

Research on a New Composite Isolator

Jie-Ying SUI^{1,a,*}, Shan-Shan WANG^{1b}, Weng-Feng LIU^{1,c}

¹School of Civil Engineering, Qingdao Technological University, Qingdao266033, Shandong, China

^asuijieying@sina.com, ^bwang15966931217@163.com, ^clwfqdlg@263.net

*Corresponding author

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Abstract. In this paper, a new type of disk spring composite rolling seismic isolator was developed. The isolator isolates horizontal earthquake with SMA to restore to normal position, and dissipate energy. The disk spring isolates vertical earthquake. Adopt Ansys to build the shear model, and contrasts the earthquake response between the base-isolated structure and the unbase-isolated structure.

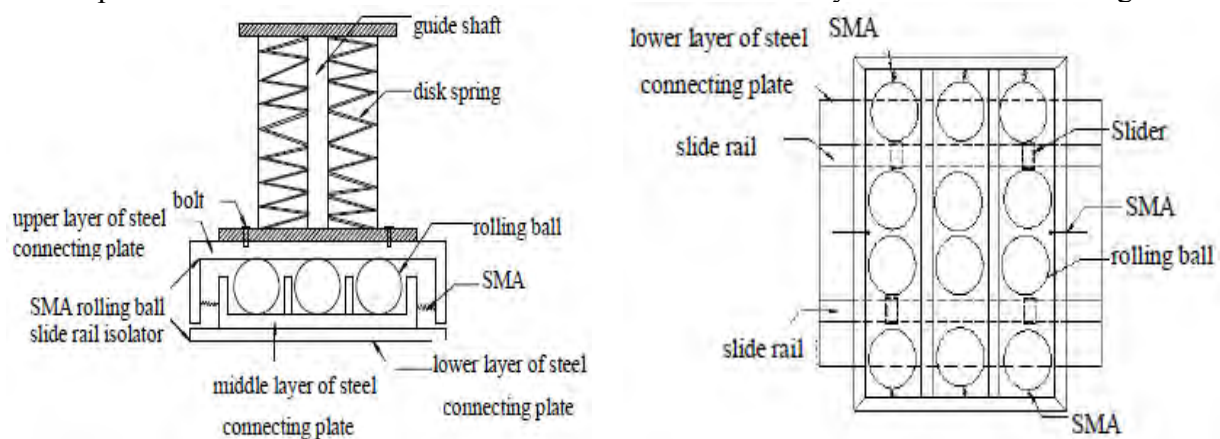
Introduction

At present, instead of the traditional way of seismic design of structures with base isolation mode is a hot research topic. Rolling isolation is an important form of base isolation. It can effectively reduce the earthquake action, and protect people's life and property safety [1, 2, 3].

The new composite isolator is one kind of three-dimensional isolation system, which can isolate horizontal earthquake and isolate verticality earthquake. It can be applied in many kinds of structural systems, it is good to decrease the seismic response, the fabrication cost is cheap, there is very good applicability.

New Composite Isolator Configuration

New composite Isolator made up of two parts, the lower portion is the rolling ball and slide rail with the SMA cable connected to the upper and lower steel plate to isolate the horizontal earthquake, the upper portion is a disc spring isolator to isolate the vertical earthquake, and the upper part and the lower part are combined to form a three-dimensional isolation system. As shown in Figure 1.



(a) Disk spring rolling ball slide rail isolator (b) The lower SMA rolling ball slide rail isolator

Fig. 1 Disk Spring Rolling Ball Slide Rail Isolator

New Composite Isolation Bearing Isolation Principle

Stiffness

The horizontal stiffness of the lower rolling ball slide rail isolator is small while the vertical stiffness is bigger, and the upper part of the disk spring bearings due to the effect of restriction of

the guide shaft, it almost occurs only vertical displacement, so the horizontal stiffness of the disc spring bearing is very big, but the vertical stiffness is a certain value. So in the design, the horizontal stiffness of the new composite isolator approximate only considers the horizontal stiffness of the lower rolling ball slide rail isolator, the vertical stiffness only considers the vertical stiffness of disc spring.

Motion Equation of the Structure with the New Composite Isolator

For the simplified calculation, make the following assumptions:

(a) Vertical seismic action is negligible; (b) That restoring force is linear and undamping, the damping is mainly composed of rolling friction.

For the buildings with the new composite isolator, the motion equation of the upper structure for a layer (for example) is

$$M_1 \ddot{x}_1 + C_1 \dot{x}_1 + K_1 x_1 = -M_1 (\ddot{x}_g + \ddot{x}_b) \quad (1)$$

Where M_1 , C_1 , K_1 —the mass, damping, stiffness of the structure;

x_1 —displacement of the structure;

x_b —displacement of the foundation;

\ddot{x}_g —The ground acceleration.

