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Use of Friction Damper in Response Control of Structure: A State of the Art Review

[1] Ankush A. Gote, [2] Dr. N.R. Dhamge
[1] M.Tech student, Civil Engineering Department, KDK College of Engineering, Nagpur
[2] Professor, Civil Engineering Department, KDK College of Engineering, Nagpur

Abstract: **-- Conventional methods of seismic reintegration with concrete shear walls or rigid steel bracing are considered expensive and tedious. The schedule and tight budget meant that these conventional options are not feasible. The principle of friction brake is most widely adopted available method to extract kinetic energy from a moving body. It is the most reliable, effective and economical mean to dissipate energy. This principle of friction brake has inspired the development of friction dampers. Similar to automobiles, the motion of vibrating building can be slowed down by dissipating energy in friction. Several types of friction dampers have been developed. For frame buildings, these are available for tension cross bracing, single diagonal bracing, chevron bracing, and friction connectors at expansion joints to avoid pounding. The paper gives the study of different literature investigation taken on friction damper.**

I. INTRODUCTION

Now-a-days, structural control is an advanced technology in the field of engineering to equip energy dissipation devices or control systems into structures to reduce excessive structural vibration, enhance human comfort and prevent catastrophic structural failure due to strong winds and earthquakes. Structural control technology can also be used for retrofitting of historical structures especially against earthquakes. The approach to vibration control of structures is with vibration damping that is added to a structure either passively or actively. This damping dissipates some of the vibration energy of a structure by either transforming it to heat or transferring it directly to a connected structure. By utilizing viscoelastic material as well as dashpots, and appending the structures with control devices are the most common ways of adding damping treatment to structures. Effective damping can result by properly treating the structure, which is not damped adequately with viscoelastic materials. In addition, viscous dampers, tuned-mass dampers, friction dampers, dynamic absorbers, shunted piezoceramics dampers, and magnetic dampers are other mechanisms that are used for passive vibration control.

FRICTION DAMPER

For centuries, mechanical engineers have successfully used the concept of the friction brake to control the motion of machinery and automobiles. This concept is widely used to extract kinetic energy from a moving body as it is the most effective, reliable and economical mean to dissipate energy. The development of friction-damping devices was pioneered in the late seventies (Pall 1979, Pall 1981). Friction dampers suitable for different types of construction have been developed for 1) Concrete shear walls, both precast and cast-in-place (Pall 1980, Pall 198l); 2) Braced steel/concrete frames (Pall 1982); 3) Low-rise buildings (Pall 1981); and 4) Clad-frame construction (Pall 1989). Patented Pall friction-dampers are available for: tension cross bracing; single diagonal bracing; chevron bracing; cladding connections; and friction base isolators. These friction dampers meet a high standard of quality control. Every damper is load tested to ensure proper slip load before it is shipped to site. Pall friction-dampers are simple and fool-proof in construction and inexpensive in cost. Basically, these consist of series of steel plates which are specially treated to develop most reliable friction. These plates are clamped together with high strength steel bolts and allowed to slip at a predetermined load. Cyclic dynamic laboratory tests have been conducted on specimen friction-damping devices (Pall 1980, Filiatrault 1986). Their performance is reliable, repeatable and possess large rectangular hysteresis loops with negligible fade over several cycles of reversals that can be encountered in successive earthquakes.

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Fig. Concordia's Library Building Connected with Pall Friction Damper

