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Technical Note

Experimental and numerical studies of trench friction pendulum system

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1. Introduction

The friction pendulum system (FPS) proposed by Zayas *et al.* (1987) has been proven as an outstanding device for isolating energy induced by earthquakes through experiments and numerical analyses. An isolation system, called the X-Y isolator, consisting of two orthogonal concave beams interconnected through a sliding mechanism has been published by Roussis and Constantinou (2005, 2006a, b).

In this paper, an innovative base isolator called the trench friction pendulum system (TFPS), as shown in Fig. 1, has been proposed to update the capability of structures for resisting earthquakes (Tsai *et al.* 2006a, b). The proposed TFPS isolator consists of the upper and lower trench concave surfaces which orthogonally cross to each other, and an articulated slider. The TFPS isolator has simpler geometry while compared to the X-Y isolator at the expense of lack of uplift restraint. The slider located between the upper and lower trench concave surfaces possesses a special articulation mechanism to accommodate any rotations in the isolator induced by various loadings, to even pressure distribution on the slider and to maintain the stability of isolated structures during earthquakes. Lengthening the individual natural periods of a structure in two orthogonal directions

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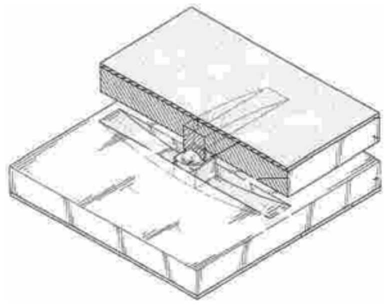

Fig. 1 A perspective view of trench friction pendulum system

can be designed by different radii in the upper and lower trench concave surfaces. In this study, a series of shaking table tests and numerical simulation of a steel structure isolated with TFPS isolators have been carried out to examine the efficiency of the TFPS isolator in seismic mitigation.

2. Shaking table tests and numerical simulation for structure isolated with trench friction pendulum system

To examine the efficiency of a structure isolated with the TFPS isolator under seismic loadings, a series of shaking table tests were performed in the Department of Civil Engineering, Feng Chia University, Taichung, Taiwan. As shown in Fig. 2, the tested building is a three story scaled-steel structure with a length of 1.1 m in each horizontal direction, and 0.9 m in height for each story. Each floor was equipped with a mass of 400 kg, and the total mass of the structure is about 2.16 tons. The natural frequency of the fixed base structure is about 10.6 Hz.

Fig. 3 shows the comparison of roof acceleration responses of the structure with and without the TFPS isolator under the El Centro. It was found from this figure that most structural responses have

Fig. 2 A TFPS-isolated structure on the shaking table

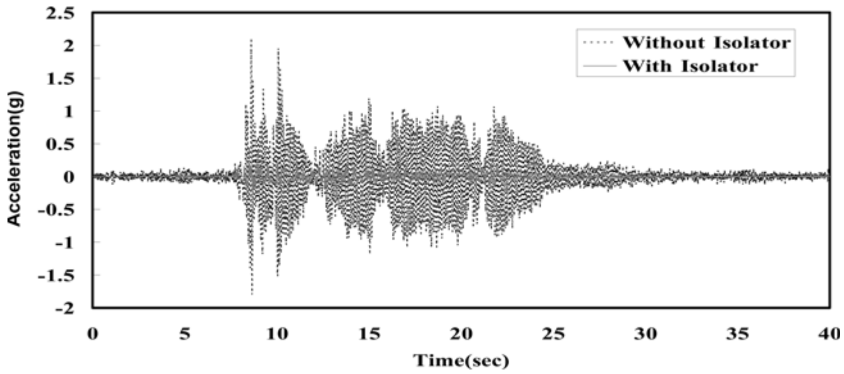

Fig. 3 Comparison of roof acceleration of structure with and without TFPS isolator under El Centro earthquake of 0.5g in PGA

Table 1 Comparison of roof acceleration between the structure with and without TFPS isolator

