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Review Evaluation of Steel Frame Improved with Bracing Systems Equipped with Yielding Dampers

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Abstract

Structural control systems are used to reduce structural damage in earthquakes. These systems have developed significantly over the last few decades. They can be broadly classified into three categories: 1) Passive control system in which structures are equipped with devices that do not require an external energy source. 2) Active control systems in which the structures are equipped with processing and transmission sensors and in which there are devices that need an external energy source to work, and 3) Semi-active control system to change There are structural properties that require little external energy. In the present review article, we have tried to fully evaluate this field of study by evaluating four valid articles in the field of evaluating the effects of energy consuming dampers in steel frames. The results of the studies showed that the presence of various dampers including new submersible metal dampers, hybrid, viscoelastic, submersible strip wave and two-level submersible torque has caused the performance indicators of the steel frame, including; Shear strength, displacement of structural floors, energy, hysterical performance (hysteresis curve), etc., which indicates the performance of the structure, has been improved and in all evaluated indicators, the structure has increased the level of performance.

Keywords: Steel Frame, Damper, Yielding Brace, Passive Control, Hysteresis Curve.

1. Note

Passive energy dissipation systems are widely used in recent years as a structural control system against natural hazards to protect structural components against damage, control the dynamic performance of structures and increase the seismic resistance of structures. Passive energy dissipation systems are divided into two categories: A) seismic isolators and B) energy dissipation systems that are divided into displacement-dependent systems. Although energy dissipation devices have been widely used to protect structures since 1990 due to their low cost and efficiency, some of them still have drawbacks [1-3]. Hardness and damping tools are the most popular energy dissipation tools. These devices can withstand a large amount of earthquake input energy with a predictable performance. These tools must have a certain relative displacement to dissipate energy. Therefore, in minor earthquakes with low displacement, they do not dissipate energy and in moderate earthquakes may have little energy loss [3-19]. In Japan, Kimura et al. [20], Mishizuki et al. [21] began research on dampers in arc braces in 1973. The first type of these elements was implemented by Wantanabe, Wada et al. In 1988 [22]. In 1989, arc braces were applied to 10- and 15-story high-rise steel frame office buildings in Japan [23]. Seridar et al. [24] and Kovahra et al. [25] improved the performance of the dampers in the arc braces in terms of capacity bearing and configuration.

2. Evaluation of Proposed Damping Systems in The Studied Research

Ranaei and Aghakouchek (2019) proposed a hybrid energy dissipation system with viscoelastic dampers and a yielding band wave with a multilevel vibration control system. The proposed damper consists of grooved (narrow) submersible (bending) strips that are connected to each other and parallel to each other and then connected vertically to the viscoelastic damper via a connecting link. Slot holes on the joint allow the maximum displacement amplitude to be controlled in the viscoelastic damper. Valves that attach the viscoelastic damper to the junction holes prevent the viscoelastic layers from rupturing due to large deformations [26]. The structure of a composite damper is shown in Figure 1.

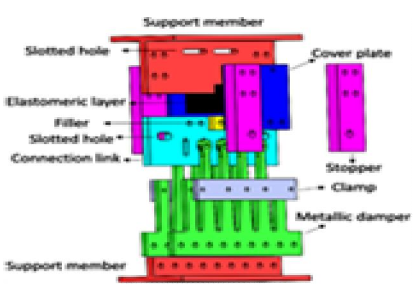


Fig. 1. The proposed damping structure in Ranaei and Aghakochak research [26]

Zibaskhan et al. (2019) performed a laboratory evaluation on a new yielding bending damper. In this study, a submersible damping device (PBYD) has been developed for use in concentric bracing frames. Some possible PBYD installation settings in concentric bracing frames are shown in Figure 2. The same capacity of this device in tension and tension makes a single diameter brace in each frame sufficient. The use of this device in Chevron and V bracing frames reduces the amount of shear force in the beam located in the brace opening due to unbalanced compressive and tensile forces. The axial force of the brace member due to lateral loading is transmitted to the PBYD device. The PBYD mechanism is designed so that the axial force is converted into a pure bending anchor converted on the damper plates. The details of PBYD that changes the axial force of net bending in thick plates are shown in Figure 3. To maintain the symmetrical geometry of the device, a four-point loading system is used to create a net bend in the middle area of the damper plates. The transfer of axial force to the intermediate supports and from there through the dissipation plates to the lateral limiting blocks is shown in Figure 4 [27].

