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A modified friction damper for diagonal bracing of structures

Habib Saeed Monir *, Keyvan Zeynali [1]

Civil Engineering Department, Urmia University, Urmia, Iran

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ABSTRACT

In this paper, the dynamic behavior of a recently developed friction damper has been demonstrated. It is made from nine steel stripes and nine high strength steel bolts and is applied in the diagonal bracing of structures. This device has a square geometric shape and should be installed in the square spans. During this research work, a prototype of the modified friction damper was tested by a universal machine. Then the damper was installed inside a SDOF steel frame and tested by the shaking table under several earthquake excitations. For numerical assessment of the system, the model of SDOF frame was created in SAP2000 and analyzed under the same excitations which had been applied during the shaking table tests. By comparing the results obtained from SAP2000 to those of experimental tests, the validity of numerical modeling was proved. In order to assess the behavior of damper in multi-story buildings, the model of a four story frame, with and without the modified damper, was created in SAP2000 and analyzed under several seismic records. The results were indicating that the lateral displacements and the base shears of the multi-story building have been significantly reduced by the installation of this modified energy absorber and a considerable energy has been dissipated by the damping system.

1. Introduction

During earthquake ground motions, large amounts of seismic energy are imported into structures. For preventing the structural collapse, conventional design methods allow structural members to dissipate the transmitted energy by inelastic cyclic deformations in the specially considered regions. These methods accept that some damage may happen, possibly to the extent that the structure is no longer repairable. In the last two decades, special vibration control systems have been developed to increase safety and reduce the damages during earthquakes [1]. These alternative protecting systems aim to control the structural seismic responses and reduce the energy dissipation demands on the structural members.

One of the most practical and reliable methods for mitigation of the seismic structural responses is the application of passive control systems. These systems can be classified as [2]: (1) seismic isolation systems and, (2) passive energy dissipation devices. Passive energy dissipaters absorb some of the vibration energy and reduce the plastic deformation of structural elements. They consist of precisely placed dampers or replaceable yielding elements that link various parts of the framing system [3]. The performed analytical and experimental studies on these protective systems strongly affirm their suitability for being applied in structures subjected to the seismic effects.

Passive energy absorbing devices are classified into two subdivisions: permanent and disposable devices. Permanent devices need no replacement after the absorption of energy and remain permanently in structures (although they may need some readjustments after the dissipation of energy). However, disposable systems usually need to be replaced after sever earthquakes. Friction dampers are permanent passive energy absorbing systems and exhibit a hysteretic behavior similar to that of metallic dampers. These devices use the resistance developed between moving solid interfaces to dissipate a substantial amount of the input energy in the form of heat. During severe seismic excitations, the friction devices yield at the predetermined loads and provide dissipation of energy by friction phenomenon while at the same time shifting the structural fundamental mode away of the earthquake resonant frequencies. Friction dampers are not vulnerable to the thermal effects and have a reliable performance with the stable hysteretic behavior [2].

Metal yielding absorbers and friction dampers differ in the used phenomenon for the dissipation of energy but they have similar design characteristics. The maximum force developed in a friction device and a metallic damper is controlled by the design slip-load and the yield load respectively. By considering high limiting loads in these dampers, the dissipated energy (area under the force–deformation curve) will be minimal since there will be no slippage within the device. In this case, the structure will behave as a braced frame. If the limiting loads are too low, the dampers will experience large inelastic slippages but again the amount of dissipated energy will be negligible [4].

PALL and DAMPTECH companies have presented commercially manufactured friction dampers for seismic structural control, which their schematic representations are shown in Fig. 1. In PALL dampers

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* Corresponding author. Tel.: +98 9143143125; fax: +98 4412773591.
E-mail addresses: h.s.monir@urmia.ac.ir (H.S. Monir), k.e.zeynali@gmail.com (K. Zeynali).

[1] Tel.: +98 9143143125; fax: +98 4412773591.

