A Review of Parallel Structure Connected By Friction Damper Using Viscoplasticity Model

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Abstract— Friction damper is used for the dissipation of an earthquake energy which may cause damage to the structure. It is a well-known energy dissipation devices. The purpose of this study is to analyze a single-degree-of –freedom (SDOF) building structure. Friction damper is used to connect parallel structure with each other. Friction damper is installed between two parallel structures to reduce inter-story displacements of structures subjected to the external loading. Numerical model (Viscoplasticity model) is used to model the friction forces in the proposed damper. The equation of motion is solved by the Newmark's step by step method and seismic response of structure is worked out under earthquake excitation. Friction damper is used to reduce the structural seismic found response. The mutual pounding of structure is also reduced by structure with a friction damper. It is that during major earthquake, the friction damper slip at a predetermined connecting load before yielding occurs in member of a frame structure and dissipates a large proportion of seismic energy during earthquake. In this paper investigation is carried out to study the structural response of a parallel structure connected by a friction damper using. The specific objective of this study is to evaluate the importance of a friction damper in reducing the seismic response of parallel structures which are connected by friction damper with each other.

Keywords: Friction damper, Energy dissipating devices, Seismic response, Inter-story displacement, Earthquake, connected structure

I. INTRODUCTION

Due to a bad seismic performance of structure, this indicates that the existing structure is susceptible to the seismic damage. An important aspect of reducing the seismic risk in the existing and a new constructed structure is due to the proper implementation of structural control strategies. There are many type of structural control system that are generally used like, Passive control system, Active control system, Hybrid control system, Semi- active control system. Damper is a device that is mainly used to dissipate earthquake energy. In place of diagonal braces, structural elements seismic damper are used which will control the seismic damage of structure. There are different types of a seismic damper like, viscous damper, friction damper, metallic yielding damper, viscoelastic damper. There are mainly two basic technologies that are used to protect building from damaging earthquake effects. These are Base Isolation Device and Seismic damper. These technologies will dissipate a large percentage of earthquake energy. The idea on which base isolation technique depend is that to isolate the building from the ground in such a way that the earthquake motion are not transmitted up through the building or at least greatly reduced. Seismic damper are special devices which is introduced in a building and reduce earthquake energy. Passive control system is used in low and medium rise building for seismic control. For tall building which is flexible structure, particularly those which are susceptible to strong wind, damper have been successfully employed. Structural control systems are used for earthquake energy dissipation and provide strength to the structure. Bhaskararao and Jangid investigated that connecting the adjacent structure with passive energy dissipation devices has attracted the attention of many researchers due to its ability in mitigating the dynamic response as well as to reduce the chance of pounding [1]. Installation of such devices does not require additional space and free space available between two adjacent structures can be effectively utilized for placing control devices. Bhaskararao and Jangid studied that the specific objectives of the study are: (i) to derive the closed-form solutions for the harmonic response of the coupled system during stick and slip phases in the friction damper; (ii) to investigate the existence and necessary conditions for three different types of motion of the coupled system, such as stick–stick, stick–slip and slip–slip; (iii) to ascertain the existence of an optimum slip force in the friction damper for minimum displacement response of the coupled structures; and (iv) to examine the effects of important parameters such as damping ratio, mass ratio and slip force on the performance of the damper (for its effective design) [4]. Lopez and Nijmeijer suggested that the friction damper are used in very diverse application, civil engineering, rotor machinery, vehicles and ring damper [5]. The main motive of using friction damper in these applications is to find out the optimum system parameters that lead to the highest amount of damping, possible for given friction design. Lyan-Ywan Lu studied that the friction damper is activated and starts to dissipate energy only if the friction forces exerted on its friction interface exceeds the maximum friction forces (slip force); otherwise, an inactivated damper is no different from a regular bracing [12]. The main objective of this study is to work out the seismic response of a parallel structure which is connected by a friction damper. The main objective of using friction damper is to connect two parallel structures and to mitigate the mutual pounding of structure and also reduce cost of investigation. When two parallel structures are connected with each other by friction damper than it will dissipate large amount of earthquake energy and prevent the structure from earthquake damages also reduce the cost of installation. In this case parallel structures are connected by friction damper.

II. FRICTION DAMPER

Friction damper is an energy dissipating device. Passive control systems are mainly used for dissipation of earthquake energy. Friction damper are designed in such way that they have a moving part that will slide over each other during a strong earthquake. When part slide over each other they create friction which uses some of the energy from earthquake that goes into the building. The damper is made of a set of steel plates, with slotted holes in them, and they are bolted together at high enough forces. The plates can slide over each other creating friction. The plates are specially treated to increase the friction between them.

