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A Review of the Performance of Buildings Improved with Passive Structural Control Systems (Metal Dampers and Shear Walls with Self-Centered Steel Sheets)

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Abstract

Structural control can be classified as active, semi-active and inactive. The main purpose of the passive control system is to reduce the participation of the main structural elements in the loss of input energy by plastic deformation. Delivery metal dampers, despite their simplicity, as structural control systems, offer special features such as economic efficiency without the need for advanced technology or expertise to build and install the system. The shear wall of a self-propelled steel plate is a lateral force-resistant system that can be replaced with steel filler plates by providing system return and limiting ductility. In the present study, it was tried to determine the characteristics and achievements obtained by evaluating four new and valid researches in order to evaluate the research of structural control systems including metal (modern) dampers and self-centered steel shear wall. The results of the present study showed that the use of metal damping system (composite, grooved and passive) and self-centered steel shear wall caused the reduction of plastic damage in columns and beams. Also, the amount of floor drift and shear axial force have a relatively large reduction. Also, due to the high cost of building construction, the use of these devices reduces the economic value of building construction.

Keywords: Passive Control of Structure, Metal Damper, Steel Shear Wall, Earthquake, Energy Dissipation..

1. Note

Conventional structures scatter seismic input energy through the deformation of elastoplastic structural components. However, it may cause large residual deformation in the structure after large earthquakes [1]-[2]. To address this issue, passive control technology was considered [3]-[4]. The key technology in passive control, using the design of dampers in the event of an earthquake, is to cause the seismic energy entering the structure to be mainly dispersed by the dampers and reduce the damage.

Traditional methods for seismic assessment in flexible structures are gradually done, which lose their importance with the development of modern control systems such as energy dissipation systems [5]. Energy dissipation systems such as metal dampers and shear walls have been developed over the past four decades to control structural vibrations caused by earthquakes. Steel dampers are among the most well-known metal dampers used in buildings in the United States, Japan, Italy and Mexico. The steel plate attenuator consists of a series of X-shaped metal plates that waste energy applied to the structure by bending. The concept of self-axis steel plate shear wall (SC-SPSW) has been proposed as a lateral force-resistant system that can be easily replaced by energy dissipation steel filler plates by providing system return and limiting ductility. U-shaped steel sheet damper was proposed by Kelly et al. In 1972, which is one of the types of metal damper with flexural performance. Pampanin et al., Baird et al., Showed that this type of damper has a very good energy dissipation capacity. Many researchers have also done extensive work on shear samples of dampers and metal dampers with torsional performance [4–10].

2. Fundamentals of Study and Research Background

In the first study, SC-SPSW prototypes were designed based on the performance-based design method proposed by Clayton et al. (2012) with minor modifications as follows. These prototypes were designed as a lateral force-resistant system for a typical two-story building located in a high-seismic area. This sample building had the same dimensions of the plan, floor heights, floor mass and loading because the lower two floors of the three-story building were used in the steel project. The building was located in Los Angeles and had spectral response values in different periods presented in FEMA (2000) and Clayton et al. (2012). In the second study, five samples of full-scale circular metal dampers named LS-1 to LS-5 were produced. A horizontal rotational load is applied by the MTS electro-hydraulic actuator and is controlled by the displacement parameter. The loading protocol is applied according to the Chinese standard for the technical specifications of seismic energy dissipation of buildings (JGJ-297-2013). Four experimental samples were made in two types. One and three single thin-walled accordion tubes are used for the test program. Table 1 shows the characteristics of the samples used for the experiment. Also, a schematic view of the coupled and single specimens is shown in Figure 3. This figure describes the mechanism of AMD damper examples, connections, and how they work. Thin-walled pipes are made of steel in accordance with ASTM A653 standard with galvanized coating for the entire thickness of the sheet [25]. Three tensile tests were performed for 0.5 mm thick sheets according to ASTM A370-97a. Three samples were made at the Structural Laboratory of Malaysia University of Technology (UTM). In order for the specimens to be usable for several other experimental tests, the internal and external components of the BFD damper were designed to be rigid so that the rebars could carry all the loads applied by the bend. Therefore, these components were used for several tests to study the effect of different diameters, values and bending lengths of different steel rebars on the behavior of BFD dampers. In order to evaluate the effect of different bending lengths of rebars, the internal distance of the pipes was correctly reduced by welding two perforated plates inside the square pipes of the BFD damper [11–18]. In the first study, for GM 50 = 50, the test specimens remained partially elastic with signs of partial life of the sheet. The maximum relative displacement of the roof for both samples was less than 0.5% relative displacement. As expected, the FR sample was harder than the NZ sample. This is due to the instantaneous effects of reduced retraction (PT) beam-to-column pressure at relatively small displacement demands, which is not available for the NZ sample. For GM = 10, some rupture of the life plate was observed in both samples. Due to the localized stress and off-plane buckling along the free plastic edge stretched at the corner of the filler plate, the onset of the die plate is attributed to the development of wide tensile strains at the corners and sides of the filler plate, creating a gap in the beam joints. The column is further intensified. A proposed analytical equation to facilitate connection details to delay such rupture effects can be found in Dauden and Bruno (2014).

