Engineering Structures 33 (2011) 3647–3656

Contents lists available at SciVerse ScienceDirect

Engineering Structures

journal homepage: www.elsevier.com/locate/engstruct

Numerical and experimental study of hysteretic behavior of cylindrical friction dampers

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ARTICLE INFO

Article history:
Received 6 December 2010
Received in revised form
26 July 2011
Accepted 28 July 2011
Available online 26 August 2011

Keywords:
Friction damper
Energy dissipation
Hysteretic loading
Passive control

ABSTRACT

Frictional dampers utilize the mechanism of friction for absorbing and dissipating the energy imparted to the dynamic systems. Frictional dampers are widely used in mechanical systems in various industries in order to mitigate the impact and vibration effects. Frictional dampers are also utilized in structures as means of passive control to improve the seismic behavior of structures.

In this investigation, an innovative type of frictional damper called cylindrical friction damper (CFD) is proposed. This damper consists of two main parts, the inner shaft and the outer cylinder. Dimensions and properties of the main parts are defined based on seismic demand of structures. These two parts are assembled such that one is shrink fitted inside the other. Upon application of proper axial loading to both ends of the CFD, the shaft will move inside the cylinder by overcoming the friction. This in turn leads to considerable dissipation of mechanical energy. In contrast to other frictional dampers, the CFDs do not use high-strength bolts to induce friction between contact surfaces. This reduces construction costs, simplifies design computations and increases reliability in comparison with other types of frictional dampers.

The hysteretic behavior of CFD is studied by experimental and numerical methods. The results show that the proposed damper has great energy absorption by stable hysteretic loops, which significantly improves the performance of structures subjected to earthquake loads. Also, a close agreement between the experimental and numerical results is observed.

1. Introduction

Many different types of energy dissipation devices have been developed and tested for seismic applications in recent years, and more are still being investigated. Frictional devices dissipate energy through friction caused by two solid bodies sliding relative to each other. Pall and Marsh [1] proposed frictional dampers installed at the crossing joint of the X-brace. Tension in one of the braces forces the joint to slip thus activating four links, which in turn force the joint in the other brace to slip. This device is usually called the Pall frictional damper (PFD). Wu et al. [2] introduced improved Pall frictional damper (IPFD), which replicates the mechanical properties of the PFD, but offers some advantages in terms of ease of manufacture and assembly. Sumitomo friction damper [3] utilizes a more complicated design. The pre-compressed internal spring exerts a force that is converted through the action of inner and outer wedges into a normal force on the friction pads. Fluor Daniel Inc. has developed and tested another type of friction device which is called Energy Dissipating Restraint (EDR) [4]. The design of this friction damper is similar to Sumitomo friction damper since this device also includes an internal spring and wedges encased in a steel cylinder. The EDR utilizes steel and bronze friction wedges to convert the axial spring force into normal pressure on the cylinder. A full description of the EDR mechanical is given in [5]. Constantine et al. [6] proposed frictional dampers composed of a sliding steel shaft and two frictional pads clamped by high strength bolts. Li and Reinhorn [7] verified the seismic performance of a reinforced concrete building with frictional dampers through a combined experimental and analytical study. Grigorian et al. [8] studied the energy dissipation effect of a joint with slotted holes both analytically and experimentally. Mualla and Belev [9] proposed a friction damping device and carried out tests for assessing the friction pad material. Cho and Kwon [10] proposed a wall-type friction damper in order to improve the seismic performance of the reinforced concrete structures. Numerical models of friction dampers for multi degree of freedom structures were proposed by Bhaskararao and Jangid [11]. The results were validated with those obtained from an analytical model. Park et al. [12] proposed a new equivalent linearization technique for a friction damper–brace system based on the probability distribution of the extreme displacement. Lee et al. [13] proposed a design methodology of friction

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0141-0296/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.engstruct.2011.07.029