During the major earthquake, it is found that friction damper slip at a predetermined load before yielding occur in member of a frame, and major portion of seismic energy is dissipated by friction damper. To extract the kinetic energy from the moving body frictional brakes is used, as it is most reliable, effective and economical means of dissipating earthquake energy.

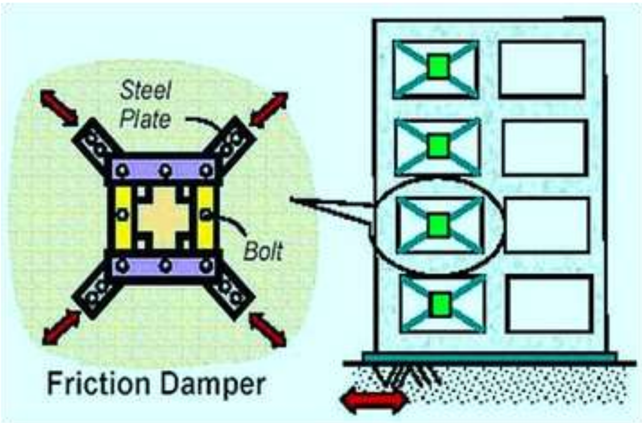

Fig.1: Friction damper that is used in multi-storey building (www.damptech.com)

Many energy dissipating system have been proposed to raise the seismic design of structure and dissipation of earthquake energy. Among all these new systems, friction damper has shown a great potential. In the plane of bracing damper lies, and does not require extra space they can be concealed within the walls. No periodic test and inspection are required. There is no action in the damper when there are no seismic activities in the structure, which can support its design static load indefinitely. Thus there is no problem of wear or fatigue.

III. ADVANTAGES OF FRICTION DAMPER

Friction damper has advantages such as a very simple mechanism. Cost of friction damper is very low as compared to the other damper. Maintenance cost of friction damper is less and has a powerful energy dissipation capacity as compare to the other passive damper. For seismic design of structure friction damper are found to be very effective and friction damper also provide strength to the existing structure. Friction damper provide a practical, economical and effective approach for the design of structure to resist excessive vibration. The performance of friction damper is independent of the temperature and velocity. On the other hand the performance of viscous and viscoelastic damper will depend up on the temperature and velocity. Maintenance cost of friction damper is less as compared to the other damper. They do not require regular maintenance, inspection, repair or replacement before and after the earthquake. Friction damper are designed in such way that do not slip during wind, storms or moderate earthquake.

IV. CONNECTED STRUCTURES

With the increase in a population and growing social and commercial activities and limited land resources available in a modern city lead to more and more building being built closely to each other. In most cases these building are separated by structural connections. Hence earthquake resistance capacity and wind resistance capacity of building will depend on itself. Thus to avoid this, buildings are connecting with each other because of the limited availability of land, poor performance of a centralized services. The most of building are not connected by any structural connection. If the distances between two adjacent buildings are not sufficient thus there is a maximum chance of mutual pounding that may occur during an earthquake. Due to insufficient distance between two buildings a mutual pounding has been occur and buildings are linked by sky bridges at several locations. To improve the seismic resistance performance of two connected adjacent structure and podium structures to main building by using a passive damper, semi-active damper or active dampers has been proposed.

