A Review of Triangle Yielding Metal Dampers (TADAS) in Braces

Alireza Saiedi,1,1

1B.S Student of Islamic Azad University of Pardis branch

Corresponding Author E-mail: Alireza_s.d@yahoo.com

Abstract

Resistant existing buildings or design of earthquake resistant buildings is one of the issues in earthquake-prone countries. Using metal dampers as an energy consuming system is an acceptable way to control the failure of structures and improve their seismic performance. These energy absorbing systems deplete the earthquake input energy by deforming the metal parts used in them and as a result of their entry into the plastic area and creating many deformations, by increasing the damping of the structure. In structures where dampers are used, the presence of dampers reduces the energy received by other members of the structure and does not cause much deformation in them, that is, before the compression brace buckles, the damper surrenders and leads to increased ductility of the system. Among the types of dampers, TADAS is one of the most effective and economical tools for absorbing seismic input energy into the structure of triangular-shaped metal dampers. These dampers are mostly used in the bracing system and have the ability to absorb a lot of energy under the behavior of hysteresis. These dampers are embedded in the structure so that they are deformed due to the relative displacement due to lateral load. In this review article, we will review the studies and research done on this system in recent decades, and while evaluating the current situation, we will identify and discuss some research gaps for future studies.

1. Introduction

Wind, traffic, and earthquakes are all common dynamic and environmental loadings that civil structures are subjected to. Earthquakes, in particular, cause extensive damage to building and bridge systems. For example, during the 1985 earthquake in Mexico City, more than 132 buildings collapsed or were severely damaged. The Loma Prieta earthquake struck Northern California in 1989, causing extensive damage to over 200 buildings[1]. Structural vibration controls have been extensively developed and successfully applied in various civil structure locations to prevent or mitigate such harms. Passive, active, semi-active, and hybrid structural vibration control systems are the four main categories[2, 3], and many state-of-the-art review publications briefly address these categories[2–13]. Control systems can be used to mitigate seismic hazard in modern structures as well as in retrofitting low-lateral-strength structures like precast frames[14–20]. Passive systems are one of the most common structural vibration controls among all categories[21–26] because they are inexpensive and protect structures from seismic loads without requiring any external energy or a control algorithm during operation. Passive control systems are distinguished by the fact that they provide additional damping and/or stiffness to the structure without requiring any external energy. Seismic isolation systems and energy dissipation devices are two types of such systems (dampers). Various seismic isolation systems have been installed and implemented in large-scale civil structures with high logistic value over the last few decades[27–30]. Hysteresis devices, relativistic devices, tuned mass dampers, magnetic negative stiffness devices, resetting passive stiffness devices, and viscous dampers are all types of passive energy dissipation devices[31]. Hysteresis devices are often classified as metallic or friction dampers, with energy dissipation that is independent of loading rate. The inelastic deformation of the constitutive material of metallic dampers dissipates steam. Metallic dampers have a number of advantages over active and semi-active dampers, including stable hysterics behavior, rate-independent rate, independent temperature tolerance, and durability, as well as the fact that practice engineers are familiar with their material behavior. A number of researchers have documented the utility of passive devices, as noted in the literature. It is also concluded that, among the various forms of passive dampers, metallic dampers have gotten the most attention from civil engineers so far. Skinner et al.[32], Kobori et al.[33], and Nakashima et al.[34] highlighted the advances of metallic dampers, despite the lack of updated studies that present and advance detailed reviews of metallic control systems. As a result, this paper provides a detailed state-of-the-art study of metallic damper production and application in structural vibration control systems since the 1970s.

2. Testing Procedure of Metallic Damper

Two tests can be used to measure the efficiency of metallic dampers: (i) the quasi-static cyclic test and (ii) the shaking table test. The quasi-static test may be performed on the energy dissipation system itself or on a structure with energy dissipation devices installed. The quasi-static cyclic test is a normal procedure for determining the ability of an energy dissipating system on which deformation is placed, according to FEMA 461[35]. Loading may be in the form of shear, bending, or torsion in the quasi-static cyclic test, with the loading procedure consisting of many gradual or constant amplitudes of cycle displacements. The loading rate is not a significant factor during the test since metallic dampers are rate-independent. The damper must be assembled on a scaled or full-scale structure for the shaking table test, depending on the shaking table dimensions. In the simulation, artificial or real ground motion records are used as input loading. FEMA 461[35] contains detailed information on both studies.

3. Hysteresis Behavior of Metallic Dampers

The hysteresis behavior of metallic dampers are caused by the nonlinear behavior of metal materials. Metallic materials have an advantage in terms of heat dissipation.
In linear systems, dynamic energy is particularly important. The behavior of metal materials under cyclic loading is briefly described in this section. When the stress level approaches the elastic limit, the material recovers as the material unloads under cyclic loading. Even after unloading, the strains obtained during loading recover as the material temperature is below Af after Figure 1 depicts general schematic hysteresis loops of metallic materials. [37] a However, depending on the geometry of the metallic dampers, the hysteretic behavior can vary slightly. Metals like steel, aluminum, lead, and copper have similar hysteretic patterns. A bilinear or trilinear Elastoplast model is often used to simplify the stress–strain relationship of steel materials. The hysterics behavior of form memory alloys (SMA) differs slightly from that of other metals. Based on the material temperature in relation to the authenticate finish temperature, Af [38], SMA exhibits two distinct behaviors. After unloading, the strains obtained during loading recover as the temperature rises above Af. During this operation, a large amount of energy is dissipated without any residual strains, a phenomenon known as super elasticity. If the material temperature is below Af after unloading, residual strains remain, and if the material reheats again, residual strains recover. The shape memory effect is the name for this phenomenon.

