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Development of box-shaped steel slit dampers for seismic retrofit of building structures

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ABSTRACT

In this study a steel slit damper is developed by combining four steel slit plates to be used for seismic retrofit of structures. The proposed damper consists of four slit plates integrated into a box shape, and can produce larger damping force in relatively small size compared with the conventional slit plate dampers composed of single slit plate. Cyclic loading tests of two damper specimens are carried out to evaluate their seismic energy dissipation capability. The slit dampers are applied to seismic retrofit of an existing reinforced concrete structure using the procedure developed based on the capacity spectrum method. Nonlinear dynamic analysis of the model structure shows that the dampers installed using the proposed procedure are effective in restraining the building displacement within a given target performance limit state. The time history of the hysteretic energy dissipation shows that most seismic energy is dissipated by the dampers while the structural elements mostly remain elastic.

1. Introduction

Metallic dampers are considered to be efficient and reliable energy dissipative devices for mitigating earthquake-induced damage in structures. They can be easily implemented in practice as no special fabrication technique or expansive material is involved. They have been developed in many forms such as ADAS [1], buckling restrained braces [2,3], honeycomb dampers [4], and steel plate dampers [5]. They are generally placed between stories where inter-story drifts are relatively large, and dissipate seismic energy by hysteretic behavior of vertical steel strips.

A steel plate slit damper has been applied for efficient seismic design and retrofit of building structures. Kobori et al. [6] developed hourglass and honeycomb type plate steel dampers to reduce the seismic response of buildings. Chan and Albermani [7] carried out cyclic loading test of steel slit dampers made from wide flange sections and verified their seismic energy dissipation capacity. Saffaria et al. [8] developed a slit damper for enhancing strength and ductility of post-Northridge connections. Seo et al. [9] investigated the effect of the slit damper made of a shape memory alloy. Kim and Jeong [10] presented a ductility-based seismic design procedure of steel plate slit dampers for seismic retrofit of asymmetric structures. Lee et al. [11,12] developed slit dampers with non-uniform strips to reduce stress concentration when subjected to cyclic loadings. Lee and Kim [13] and Kim and Shin [14] developed a steel slit damper combined with friction dampers and showed its efficiency by numerical analysis. According to the results of previous research, the steel slit dampers generally show reliable performance for earthquakes and their behavior can be precisely predicted using simple formulas derived from elementary structural mechanics.

In this study a steel slit damper is developed by combining four steel slit plates into a box shape to be used for seismic retrofit of structures. They are designed to be installed as knee or diagonal braces between stories. The proposed damper with four slit plates integrated into relatively small size can produce larger damping force compared with the conventional slit plate dampers composed of single slit plate. Cyclic loading tests of the dampers are carried out to evaluate their seismic energy dissipation capability. The slit dampers are designed for seismic retrofit of an existing reinforced concrete structure using the capacity spectrum method, and their applicability is verified by nonlinear dynamic analysis.

2. Performance of box-shaped slit dampers

2.1. Configuration and modeling of the dampers

A steel slit damper is developed by combining four steel plates with slits and internal and external steel casings into a box shape. One side of each steel plate with slits is bolted to the interior casing and the other side is connected to the exterior casing. A cap plate is

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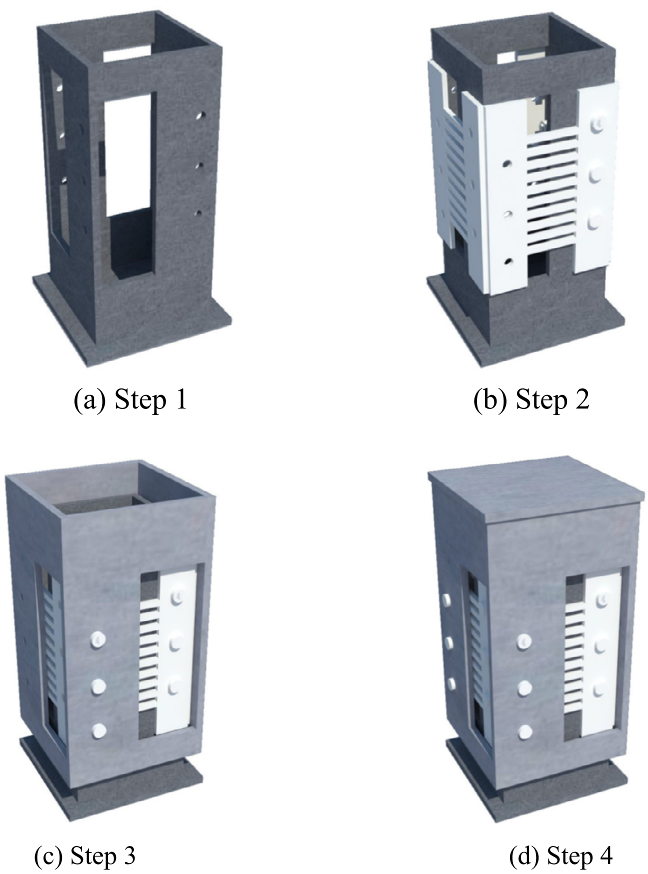

