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Original Research Article

# Experimental and numerical investigation of rotational friction dampers with multi units in steel frames subjected to lateral excitation

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ABSTRACT

Performance of rotational friction dampers with two and three units was evaluated experimentally because of a lack of research data on performance of these dampers with multi units. Results of multi-unit dampers were compared with the results of one-unit damper. Increasing trend in dissipating energy was observed. Then, the behavior of these dampers in frames of 3, 7 and 12 stories was studied by modeling the damper directly. Nonlinear time history dynamic analysis was used. It was observed that by increasing the number of stories in the buildings, dampers with multi units should be used to perform properly against earthquake. The equivalent damping method was also investigated to consider the effects of this damper without direct modeling of the damper. Effective damping of the frames equipped with this type of damper was estimated and used in nonlinear time history dynamic analysis and it was observed that the responses of these structures with dampers can be approximated by the responses of moment resisting frames without damper but with damping equal to the effective damping due to rotational friction damper.



## 1. Introduction

Vibration control is a fairly new category in different methods of improving the seismic behavior of structures and designing seismic resistant buildings. Based on this concept, response of structures under dynamic loads is controlled using embedded appropriate devices and equipments by which displacements are reduced and dynamic response is improved. In the last two decades considerable progress has been achieved in control of structures. These control systems are classified into three categories which include: active control, semi-active control and passive control [1].

Using energy dissipation devices or dampers is one of the control methods for structures subjected to seismic loads. These devices are used in the design of new buildings and retrofitting of existing buildings. Instead of increasing ductility of structural elements, dampers reduce the level of seismic

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energy imposed on these elements. Friction devices are displacement-dependent types of passive systems which have high energy dissipation potential. Their application in the structures is increased progressively in many projects in the world [2]. It is worth mentioning that semi-active type of this damper is also produced recently which is used in braces and base isolation [3–5]. Performance of passive friction dampers has been investigated, and algorithms for analyzing structures with this type of damper have been developed that indicate satisfactory performance of these dampers in reducing the seismic response of structures [6]. All friction dampers have a fixed part that the other part slides on it dynamically. Start of sliding occurs in a certain level of force and before reaching this level no motion can occur. But after this level, sliding movement begins. These dampers usually create stable hysteresis loops [7,8].

Rotational friction dampers were introduced by Mualla in 2000 for the first time [9]. They are specific types of passive friction dampers that dissipate energy by friction in rotating plates. Sometimes they are called novel friction dampers which can be used in various types of braces [10]. Rotational friction damper has very simple technology and its construction, installation and maintenance are easy and can be used in steel and concrete buildings. Experimental investigation has been made on this new damper in Denmark, Japan and Taiwan. In addition to experimental works, numerical modeling has been done and behavior of this damper has been predicted and effective parameters have been identified [11–13]. Moreover, another type of rotational friction damper was introduced by Sanati et al. recently. In this damper some viscoelastic pads were added to the rotational friction damper. It was seen that the amount of energy dissipated by this damper increased in low excitation frequencies [14].

In this study, through an experimental investigation performance of the rotational friction dampers with one, two and three units were tested; because there is no experimental research on the behavior of multi-unit dampers and their level of dissipating energy. Subsequently, a numerical study was conducted to assess their performance in the real structures. In past studies about the use of rotational friction dampers, dampers were modeled nonlinearly but structural members such as beams and columns were modeled linearly. In this study, initially behavior of this type of damper in the structures was studied by modeling the damper directly and by consideration of nonlinear behavior of frame components and dampers. For seismic response analysis, nonlinear time history dynamic analysis was used. Different methods exist to calculate the effective damping of structures. A suitable method is presented to obtain the effective damping of the structures equipped with rotational friction dampers. Then the equivalent method was investigated to consider the effects of this type of damper in the structures without direct modeling of the damper.

## 2. Damper components and mechanism of action

Rotational friction damper includes a vertical central plate and horizontal side plates. Moreover, circular friction pad discs are used in both sides of central plates. These discs were selected from an asbestos-free composite material with friction coefficient of 0.35–0.45 and satisfied three properties of high wear resistance to friction, optimum friction coefficient for providing maximum energy dissipation and stable hysteresis for large number of cycles [11]. One, two and three-unit dampers have two, four and six friction pad discs, respectively. Components of rotational friction damper are shown in Fig. 1. Fig. 2 shows rotational friction dampers with two and three units.

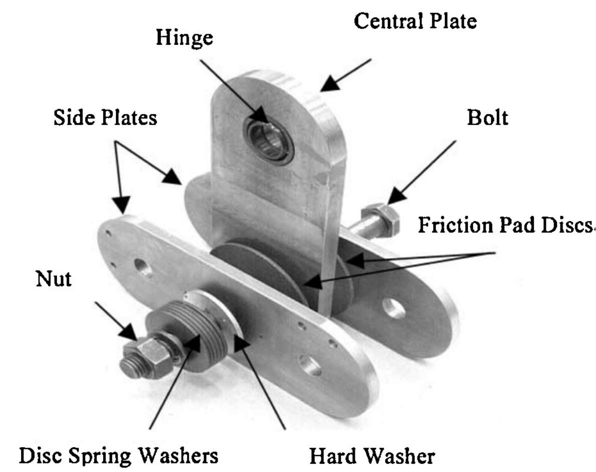


**Fig. 1 – Components of rotational friction damper [11].**

Steel grade S235 was used for the device plates. Steel plates can rotate against each other. This results in producing friction and finally dissipating energy.

Rotational friction damper is connected to the frame by a hinge in the vertical plate and two bracing bars pinned to the horizontal plates of the damper. In order to avoid compression stress and buckling of the bars, the pretension load is applied to them.

Earthquake and wind gust cause a horizontal displacement of the beam which would resist by the combination of the bracing system and the friction forces between the friction pad discs and the steel plates. Fig. 3 illustrates the mechanism of

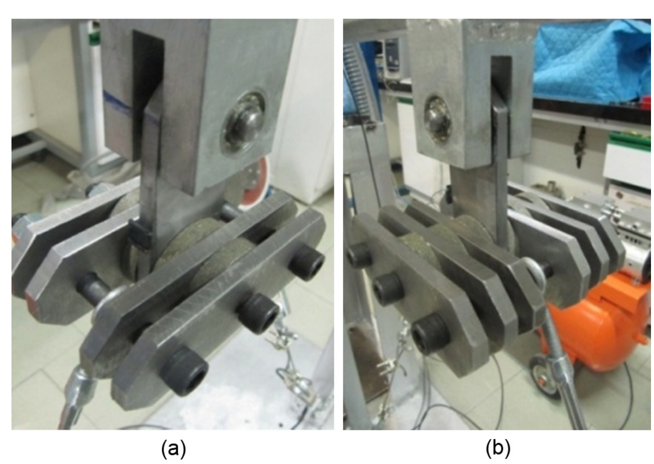


**Fig. 2 – Rotational friction damper: (a) with two units and (b) with three units.**