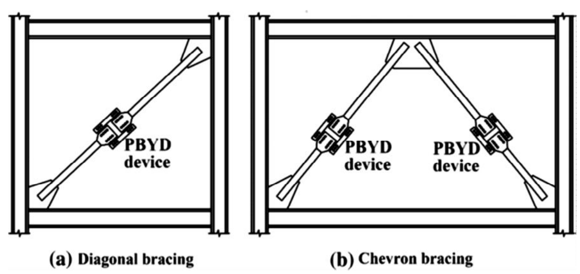


Fig. 2. How to place the damper system in the center brace in the research of Zibaskhan et al. [27]

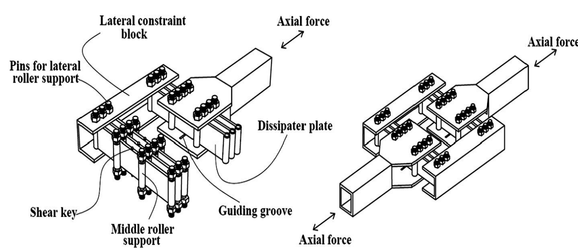


Fig. 3. Structure of conversion of axial force to pure bending in a damper proposed by Zibaskhan et al. [27]

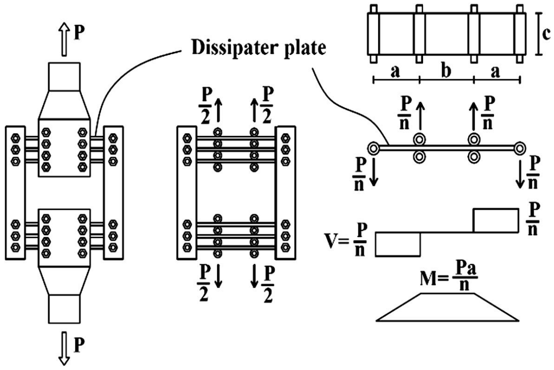


Fig. 4. Diagram of axial force and bending in a damper proposed in the research of Zibaskhan et al. [27]

Lee et al (2019) performed a laboratory evaluation on two-level surrender surreptitious braces. Two-level surreptitious bow surge arresters consist of limited cylindrical braces and metal tubular braces (Figure 5). The braced pipe in normal torque braces is filled with mortar, it enters the pipe damper with only a small piece and the gap between them is for easy installation in the corner of the pipe damper. One end of the tube damper is free and the other end is connected to the arc brace with the end plate fixed in the knot area. The main components of a tube damper are metal strips that can be yielded when the relative displacement of their two ends reaches a certain value. To achieve the delivery mechanism, the free end of the strips should be secured with filler tubes to the torque braces by filler welding [28].

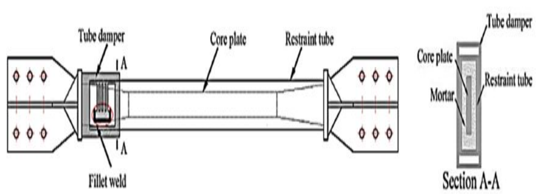


Figure 5 - Archetype damping structure proposed in the study of Lee et al. [28]

Gary et al. (2017) performed a complete experiment on a steel frame with a yielding bracing system. In this study, a steel frame with a yielding bracing system is made of two welded cast iron joints to the end of an old bracing member (Figure 2). Each joint has one arm and several resilient elastic teeth. The yielding teeth are screwed to a specially designed mesh plate, connected to the beam-column connection [29]. All damper teeth are triangular in shape, resembling a yielding metal damper [30].