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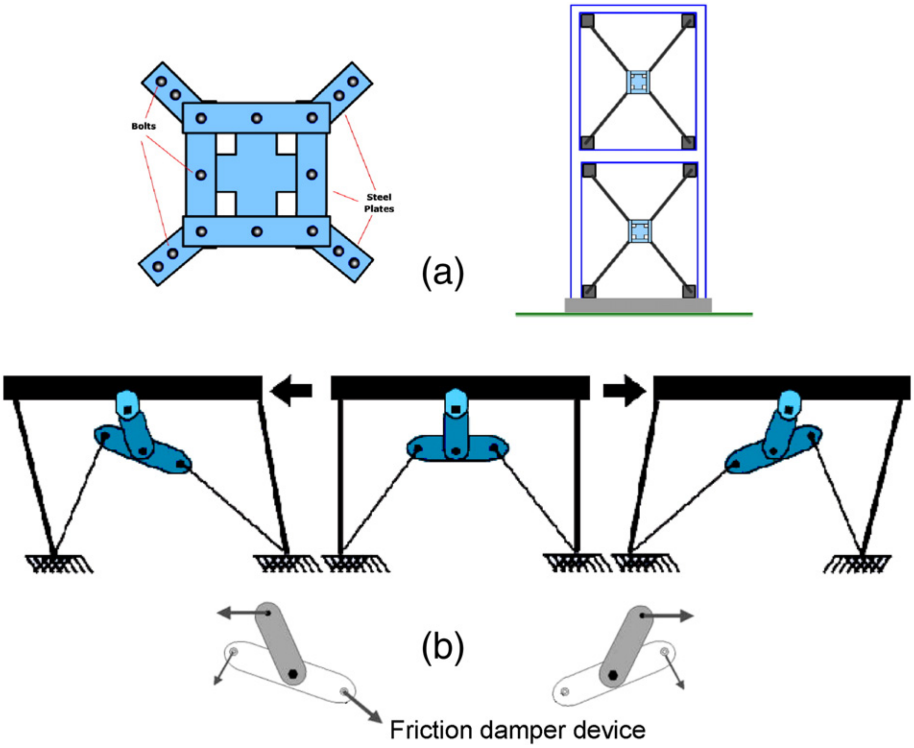

Fig. 1. Schematic representation of: (a) Friction device presented by PALL Company and (b) tension-only concentric bracing by DAMPTECH.

[5], there are translational movements between solid interfaces while in DAMPTECH devices, the movements are rotational [6].

2. The modified friction damper

In this research, a modified friction damper (MFD) has been developed for the improvement of the seismic behavior of steel structures under earthquake excitations. This damper is applied at the intersection of X-shaped diagonal braces and its friction hinges have only rotational movements. This causes the friction interfaces to be away from environmental effects. Fig. 2 is the schematic representation of MFD and Fig. 3 is its cross section.

MFD consists of 9 steel strips, 10 circular friction pads and 9 high strength steel bolts as shown in Fig. 3. Friction pads are located between steel strips and are clamped by bolts to create friction for the

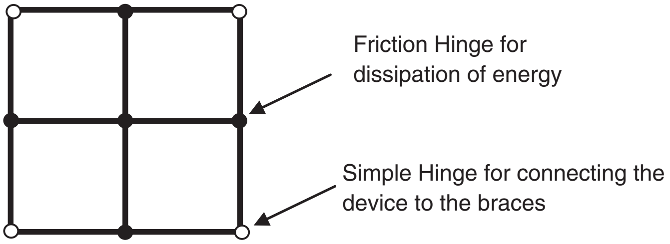

Fig. 2. Schematic representation of MFD.

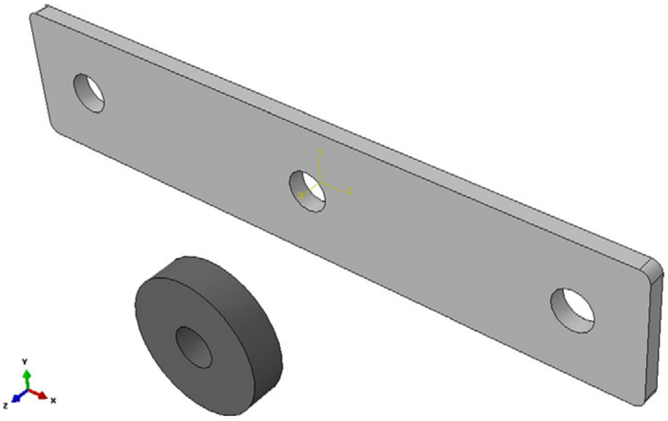

Fig. 4. The steel plate and the friction pad.

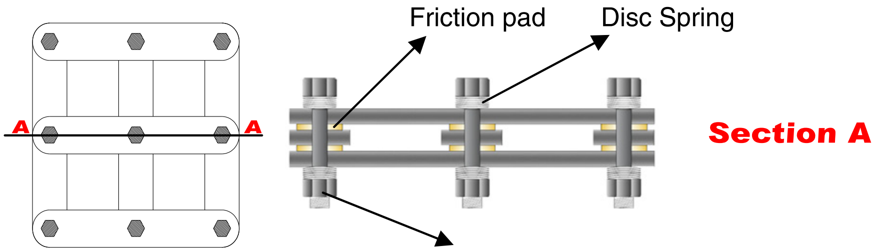

Fig. 3. Cross section of MFD.