Rupture of the die plate has no significant effect on the strength of the sample. Because the rupture was minimal and the increase in the strength of the retracted frame with the increase in relative displacement demands was greater than the losses due to the rupture of the die plate. Partial local yield in the boundary frame was also observed in both samples during GM = 10. The maximum relative displacement of the roof reached approximately 2%. The residual relative displacement, determined from the free vibration response of the rotten earth motion, was less than 0.2%, which is considered the return threshold and is consistent with the out-of-pipe tolerances for new construction. Rupture began at the corners of the die plate near the boundary frame. For GM=2, rupture of the extra die was observed. The dense local yield in the boundary frame was negligible, and the boundary frames remained essentially elastic for 2=50 GM. The results show that while the FR specimen is returning, both specimens have a relatively low residual displacement. (Residual relative displacement less than 0.2%). The following figures provide illustrations of important areas in the research under evaluation.

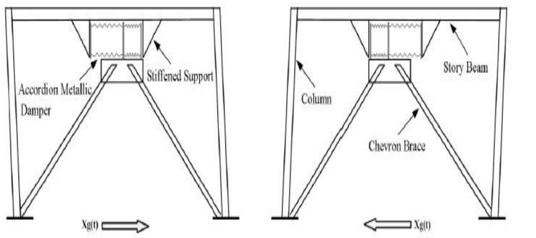

Fig 1. Installation scheme for AMD and the deformation mechanism

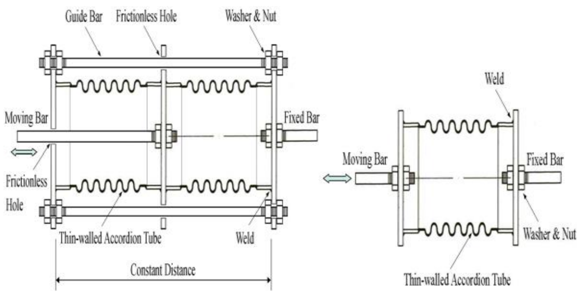

Fig 2. Schematic view of the specimens prior testing: a) coupled specimen; b) single specimen.

Fig. 3. Experimental test setup using uni-axial testing machine

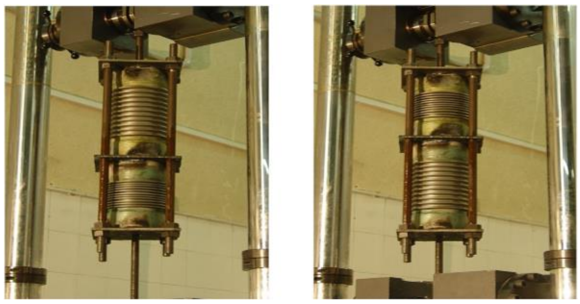

Fig. 4. Axial deformation of coupled Accordion Metallic Damper during cyclic test (Specimen 1)

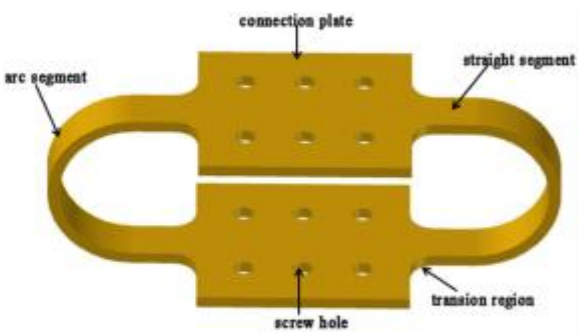

Fig. 5. Constitution of annular metal damper.

Fig. 3. Test setup of annular metal damper.

3. Conclusion

1- The research showed that the SC-SPSW system is able to achieve the proposed performance goals of buildings in areas with high seismicity. Laboratory instantaneous demands and the determined axial force of the strain gauges along the beams in the FR sample showed that the design equations presented in Davuden et al. (2012) are reasonable and conservative estimates of wing cradle demand in relative surface displacement ratios. Offer design. These full-scale experiments demonstrate the concept that SCSPSW systems can be a durable system resistant to lateral force. The results also show that while the desired level of seismic performance can still be maintained, Reduced the size of the border frame members.

2- 1- In the second study, it was found that the deformation capacity and energy dissipation capacity of the new damper are large, its hysterical behavior is stable and it is anti-depreciation. The performance of the damper in large deformations is in accordance with the conditions specified by the Chinese standard. It was also found that the new compound could be used to improve responses as well as reduce damage to building components under several seismic levels, including frequent earthquakes, moderate earthquakes and rare earthquakes. Multilevel metal dampers are much better at controlling displacement in reinforced concrete flexural frames with single metal dampers.

3- In the third study, it was found that the composite metal damping system has a large deformation capacity with sufficient energy dissipation. Energy dissipation in AMD is based on plastic deformation. Steel groove pipes are mainly invented in the form of bending due to the circular mechanism of axial deformation. In the samples, it was experienced that the deviation up to 70 mm and 70 cycles was created in a stable model without any rupture or damage. The stability of the residual loops showed that no failure, hardness degradation and reduction of resistance in the axial mechanism caused the deformation. Also, analytical studies on calibrated models showed that the deformation is axial in a metal damper with a uniform stress distribution in thin walls. Accordion tubes in AMD models move the waste rings with high flexibility compared to many existing metal dampers. Also, the amount of wasted energy, bearing capacity and elastic stiffness are controlled by changing the geometry parameters, and by selecting the appropriate parameters, the optimal shape for using this device can be obtained according to the seismic demand in a structure.

4- In the fourth research, it was found that BFD dampers can be in one of the highest positions in the list of metal yield dampers with three top factors: economic, low weight, replacement of rebars as energy absorbing members. While the proposed device shows promising results in this feasibility study, it is believed that more laboratory research is needed, such as seismic table tests on a frame equipped with a BFD damper before practical use of the device.

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