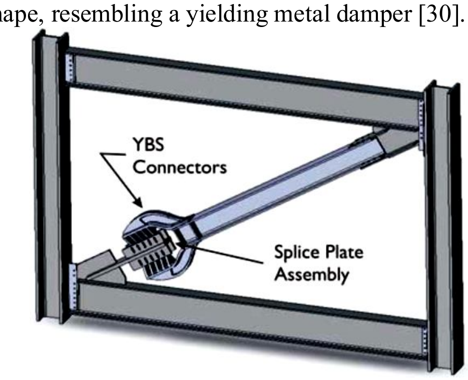
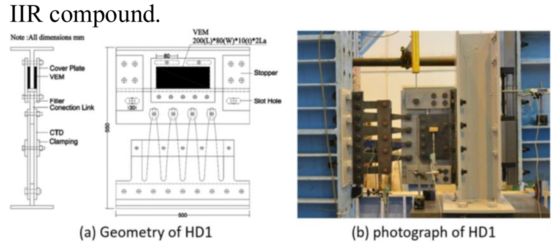


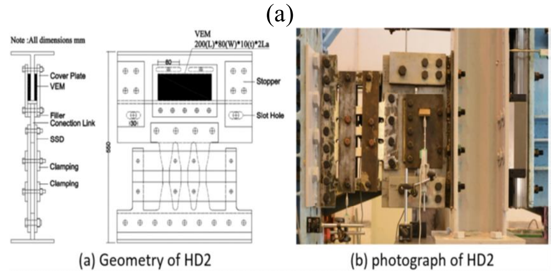
Fig. 6. Proposed damper structure in research et al. [30]

3. Evaluation of Research Method

In Ranaei and Aghakouchek (2019) research, three samples were made with different geometric strips, different elastomeric compositions and different loading conditions and standards. Initially, two samples of hybrid dampers were made as follows; (A) The proposed composite damper 1 consists of a toothed damper and a viscoelastic damper based on the NR compound, and (b) consists of a grooved damper (bean) and a viscoelastic damper based on the IIR compound.



(a)

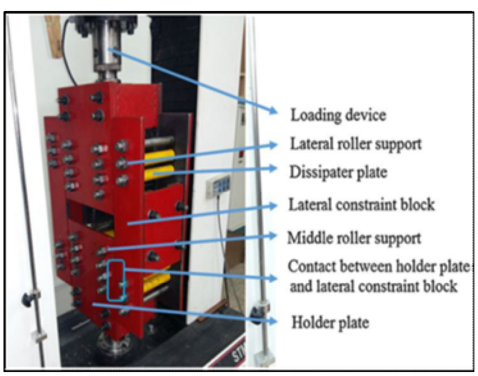


(b)

Fig. 7. Combined dampers proposed in the research of Aqakoochak and Ranaei [26]

In the research of Zibaskhan et al. (2019), a total of 16 samples of the proposed damping device have been prepared and tested in the laboratory. In order to compare the performance of the configured device with different design parameters, the samples were designed at two final capacity levels. 11 samples with a final design capacity of 50Kn (sample 1-11) and 5 samples with a final design capacity of 90Kn (sample 12-16) were designed. Depreciation plates are made of St37 steel with nominal performance and final stress of 240 and 370 MPa, respectively. Other rigid parts are made of 12 mm thick St52 steel plates with nominal performance and final stress of 360 and 520 MPa, respectively.

(a)



(b)

Fig. 8. The structure of the damper and the plates submitted in it in the research of Zibaskhan et al [27]

In the study of Lee et al. (2019), two samples of main plate dampers (20 mm × 60 mm) and delivery tube (200 mm×80mm×10mm) were designed (Fig 9).

