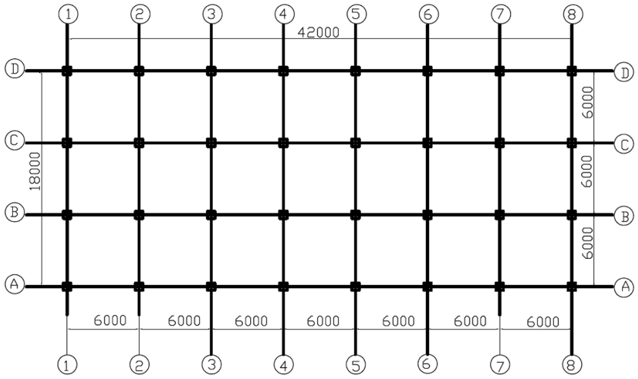


Figure 1 the plan of the prototype building

2.2 Test speimens

According to designing axle force and disk spring characteristic, one bigger disk spring group is put in the center of vertical seismic isolation device, other several little disk spring groups and damper with viscidity and elasticity are distributed outside the big one. And for comparing with the damping effect, another vertical isolated device is made but without damper in it. The device is as Figure 2 and 3 shows.

Figure 2Test system of the seismic isolation system without damper

Figure 3 Test system of the seismic isolation system with damper

The comparability for the force of inertia and elastic resilience may be maintained mainly but not to consider other factors for researching structure vibration characteristic (base frequency and vibration mode). Because in this experiment the material of model is consistent with the prototype, it is not necessary to keep the geometry similar relations strictly in order to maintain the similar elastic resilience. Therefore the similar scale of period and length are controlled chiefly in model design

2.3Test setup and instrumentation

2.3.1 the static tests

According to the test equipment characteristic, the load is started from the zero controlling by displacement until the biggest displacement which is 48mm while the load - displacement curve is measured for obtaining the vertical rigidity of isolation device.

2.3.2 the dynamic tests

In order to examine the stiffness and damper performance of this device, several test have been put up including examination of bearing capacity and the vertical dynamic characteristic. In vertical test, which equilibrium position is 20mm or 25mm(indicating small and large earthquake), the different displacement has been selected from 2mm to 10mm according to the different frequency from 0.1Hz to 5Hz. The Test system is shown in figure 2 and 3.

3. EXPERIMENTAL RESULTS

3.1 The vertical carrying capacity and static stiffness

A maximal carrying capacity test under static loads is put up to the vertical isolation system by disk spring. Loading slowly, the load that arrived 51 tons while the vertical displacement of this device is 75% of its limit traveling, and it is bigger than the design capacity. When loading, the disk spring is pressed evenly at first (i.e. presses to its 100% limit displacement), then unloading slowly. And when this course is carried on repeatedly, the original altitude can be restored every time. The conclusion may be drawn by above experiment that a very high vertical supporting capacity will be provided with by reasonable designs to the vertical seismic isolation devices by disk spring.

The static load- displacement curve is provided in Fig. 4. And the contrast between test and theory results are as shown in table 1 and 2.

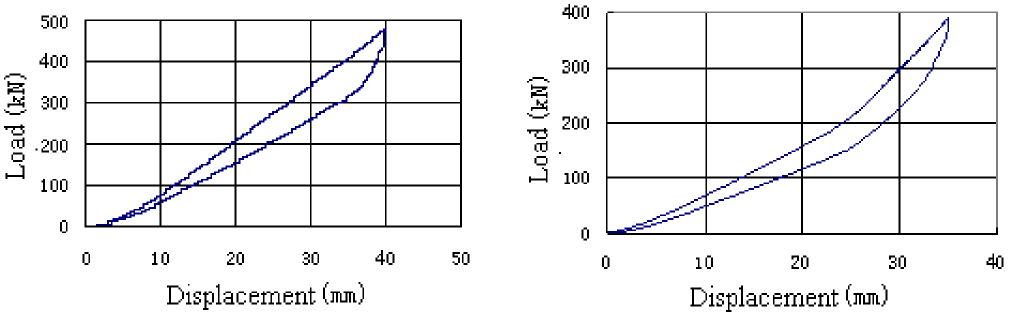


Figure 4 The experimental curve of vertical rigidity for model

Table 3.1 The vertical stiffness of test and theory for model 1

	The vertical carrying capacity P(kN)	The vertical stiffness K （kN/mm）
Test results	475.2	11.875
Theory results	436.7	11.7
difference	8.8%	1.5%