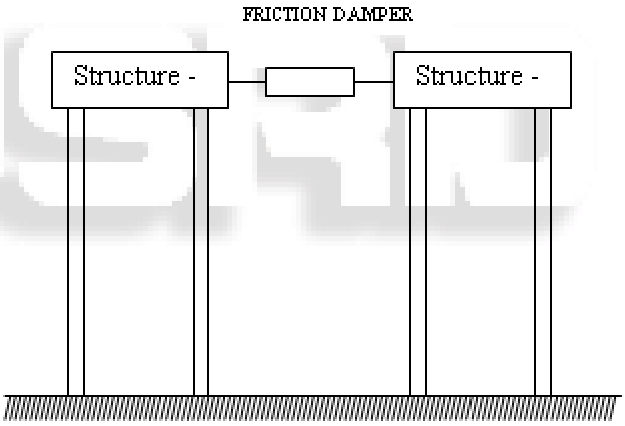

Fig. 2: Parallel structure connected with friction damper

When two adjacent structures are connected with passive energy dissipating devices, it attracts the attention of many researchers because of its ability in mitigating the dynamic response as well as minimizing the chance of pounding. By the proper implementation of special energy dissipating devices in proper positions between two structures, this technique increases the earthquake energy dissipation capacity of structure. Westermo B. suggested that to prevent mutual pounding between adjacent building during an earthquake, using hinged links to connect two neighboring floor if the floor of adjacent building are in alignment [3]. It is obvious that this system can reduce the chance for pounding, but it alters the dynamic characteristics of the unconnected buildings, enhances undesirable tensional response if the building has asymmetric geometry, and increase the base shear of the stiffer building. Connecting two structures with each other by damper is a most economic phase of construction of building and to mitigate the earthquake energy. It reduces the overall cost of construction of building. Generally the dampers in the building are mostly provided at a maximum displacement level. It is not necessary to provide a damper at each floor level of building. Damper mainly replaces a bracing system of a building.

V. PARALLEL STRUCTURE CONNECTED BY FRICTION DAMPER USING VISCOPLASTICITY MODEL

Consider two parallel structures which are connected by a friction damper. The main purpose is to analyze a single-degree–of-freedom system (SDOF) and to calculate seismic response of the structure under earthquake excitations. Seismic response is calculated by using Newmarks's γ, β method and the equation of motion is solved by this method. Newmarks's step by step equation is given below.

$$\dot{x}_{i+1} = \dot{x}_i + [(1-\gamma)\Delta t]\ddot{x}_i + (\gamma\Delta t)\ddot{x}_{i+1} \quad (1.1)$$

$$x_{i+1} = u_i + (\Delta t)\dot{x}_i + [(0.5-\beta)(\Delta t)^2]\ddot{x}_i + [\beta(\Delta t)^2]\ddot{u}_{i+1} \quad (1.2)$$

The parameters β and γ define the variation of acceleration over a time step and determine the stability and accuracy characteristics of the method. Typical selection for γ is $\frac{1}{2}$ and $\frac{1}{6} \leq \beta \geq \frac{1}{4}$ is satisfactory from all points of view, including that of accuracy. These two equations, combined with the equation of motion at the end of the time step, provide the basis for computing x_{i+1}, $\dot{x}_{i+1}$ and $\ddot{x}_{i+1}$ at time $i+1$ from the known x_i, $\dot{x}_i$ and $\ddot{x}_i$ at time i.

Using the Wen equation [15] the friction force in damper is expressed by.

$$f_d = \mu N Z \quad (1.3)$$

Where f_d = damping force
μ = Friction coefficient
N = Clamping force (mg)
Z = Hysteretic dimensionless quantity
The value of friction coefficient is constant.
Non–linear first order differential equation is expressed as

$$q\frac{dZ}{dt} = A(\dot{x}_2 - \dot{x}_1) + \beta\,|(\dot{x}_2 - \dot{x}_1)|\,Z\,|Z|^{n-1} - \tau(\dot{x}_2 - \dot{x}_1)|Z|^n \quad (1.4)$$

$(\dot{x}_2 - \dot{x}_1)$ = relative velocity at the damper ends.

The viscoplasticity model is a continuous model of the frictional force proposed by Michalakis Constantinous, Anoop Mokha and Andrei Reinhorn [16]. Where q is the yielding displacement; β, τ, n and A are the non-dimensional parameters of the hysteretic loop. The shape of loop will depend up on parameters like β, τ, n and A. These parameters are selected in such way that they will provide a rigid-plastic behavior. The recommended value of these parameter are q = 0.25 mm, A=1, β = 0.9, τ = 0.1 and n=2. Thus viscoplasticity model is continuous model in which the system is analyzed for entire degree- of-freedom irrespective of the phase of motion. Value is calculated by Ranga-Kutta Fourth Order Method. Value of Z may vary in between ±1. It will depend up on the sliding non-sliding of structure. Thus it should be noted that during sliding (yielding), the value of Z varies from -1 to +1. But during sticking (elastic behavior), the absolute value of Z is taken as unity.

VI. CONCLUSION

The main purpose of this investigation is to work out the seismic response of parallel SDOF structure connected with friction damper using numerical model under earthquake excitation. In this investigation it is worked out that a large amount of energy is dissipated after implementation of friction damper in between two parallel structures. It also reduces the total installation cost of entire work. Friction damper is found to be effective because it reduce the dynamic response of connected structures. In softer structure friction damper are found more beneficial as compared to the stiff structure of the combined system. Friction damper is used to connect adjacent structures because of its low investigation cost. It also has less maintenance cost and powerful energy dissipation as compared to other passive damper. The main motive of this investigation is to calculate the seismic response of two connected structures under earthquake excitation.

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