Fig. 1. Assembly sequence of the box-shaped slit damper.

welded to the exterior casing, and a bottom plate is welded to the interior casing. Fig. 1 shows the configuration and the assembly procedure of the box shaped slit damper. The damper is devised

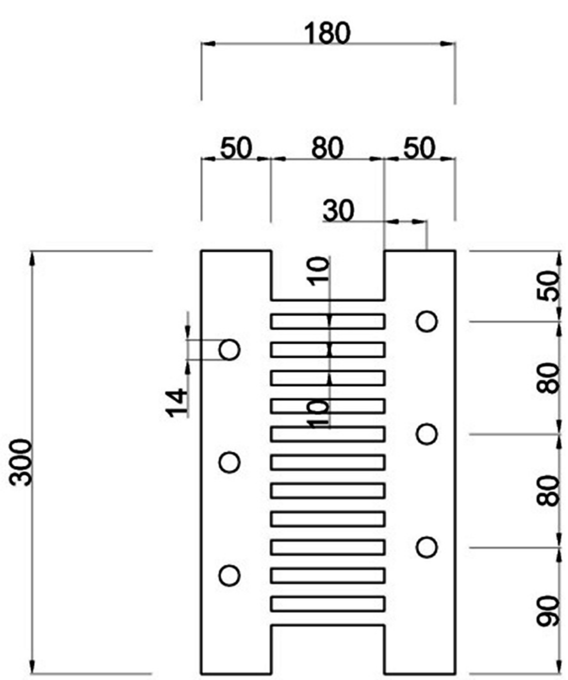

Fig. 2. Dimension of the steel plate with slits.

Table1
Dimensions of the box-shaped slit dampers.

Specimen	T (mm)	N	b (mm)	L_0 (mm)	b/L_0
1	8	10	10	80	0.125
2	16	10	10	80	0.125

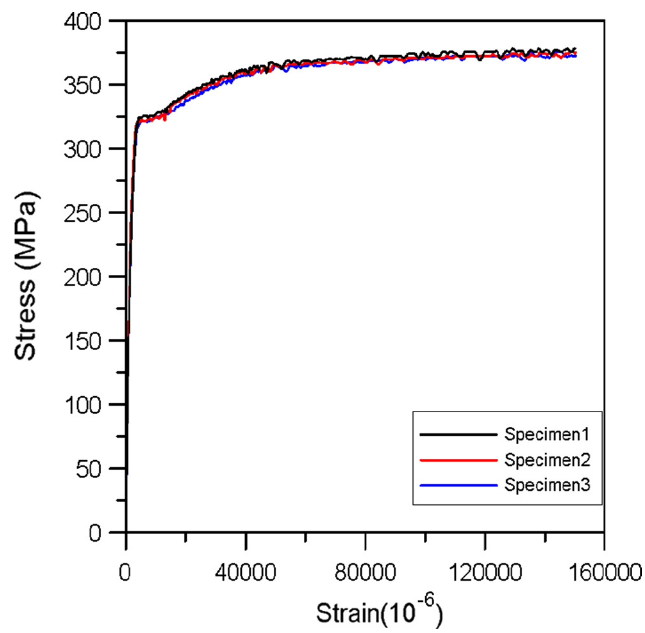

Fig. 3. Stress-strain curve of the steel obtained from coupon tests.

Table 2
Properties of the specimens.

Specimen	f_y (N/mm^2)	E (N/mm^2)	ε_y	P_y (N)	δ_y (mm)
1	325	205,000	0.00159	16,250	0.51
2	325	205,000	0.00159	32,500	0.51

Table 3
Axial displacements of the dampers installed with 30 and 45 degree slopes with beams corresponding to the three inter-story drift ratios.

Inter-story drift ratio	Displacement (mm)
(a) 30 degree	
5%	43.3
2.5%	21.7
2%	17.3
(b) 45 degree	
5%	35.4
2.5%	17.7
2%	14.1

to be installed as a knee brace at the beam-column joint. Fig. 2 shows the steel plate with slits having overall dimension of 180 × 300 mm with the length l_o and width b of slit column 80 mm and 10 mm, respectively. Two specimens are prepared with different plate thickness of 8 mm (specimen 1) and 16 mm (specimen 2). The number of slit column is 10 in both specimens. Table 1 shows the dimensions of the slit dampers. The overall dimension of the interior and the exterior casings of specimen 1 are 180 × 180 × 450 mm and 216 × 216 × 450 mm, respectively. The dimensions of the interior casing of specimen 2 are the same with those of specimen 1, and the dimensions of the exterior casing