II. LITERATURE REVIEW

Imad H. Mualla and Borislav Belev (2002) investigated the performance of a friction damper installed in a single storey steel frame subjected to seismic loading. Numerical simulations based on non-linear time history analysis were used to evaluate the seismic behavior of steel frames with inserted FDD. The governing parameters were identified and their influence was traced and summarized along with implications for practical design. The results showed that the friction damper can be used improve the dynamic response of innovative structures as well as the existing building compared to the conventional design. W. L. He et. al. (2003) demonstrated semi active friction dampers (SAFD) to be more effective than passive friction dampers in reducing the structural response due to earthquakes. The motion of friction dampers, either passive or semi active, involves sticking and slipping phases. Two buildings, a six-story base-isolated building and a three-story fixed base building model, have been used to demonstrate the performance of the proposed control strategies using different far-field and near-field earthquakes. Further, the performances of various combinations of passive and semi active energy dissipation devices have been evaluated and compared. Based on numerical simulation results, it was demonstrated that the proposed semi active friction control strategies are very effective. A.V. Bhaskararao and R.S. Jangid (2004) investigated on seismic responses of two adjacent structures which was modelled as single degree of freedom (SDOF) structures connected with a friction damper. Friction dampers connected to two numerical models were also proposed for multi degree of freedom structures (MDOF) as the process involved was quite cumbersome as some dampers were required to be vibrated in sliding phase and the rest in non-sliding phase. They found that the two numerical models were predicting the dynamic behavior of the two connected SDOF structures accurately. The results showed that if the slip force of the friction dampers was selected appropriately the different fundamental frequencies of adjacent structures can effectively reduce earthquake-induced responses of either structure. They further concluded that lesser dampers at appropriate locations can significantly reduce the earthquake response of the combined system rather than connecting the dampers at all floors.

M. D. Symans et. al. (2008) investigated on recent developments and current codal practices in the application of passive energy dissipation systems for seismic protection of structures. The emphasis is on the application of passive energy dissipation systems within the framing of building structures. Extensive topics were discussed which included basic principles of energy dissipation systems, descriptions of the mechanical behavior and mathematical modeling of selected passive energy dissipation devices, advantages and disadvantages of these devices, development of guidelines and design philosophy for analysis and design of structures employing energy dissipation devices, and design considerations that were unique to structures with energy dissipation devices.

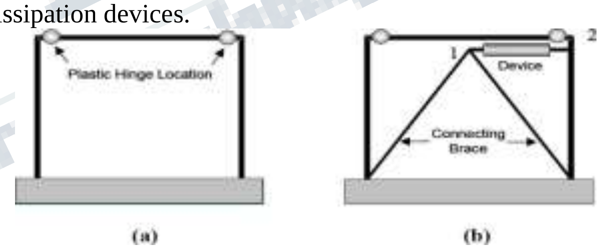

Fig. Frame connected without and with passive energy dissipation devices.

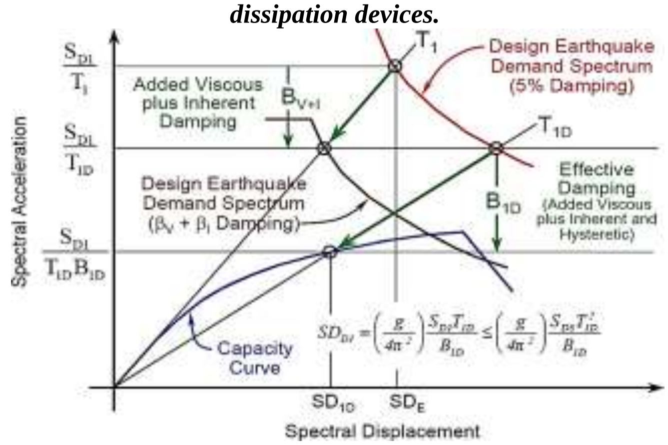

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Fig. Reduction of design demand due to effective damping. They concluded that the basic characteristics of the device in terms of its displacement and velocity dependence must be considered in the analysis and design process as explained in the 2003 NEHRP Recommended Provisions and the 2005 ASCE/SEI 7-05 standard. The Provisions permit linear static and dynamic analysis under certain conditions. These methods make use of equivalent linear properties from an assumed elastoplastic pushover capacity curve along with an effective damping ratio to predict the response of the structure. A selection of recent applications of passive energy dissipation systems is also presented.

Songye Zhu and Yunfeng Zhang (2008) investigated on a special type of bracing element termed self-centering friction damping brace (SFDB) for use in seismic-resistant concentrically braced frame (CBF) systems. The SFDB is a passive energy dissipation device with its core re-centering component made of stranded super elastic nitinol wires while enhanced energy dissipation mechanism of the SFDB is achieved through friction. A comparative study of SFDB frame and buckling restrained braced (BRB) frame was carried out, which is based on nonlinear dynamic analysis of two prototype CBF buildings, a three and a six-storey steel frame. The results of the nonlinear time-history and pushover analysis showed that the SFDB frame can achieve a seismic response level comparable to that of the BRB frame while having significantly reduced residual drifts. The SFDB thus has a potential to establish a new type of CBF system with self-centering capability.