According to the figure 2, the motion equation of the foundation is

$$M_b \ddot{x}_b + K_b x_b - C_1 \dot{x}_1 - K_1 x_1 = -M_1 (\ddot{x}_g + \ddot{x}_b) - F_b - F_s \quad (2)$$

Where F_b [4]- the force between the rolling ball and the lower plate; F_s — the initial friction force.

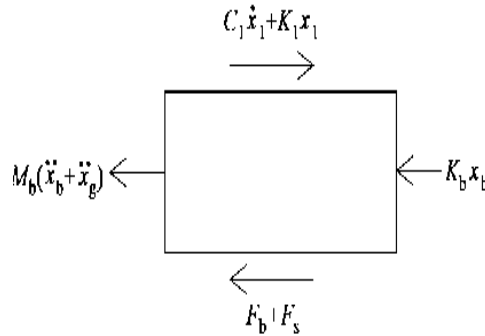


Fig. 2 Vibration Force of the Foundation of the Base-isolated Structure

Numerical Examples

A 5-story concrete frame structure, it is 36.8m long, 20.2m wide, 16.8m high. The column section size is 600 × 600mm². Seismic level of framework is 3 grade, seismic fortification intensity is 8 degrees, the design earthquake acceleration is 0.20g, seismic group is the second group, site soil category is Class II. Each story height is respectively 4.5m, 3.6m, 3.6m, 3.3m, 1.8m; each story mass is respectively 1030t, 952t, 865t, 775t, 161t; each story stiffness of x direction is respectively 2.20×10⁹N/m, 2.38×10⁹N/m, 2.44×10⁹N/m, 2.97×10⁹N/m.

As an example, using El Centro wave, under horizontal earthquake or vertical earthquake, Horizontal earthquake acceleration peak value is 0.40g.

Inputting the seismic waves, response-history analysis of the structure has been conducted using ANSYS programming.

Modal Analysis

The modal analysis results of the structure are shown in table 1.

According to table 1, the first natural period of unbase-isolated structure is 0.36 s, close to the site predominant period of $T_g = 0.4$ s, which is harmful to the structure seismic. The first natural period of the base-isolated structure is 2.817s, which is about 7.8 times of the first natural period of

unbase-isolated structure, avoided the site predominant period. It can reduce the horizontal earthquake effect, the seismic response of the upper structure such as displacement, velocity and acceleration can also decrease. This is obvious isolation effect.

Tab. 1 Period

vibration mode	base-isolated structure	unbase-isolated structure.	T_1 / T_2
	Period T_1 (s)	Period T_2 (s)	
1	2.847	0.36	7.833
2	0.406	0.125	3.244
3	0.215	0.095	2.253
4	0.155	0.073	2.113
5	0.133	0.065	2.036

Time History Analysis

Time History Analysis under Horizontal Earthquake

Top floor displacement time history analysis curve and top floor acceleration time history analysis curve with isolation or not were given respectively. As shown in Figure 3, 4.

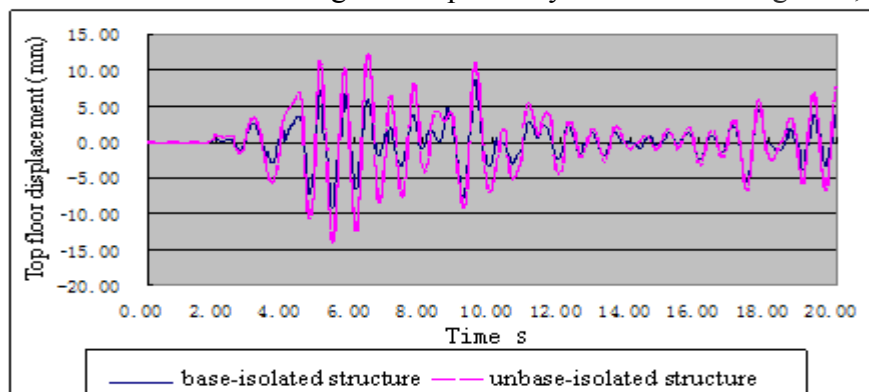


Fig. 3 Top Floor Displacement of Isolated and Un-isolated Structures under Horizontal Earthquake