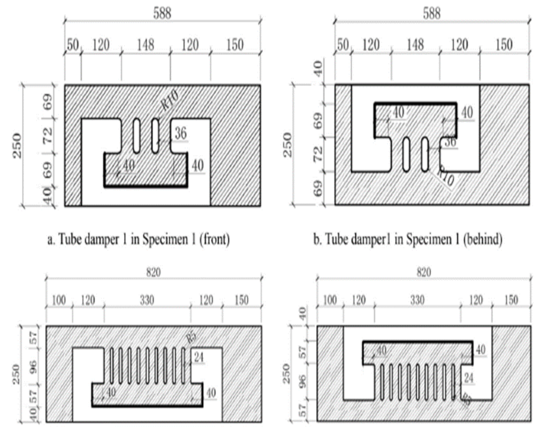


Fig. 9. Structure of the proposed combined dampers in the research of Lee et al. [28]

In Gari et al. (2017), a prototype with real dimensions of a steel frame with a surreptitious bracing system is designed for the second floor bracing of a six-story office building. A prototype of ten types of yielding teeth, every 250 mm (10 inches) long, every 250 mm (10 inches) wide for the floor and 34 mm (1.34 inches) thick is shown in Figure (3). The nominal operating capacity of the designed brace is 1150Kn (250Kn). The elastic stiffness of the brace in the prototype is 140Kn/mm (799Kpa) and the elongation of the brace is 39.7 mm (1.56 s) (Fig 10).

(a)

(b)

Fig. 10. Experimentation on a proposed hybrid damper in research et al [29]

4. Results

In Ranaei and Aghakochak (2019) research, experimental results show stable hysterical behavior without any sudden decrease in strength, stiffness and energy dissipation capacity proportional to multilevel vibrations. It was observed that the damping capacity for the displacement amplitude of 15 mm in viscoelastic dampers is at least 10%, while the amplitude of CL displacement was measured by LVDT3, which should be less than 2 mm. This indicates that at this stage the remaining metal dampers are in the elastic stage and there is no reduction in capacity. After performing successive cycles and in the last cycle (seventh cycle), the experiment was stopped because the maximum and minimum strength in zero displacement was reduced by 15%, while in composite dampers 1, there were no cracks or damage. Is. However, at the beginning of the loading protocol for the second sample, the hybrid damping 2 with a displacement of 75 mm broke one of the metal damping strips.

In the numerical evaluation section, using Abacus software, a separate strip of metal damper was first modeled and its nonlinear behavior was investigated. Each of the individual bands was modeled using three-dimensional solid elements and reduced quadratic elements (C3D20R). Coupon tensile test information is used to define the linear and nonlinear behavior of metal strips. Numerical results showed that the plastic deformation with distribution is quite uniform, the results were observed above the height of the strips as expected. In the end, it turned out that the matching of numerical and laboratory results is very appropriate.

In the research of Zibaskhan et al. (2019), it was found that increasing the axial deformation of the PBYD device increases the rotation of the consumable plate in the middle part. Due to the juxtaposition of the wear plates, a significant increase in the rotation of the wear plate at the center abutment limits slippage at the roller bearings. These conditions increase the axial force of the consuming plates and lead to an increase in the nonlinear stiffness and strength of the consuming device in large axial displacements. The PBYD device also shows a type of behavior in pressure and tension. Due to the nonlinear increase in strength, strain hardening and slip of the wear plates, the final strength of the specimens in large displacement is significantly higher than the functional strength.

In the study of Lee et al. (2019), it was found that good hysterical curves were obtained which showed that the energy dissipation capacity of the extinguished attenuator was good. The results showed that the final resistance in the tube damper was very good.

In Research et al. (2017), the experimental results showed that the prototype of the steel frame with the yielding bracing system had excellent flexibility. Both specimens have exceeded the requirements of the plastic displacement aggregation protocol in bracing systems by more than 200 times the yield displacement.

5. Conclusion

- ❖ The results showed that the design, fabrication and use of new hybrid damping systems including viscoelastic and metal dampers, yielding braces, new yielding dampers with pure bending mechanism and two-level submersible buckling braces caused that:
- ❖ Increase energy consumption throughout the steel frame.

- ❖ Due to the reduction of vibrations caused by applied earthquakes and the reduction of the final displacement of the frame, the hardness of the steel frame will increase.
- ❖ In the case of small vibrations, the effectiveness of the proposed dampers is low. But in large earthquakes, the effect of dampers on increasing the performance level of the structure is greater.
- ❖ The results of numerical studies and laboratory studies are well matched with a very low error rate.

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