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OPTIMISATION OF FRICTION DAMPER FOR SEISMIC RESPONSE CONTROL OF STEEL FRAMED BUILDINGS

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Abstract

There have been many researches to reduce the seismic response of large-scale building structures using the friction type damping device, because friction is effective in dissipating a large amount of energy. Pall and Marsh proposed a friction damper installed at the crossing joint of the X-brace to avoid the compression in the brace member. Constantinou et al. proposed a friction damper composed of a sliding steel shaft and two friction pads clamped by adjustable bolts. Li and Reinhorn verified the seismic performance of a building model with friction dampers both analytically and experimentally. Grigorian et al. examined the energy dissipation effect of a joint with slotted bolt holes. Mualla and Belev proposed a rotational friction damper with adjustable slip-moment. Cho and Kwon conducted numerical modelling and analysis of a wall-type friction damper in order to improve the seismic performance of the reinforced concrete structures. In the design of the friction damper for seismic structural control, it is the most important factor to determine the quantity and slip-load of the damper and the brace stiffness systematically. Filiatrault and Cherry proposed a design procedure for equally-distributed friction dampers minimizing the sum of normalized displacements and dissipated energy through parametric study on the natural period, the frequency content of an earthquake and the slip-load of the friction damper. Fu and Cherry proposed a design procedure of the friction dampers using a force modification factor. Ciampi et al. developed a simple approach for determining the distribution of stiffness and strengths within the elastic and inelastic structures.

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1. INTRODUCTION

There have been many researches to reduce the seismic response of large-scale building structures using the friction type damping device, because friction is effective in dissipating a large amount of energy. Pall and Marsh proposed a friction damper installed at the crossing joint of the X-brace to avoid the compression in the brace member. Constantinou et al. proposed a friction damper composed of a sliding steel shaft and two friction pads clamped by adjustable bolts. Li and Reinhorn verified the seismic performance of a building model with friction dampers both analytically and experimentally. Grigorian et al. examined the energy dissipation effect of a joint with slotted bolt holes. Mualla and Belev proposed a rotational friction damper with adjustable slip-moment. Cho and Kwon conducted numerical modelling and analysis of a wall-type friction damper in order to improve the seismic performance of the reinforced concrete structures. In the design of the friction damper for seismic structural control, it is the most important factor to determine the quantity and slip-load of the damper and the brace stiffness systematically. Filiatrault and Cherry proposed a design procedure for equally-distributed friction dampers minimizing the sum of normalized displacements and dissipated energy through parametric study on the natural period, the frequency content of an earthquake and the slip-load of the friction damper. Fu and Cherry proposed a design procedure of the friction dampers using a force modification factor. Ciampi et al. developed a simple approach for determining the distribution of stiffness and strengths within the elastic and inelastic structures. Kim and Choi calculated the yield load of the buckling-resistant-brace system using energy spectrum.

A significant amount of research work on various structural aspects of use of friction damper and their working mechanism has been published by many investigators. Some of them are briefed below.

2 .REVIEW OF TECHNICAL PAPER

Pall and Marsh (1982) studied an existing scale model of 9 story steel moment resisting frame (MRF). It was modified to include friction damped bracing as part of the lateral load resisting system. The frame was one bay wide and three bays long and represents a typical section in the weak direction of a steel frame building of approximately one quarter scale. It was observed that the friction damped braced frame (FDBF) system had the ability to behave in a nonlinear fashion without demanding inelastic behavior in the frame itself. This implied continued integrity of the structure during and after a seismic event.

Filiatrault*et al.* (1987), tested a three-storey frame equipped with friction dampers on a shake table at the University of British Columbia, Vancouver. Even an earthquake record with a peak acceleration of 0.9g did not cause any damage to friction damped braced frame, while the conventional frames were severely damaged at lower seismic levels.

Kelly *et al.* (1990), tested a nine storey three bay frame, equipped with friction dampers on a shake table at the Earthquake Engineering Research Center of the University of California at Berkeley. All members of the friction damped frame remained elastic for 0.84g acceleration, while the moment-resisting frame would have yielded at about 0.3g acceleration.

Moreschi and Singh (2000),discussed the optimal design of yielding metallic dampers and friction dampers together as they both have similar design characteristics and parameters. Ample tests and analytical studies have confirmed the effectiveness of these energy dissipation devices for seismic response control and protection of building structures. A methodology was presented to determine the optimal design parameters for the devices installed at different locations in a building for a desired performance objective. For a friction device, the parameters were the slip load level and brace stiffness. Since the devices and the structures installed with these devices behave in a highly non-linear manner, and thus must be evaluated by a step-by-step time history approach, the genetic algorithm was used to obtain the globally optimal solution.

Garcia and Eeri (2001),used Sequential Search Algorithm method to control the number of different sizes of dampers. The simplified Sequential Search Algorithm has been proposed in the paper which can be easily integrated into conventional design procedures dealing with damper added structures. The applicability of the method was limited to those cases where the response of the structure with added dampers was always linear.