Table 3.2 The vertical stiffness of test and theory for model 2

	The vertical carrying capacity P(kN)	The vertical stiffness K （kN/mm）
Test results	382.2	19.914
Theory results	343.3	19.7
difference	11.3%	1.1%

3.2 The vertical equivalent dynamic stiffness and damper

The vertical initial stiffness attained in seismic isolation device is 19 kN/mm while in same building but non-isolated it is about 1.2×10^2kN/mm. The basic frequency is 1.6Hz whereas in non-isolated it is 9.6Hz. Figures 5 to 6 show the measured load-drift response under Vertical dynamics load. All of the dynamic hysteresis loops with full shape indicated a good dissipation capacity of the device. According to the curve, the equivalent stiffness and damper are evaluated in two devices. Respectively, it is 14 kN/mm and 0.14 without damper while 20 kN/mm and 0.23 with damper. Otherwise than, there are some conclusions involved the effect of frequency, amplitude and equilibrium position on the performance of compound device.

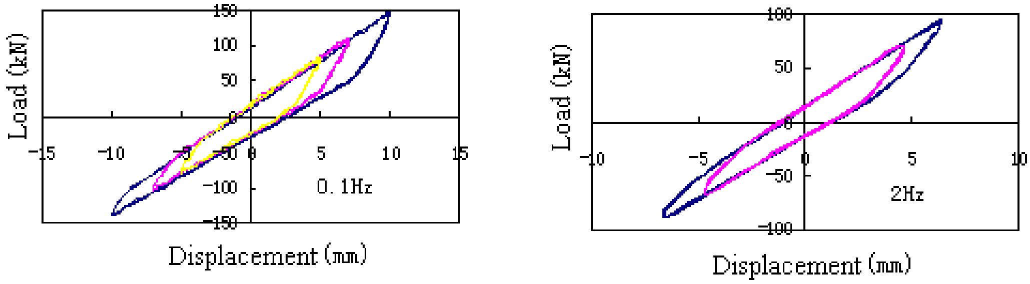


Figure 5 The hysteresis loop of model 2

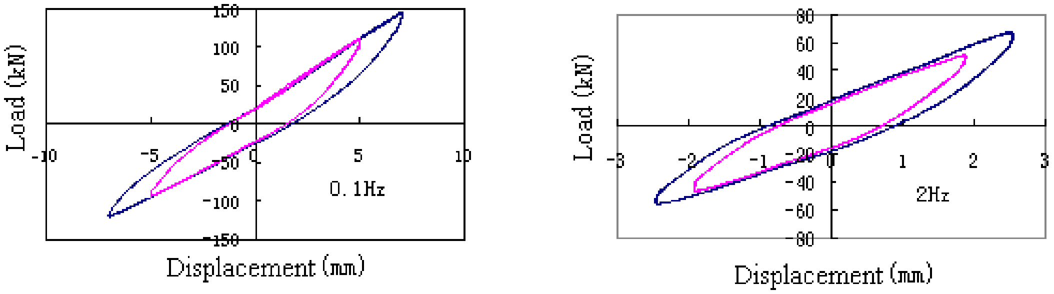


Figure 6 The hysteresis loop of model 2

The equivalent stiffness calculated from formula 3.1 and the equivalent ratio of damper calculated from formula 3.2. The results as shown in table from 3.3 to 3.6.