Figure 1. Hysteresis behavior of a metallic and b SMA materials

4. Steel Dampers

Kelly et al. proposed the first steel dampers in 1977. [39] In the early 1970s. After that, the torsional U-strip damper is used. As shown in Fig. 1, a beam damper, a flexural beam damper, and a single-axis damper were designed and tested for use in structures. [52] 2a–d. The U-strip damper is made up of a steel strip in the form of a U that is positioned between the moving plates (Fig. 2a). The U-strip damper is only deformed in one direction, resulting in a wide elastic range deformation. The torsional beam damper is made up of a square or rectangular plate with fixed ends, with the middle section subjected to torsional and flexural movements (Fig. 2b). The torsional beam damper has a high load-bearing capacity and can be used at the foundations of buildings and structures caused by extreme earthquakes. The flexural beam damper, on the other hand, is a little more complicated. The damper’s main component is a square or circular portion that is anchored at the bottom and top and allows rotation and displacement (Fig. 2c). This seismic damper is durable and dissipates seismic loads in both directions. A large beam with a high loading capacity makes up the single-axis beam damper (Fig. 2d). Tyler [40] proposed a tapered-steel energy dissipation system that combines two or more beams to form a compact damper that is ideal for the diagonal portion of flexible frame structures. This system is made up of a cantilever made up of a tapered shaped round steel bar or steel plate welded to the anchorage plate at the bottom (Fig. 2e). The system dissipates energy by taking advantage of the plastic deformation of steel. Pinelli et al. [41] suggested a steel damper design based on a steel tube. A rectangular steel tube is cut into a taper shape on two sides of the proposed device, distributing stresses evenly along the tapered portion of the tube (Fig. 2f). Another form of steel damper is the buckling-restrained brace (BRB), which was first introduced by Takeda et al. in 1976 [42]. As can be seen in Fig. 3a, the BRB, consists of traditional bracing (as the core) encased in a square hollow steel portion filled with mortar material. The steel core can withstand axial loads, while the infilled material prevents shear transfer when compressed. When compressive loadings were formed for the BRB, including circular core (CBRB), cross and crosswise core, and linear core (Fig. 3c) [43, 44]. Since 1987, these have been widely implemented around the world, especially in Japan and the United States [45]. For example, Black et al. [44] performed extensive research on the BRB and came to the conclusion that it is a more effective and realistic alternative to traditional bracing systems. Zhao et al. [46] developed another BRB system called the angle buckling-restrain brace (ABRB) to key address issues with BRBs such as inconsistent material behavior, low-cycle fatigue existence, and steel core geometric imperfections. 3a. The ABRB is made up of four angled steel plates with stiffeners and connectors welded to the ends. Two more angle plates are welded together to form a square tube around the four angle plates. At the weld ends of the angle plates, ABRB failure has been observed. Furthermore, during rapid loadings, the steel core was designed to stay in the elastic range. The H-type steel unbuckling brace (SUB) was designed by Hao et al. [47] and consists of a steel plate core confined in a steel element. As shown in Fig. 1, the steel core plate’s end is attached to Phillips formed steel plates. 3rd Dimension Under compression and tension loadings, the confining factor prevents the steel core from buckling. The SUB damper adds stiffness to the frame system to regulate structural displacement. Dongbin et al. [48] recently proposed a new form of BRB damper with a circular heart (CBRB). The damper is made up of three circular steel tubes, with the central tube with slotted holes being restrained against out-of-plane buckling deformation by the inner and outer tubes. The core tube is spot welded to the restrained tubes in the center. The CCBR is much lighter than current BRBs. Bergman [49] suggested the added damping and stiffness (ADAS) system, which is a well-known metallic damper. ADAS is made up of X-shaped steel plates that are bolted together in parallel to the base plate to provide additional damping and stiffness to the structure. On the basis of the ADAS principle, Tsai et al. [50] created the triangular-plate added damping and stiffness (TADAS) system. TADAS works in the same way as ADAS, with many triangular steel shaped plates welded in parallel to the base plate and the narrow end of one plate to another plate. To improve the damping improvement moment resistant frames, both ADAS and TADAS dampers are recommended. Shih et al. [51, 52] designed a rhombic ADAS damper with hinge supports on both ends made of low yield strength steel. Unfavorable axial forces on the plate are eliminated by the hinge supports. Low yield strength steel’s strain hardening property aids in preventing local cracks in the damper. Furthermore, the mechanical properties of low yield strength steel minimize yield displacement while improving the damper’s energy dissipation capacity and ductility [53]. Damper symmetry also minimizes the effects of welding damper efficiency.
Declarations of Conflict of Interests

The author declares that there is no conflict of interest. There are no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References