Wen-I *et al.* (2004), discussed results from an international research project devoted to evaluating the seismic performance of a three-storey steel frame structure with a friction-damping device (FDD). Experimental results illustrate that the FDD has very perfect performance in reducing the lateral storey drifts of the test frame. Numerical simulation of the seismic response of the primary and friction damped frame was also conducted.

Bhaskararao and Jangid (2006), studied the analytical seismic responses of two adjacent structures, modeled as single-degree-of-freedom (SDOF) structures, connected with a friction damper. However, the derivation of analytical equations for seismic responses was quite cumbersome for damper connected multi-degree-of-freedom (MDOF) structures as it involves some dampers vibrating in sliding phase and the rest in non-sliding phase at any instant of time. To overcome this difficulty, two numerical models of friction dampers were proposed for MDOF structures and were validated with the results obtained from the analytical model considering an example of SDOF structures. Results showed that using friction dampers to connect adjacent structures of different fundamental frequencies can effectively reduce earthquake-induced responses of either structure if the slip force of the dampers was appropriately selected. Further, it was also not necessary to connect two adjacent structures at all floors but lesser dampers at appropriate locations can significantly reduce the earthquake response of the combined system.

Sung-Kyung et al. (2008), dealt with the numerical model of a bracing-friction damper system and its deployment using the optimal slip load distribution for the seismic retrofitting of a damaged building. The Slotted Bolted Connection (SBC) type friction damper system was tested to investigate its energy dissipation characteristic. Test results coincided with the numerical ones using the conventional model of a bracing-friction damper system. The placement of this device was numerically explored to apply it to the assumed damaged-building and to evaluate its efficiency. Numerical results for the damaged building retrofitted with this slip load distribution showed that the seismic design of the bracing-friction damper system under consideration was effective for the structural response reduction.

Patro and Sinha (2009), presented review on energy dissipation systems for vibration control of framed building.Use of supplemental energy dissipation devices that can dissipate a large proportion of the vibration energy was considered to be a viable option to safeguard the occupational and functional systems. An examination of the behavior and effects of these systems considered the distribution of energy within a structure. During a seismic event, energy was input into a structure. This input energy was transformed into both kinetic and potential (strain) energy, which must be either absorbed or dissipated. There was always some level of inherent damping, which dissipated energy from the system and therefore reduced the amplitude of vibration until the motion ceased. It was concluded that, the structural performance can be improved if a larger portion of the input energy can be absorbed, not by structure itself, but by some type of supplemental energy-dissipating devices.

Vaseghi*et al.* (2009), investigated the behavior of eccentric braced frame (EBF). They studied replacing friction damper (FD) in confluence of these braces, in 5 and 10-storey steel frames. Two buildings have an identical 3 bay layout in plan, 6m span and 3m storey height. The methodology proposed in this study was based on performing a numerical parametric analysis of building structures occupied with FD system. In this paper, the nonlinear dynamic analyses were performed using three earthquake records. These records include El-Centro (1940), Tabas (IRAN, 1978) and Kobe (1995) earthquakes. Results of this study show that, roof displacement, base shear and axial loads of columns of two buildings have been decreased by using friction dampers.

Pujari and Bakre (2011), investigated the effect of placement of X-Plate damper on square shaped buildings. The most optimal damper placement location was selected from some fixed location formats. To seek the optimal location of dampers, a linear combination of maximum inter-storey drift and maximum base shear of the damped structure normalized by their respective undamped counterparts was taken as the objective function. The response and optimal locations of XPDs were checked for three different heights of buildings namely G+3, G+5 and G+8. All these buildings were investigated under four real earthquake ground motions using Nonlinear Time History analysis. It was concluded that, the optimal placement of XPDs provides more reduction in response compared with other schemes of placement of XPD considered in the study.

3. SCOPE

- ➢ The optimization can be done based on slip load and number of friction damper by developing algorithm.
- ➢ The soil structure interaction could be considered during analysis.
- ➢ Experimental study can be carried out to validate analytical results.

4. CONCULSION:-

Following conclusions are drawn based on the result

- ❖ The structural behavior of the building is altogether different with and without friction damper.
- ❖ From the analytical results, it is observed that friction damper reduces the seismic response of all building models considered, irrespective of location format, height of building, plan geometry considered and ground motion record used for excitation.
- ❖ For the same number of friction damper used for building, change in location of friction damper changes amount of energy dissipated.
- ❖ From the analytical results, it is found that the maximum value of base shear reduces with the use of friction damper in the building. This is use to the use of friction damper which increases damping to 20%-30% of the critical and dissipates maximum amount of input energy.
- ❖ The considerable reduction in lateral displacement is observed in the damped building when compared to undamped building. The reduction of displacement of storeys is due to increase in stiffness of structure as well as decrease in velocity and acceleration.

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