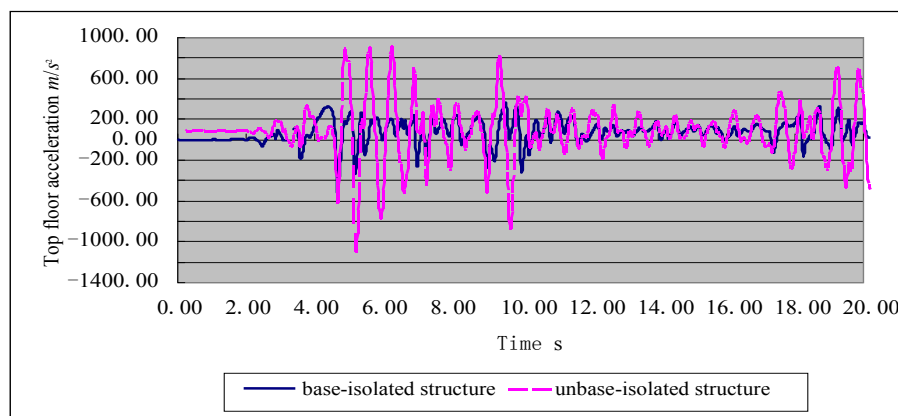


Fig. 4 Top Floor Acceleration of Isolated and Un-isolated Structures under Horizontal Earthquake

The horizontal floor displacement and the acceleration of isolated structures are much smaller than the un-isolated structures'. Isolation effect of the isolator is obvious.

Time History Analysis under Vertical Earthquake

Top floor displacement time history analysis curve and top floor acceleration time history

analysis curve with isolation or not were given respectively. As shown in Figure 5, 6.

The vertical floor displacement and the acceleration of isolated structures are much smaller than the un-isolated structures'. Isolation effect of the isolator is obvious.

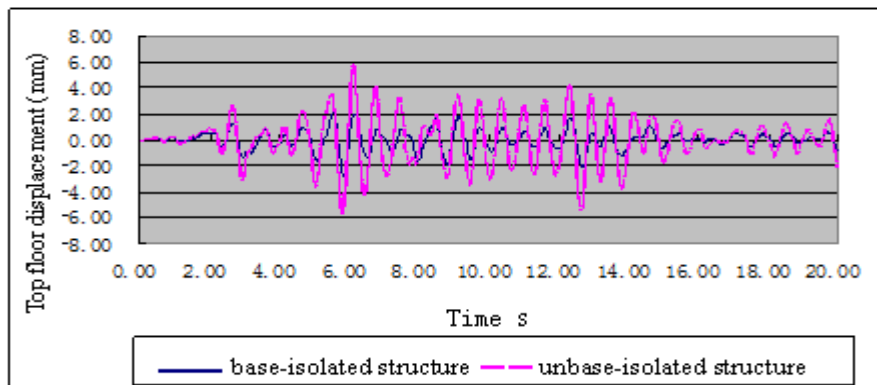


Fig. 5 Top Floor Displacement of Isolated and Un-isolated Structures

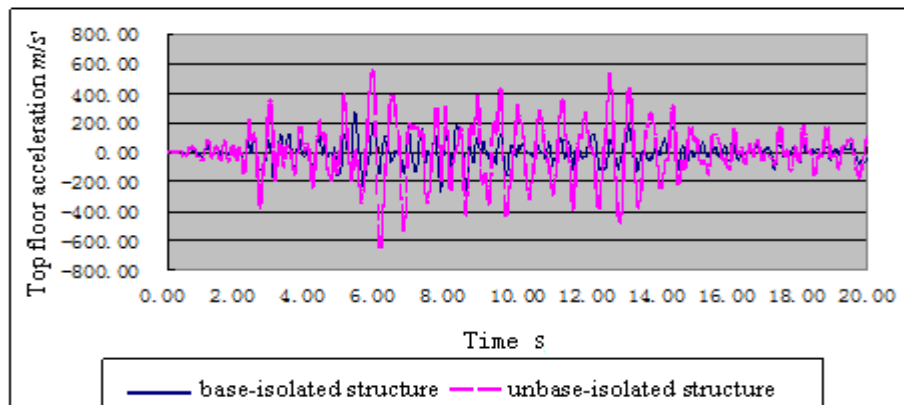


Fig. 6 Top Floor Acceleration Response of Isolated and Un-isolated Structures

Conclusion

1. Under rare earthquake action, the top floor displacement and acceleration of isolation structure significantly reduced, show that isolation device has obvious isolation effect
2. The new composite isolator is a kind of seismic isolation device with better performance.

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References

- [1] Z.Y. Sun, H.Wang, G.F. Zhao. Engineering Mechanics, 2010, Vol. 27(1): 160-164. (In Chinese)
- [2] M. Hamidi, M.H. El Naggar, A. Vafai et al. Earthquake Engineering and Structural Dynamics, 2003, vol. 32: 15-29
- [3] K.M. Zhang, X.J. Fan, Y.L. Huang. Journal of Xi'an jiaotong University. 2002, Vol. 36(1): 70-73. (In Chinese)
- [4] L.Li, H.F. Shi, J. Fan, A.W. Fan. Earthquake Resistant Engineering and Retrofitting. 2005, 27(3): 46-50. (In Chinese)