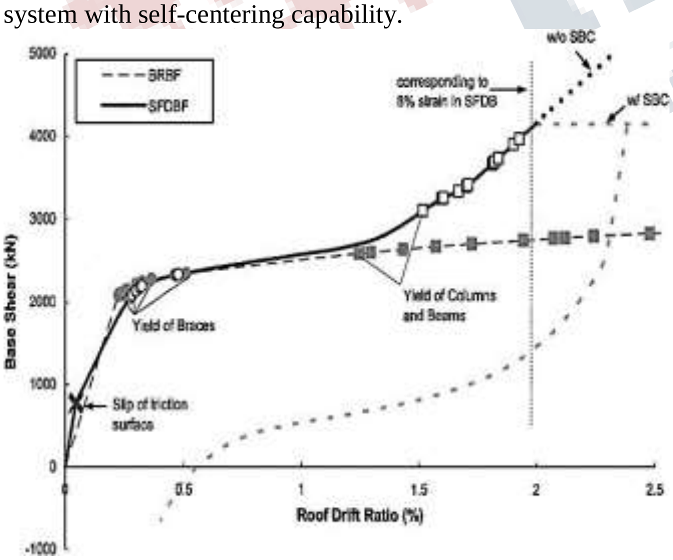

Fig. Static pushover analysis of six-story BRB frame and SFDB frame

You-Lin XU and C.L. Ng (2008) preformed an experiment on control of seismic response of a building complex with the use of variable friction damper. Building complex consisted of a 3-storey podium structure coupled and a 12-storey building. The performance test was conducted under constant or varying voltage to identify motion-independent characteristics on the piezo-driven variable friction damper. Two classes of semi active controllers; local-feedback controller and global-feedback controller, together with a closed-loop operating scheme was proposed for real-time operation of the damper as per characterization results. Finally, the building complex was tested in rigid-coupled, uncoupled, semi active damper-coupled, and passive damper-coupled configurations. Also the variable friction damper's performance was examined for the building complex and results were compared. The results showed that semi active coupling control was promising for reducing seismic responses of both buildings.

Brian G. Morgen and Yahya C. Kurama (2008) evaluated seismic response of unbonded post-tensioned precast concrete moment frames that used friction dampers at selected beam ends. The parameters investigated included the number of stories, number and strength of the dampers, and amount of post-tensioning. Nonlinear static and dynamic time history analysis of prototype structures showed that the dampers provided a considerable amount of energy dissipation to a frame, while the post-tensioning force provided a restoring effect resulting in self-centering capability. The seismic design of the structures to achieve target displacement-based performance objectives was critically evaluated based on the analysis results. The dynamic analysis results also indicated that, in comparison with post-tensioned precast concrete frames, fully emulative structures that used only mild steel reinforcement through the beam-column joints have undergone smaller peak lateral displacements; however, they accumulate significant residual displacements at the end of a ground motion, indicating a larger amount of damage in the structure. The peak displacement demands for fully post-tensioned frames without friction dampers are significantly larger than frames with friction dampers.

Usha K and Dr. H. R. Prabhakara (2017) analyzed two models (i.e. G+3 and G+7) equivalent static method, response spectrum method and time history method. The modeling and analysis was done with SAP 2000 v 14 software and the results that were, seismic parameters such as Time period, Base shear, Lateral displacement and Inter storey drift were tabulated and then comparative study of structures with and without Friction dampers has been done. They concluded that lateral displacements due to earthquake forces were reduced by providing friction dampers and the storey drift also reduces shear resistance of the building increases.

III. CONCLUSION

The seismic performance of the frame can be considerably enhanced by the inclusion of friction damper in the structural system. The dissipation characteristics of the friction damper are reliable and the devices are not damaged by large loads. By confining the energy dissipation to the friction damper which are specifically designed to perform under extreme loading conditions without sustaining damage, the main structural elements are able to remain elastic. From the literature study it is found that the device provides a significant increase in the available damping within the structure and that leads to a direct improvement in performance.

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