$$k_e = \frac{F_{\max} - F_{\min}}{\Delta_{\max} - \Delta_{\min}} \tag{3.1}$$

$F_{\max}$、$F_{\min}$— the supreme and minimal load in a circle

$\Delta_{\max}$、$\Delta_{\min}$—the supreme and minimal displacement in a circle

$$\xi = \omega_D / 4\pi\omega_s \tag{3.2}$$

ω_D—the area enveloped by actual load-displacement curve

ω_s—the area enveloped by stiffness load-displacement curve

Table 3.3 The equivalent ratio of damp for model 1

Load frequency displacement		0.1hz	0.2hz	0.5hz	1.0hz	2.0hz	3.0hz	5.0hz
Beforehand pressed 20mm	10mm	0.110	0.115	0.120				
	7mm	0.112	0.119	0.130	0.142			
	5mm	0.128	0.133	0.136	0.145	0.152		
	2.5mm						0.173	0.187
	2mm						0.179	
Beforehand pressed 25mm	10mm	0.121	0.128	0.130				
	7mm	0.126	0.131	0.139	0. 149			
	5mm	0.135	0.146	0.153	0.159			
	2.5mm					0.212		
	2mm						0.223	

Table 3.4 The equivalent ratio of damp for model 2

Load frequency displacement		0.1hz	0.2hz	0.5hz	1.0hz	2.0hz	3.0hz	5.0hz
Beforehand pressed 25mm	7mm	0.191	0.199	0.212	0.233			
	5mm	0.199	0.221	0.256	0.272			
	3mm					0.262		
	2.5mm						0.283	
	1.5mm							0.296

Table 3.5 The equivalent stiffness for model 1

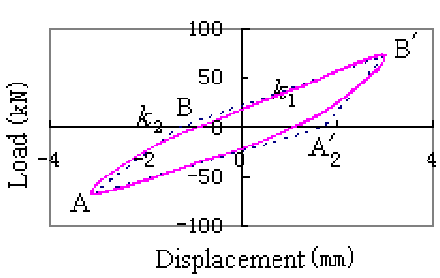
Load frequency displacement		0.1hz	0.2hz	0.5hz	1.0hz	2.0hz	3.0hz	5.0hz
Beforehand pressed 20mm	10mm	14.285	14.712	15.571				
	7mm	13.810	14.621	15.433	16.142			
	5mm	13.101	14.500	15.411	17.032	17.231		
	2.5mm						17.639	18.217
	2mm						17.236	
Beforehand pressed 25mm	10mm	15.800	16.412	17.103				
	7mm	15.423	15.571	15.715	17.857			
	5mm	13.901	15.000	15.521	18.096	18.933		
	2.5mm							
	2mm						19.025	

Table 3.6 the equivalent stiffness for model 2

Load frequency displacement		0.1hz	0.2hz	0.5hz	1.0hz	2.0hz	3.0hz	5.0hz
Beforehand pressed 25mm	7mm	20.512	20.811	21.036	21.166			
	5mm	20.785	21.103	21.385	21.469			
	3mm					23.339		
	2.5mm						25.526	
	1.5mm							26.068

4. ANALYSIS AND DEDUCTION

According to the test result and the related literature, the bilinear form is adopted approximately in vertical resilience model, as shown in Fig. 7 and 8.



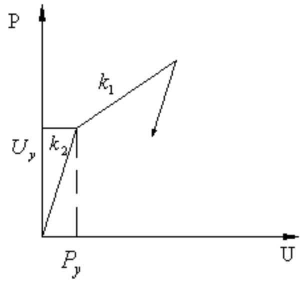


Figure 7 The lateral resilience model

Figure 8 The vertical resilience model

The initial rigidity is K_2, can be educed approximately by slope of parallel line *AB*, the yielding rigidity is K_1, can be obtained approximately by slope of parallel line $A'B'$.

5. CONCLUSIONS

The vertical seismic isolation system performed better in carrying capacity, damping, stiffness and dissipation capacity, and it is adapted to work as a vertical seismic isolation device for mitigating vertical earthquake disaster in building.

The equivalent damping ratio and the equivalent stiffness of vertical isolation device have increased slightly along with the increase of load frequency, but it is not obvious.

The degeneration bilinear form can be used approximately in vertical seismic isolation system by disk spring.

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