Max. Response	Roof Acceleration (g)			
Earthquake	PGA	EL Centro	Kobe	Chi-Chi
Fixed-Base Structure	0.38g	1.16g	0.79g	0.64g
	0.50g	1.55g	1.05g	0.85g
	0.63g	1.94g	1.31g	1.07g
TFPS-Isolated Structure	0.38g	0.21g	0.18g	0.18g
	0.50g	0.23g	0.19g	0.18g
	0.63g	0.24g	0.20g	0.21g

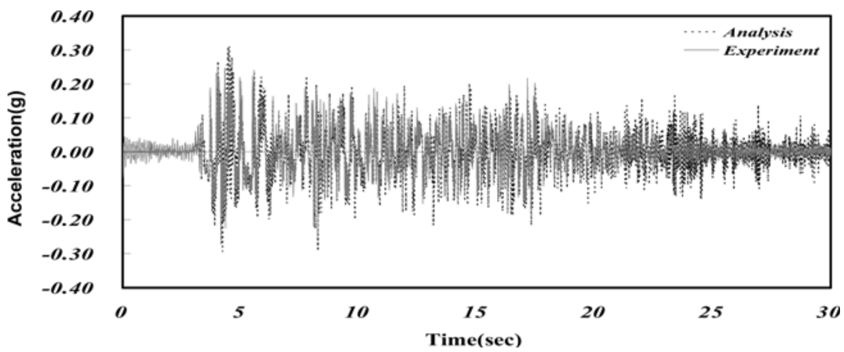

Fig. 4 Comparison of roof acceleration of structure with TFPS isolator between experimental and numerical results under El Centro earthquake of 0.5g in PGA

been significantly reduced by the TFPS isolator. Table 1 also shows that the proposed isolator provides an excellent efficiency in seismic mitigation.

In order to simulate the behavior of a structure with the TFPS isolator subjected to seismic loadings, the mathematical formulations derived in the paper by Tsai *et al.* (2006a, b) were used to simulate the response of the tested building with proposed isolators. Fig. 4 shows the comparison of the roof acceleration between experimental and numerical results under the El Centro earthquake of

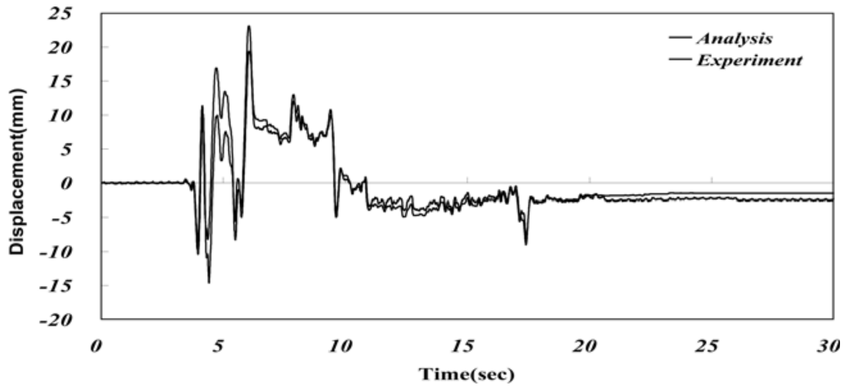

Fig. 5 Comparison of bearing displacement of structure with TFPS isolator between experimental and numerical results under El Centro earthquake of 0.5g in PGA

0.5g in PGA. Fig. 5 shows the comparison of the bearing displacement between experimental and analytical results. It is clearly demonstrated from these simulated results that the mathematical formulation can well simulate the response of a structure isolated with the TFPS isolator.

3. Conclusions

The TFPS isolator proposed in this study is capable of having different radii and displacement capacities in the two orthogonal directions. By virtue of different features in two directions, the isolator can be optimized in two directions individually, especially for a structure possessing very different natural frequencies in two directions. Furthermore, the good efficiency in seismic mitigation had been proven through shaking table tests in this study. In addition, numerical analyses can well predict the response of a structure isolated with the TFPS isolator under seismic loadings.

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