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Review Paper on Study of Connected Buildings using Dampers Subjected to Seismic Excitations

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Abstract: Passive energy dissipating devices have been a topic of research all over the word, because of its inherent characteristics in controlling the dynamic response of the structure during base excitation. In the present study an attempt has been made in order to connect three adjacent building with the help of fluid viscous dampers to control the response of the most flexible building. The properties of the dampers affect the performance of the structure during base excitation.
Keywords: Fluid Viscous Dampers, base excitation, flexible building.

I. INTRODUCTION

Man has lived with earthquakes. Some of them are so small that they are not even felt; others are so strong that they can destroy the entire city, cause major damage to infrastructure (bridges, buildings) and kills thousands of people. During a seismic event, tremendous amount of energy emitted is transformed into kinetic and potential energy which must be either absorbed or dissipated through heat. In addition to the loads due to the effect of gravity, earthquake loading must be considered while designing structures in seismic prone areas.

The philosophy in the conventional seismic design is that, structure is designed to resist the lateral loads corresponding to wind and small earthquake by its elastic action only, and the structure is permitted to damage but not the complete collapse while it is subjected to a lateral load associated with moderate or severe seismic events. As a result, plastic hinges in the structure must be developed in order to dissipate the seismic energy when the structure is subjected to severe shakings. The design methods on this philosophy are acceptable to account for needs for both economic consideration and life safety. However, the development of the plastic hinges relies on the large deformation and the ductility of the structure. If the structure is more ductile, it undergoes more deformation and more damage it suffers.

Besides, some important structures such as hospitals have to remain in function after the major earthquakes; the former mentioned design philosophy (life safety based) may not be appropriate.

These structures should be strong enough to resist large displacement and acceleration so that they can maintain their function when excited by severe ground motions.

Tremendous research and advancement in the field of earthquake engineering has minimized the computational efforts of complex problems by using software packages and coding. From the previous records of catastrophic earthquakes such the 1985 Mexico City earthquake and 1989 Loma Prieta earthquake, which resulted in heavy toll of life and property, it is clear that inherent damping of the material alone cannot dissipate the unwanted energy due to earthquake and heavy wind actions. Hence there was an emerging need of structural vibration control devices which can reduce the severe responses of structure without altering the dynamic characteristics of structure, they are also known as supplemental damping devices. Structural passive control systems have been developed with the design philosophy different than the conventional design seismic design method, which have immediate effect of increasing the critical damping ratio right up 25-30% (against 5% value usually used for metal structures) and at the same time reducing the response of the structure during seismic event.

The passive energy dissipating system equipped in the main structure does not behave as independent dynamic system but rather interact with main structure. The reduction in the response when dampers are equipped within the system shows the formidable potential of dampers in controlling responses of the structure. However, the use of such dampers may also be extended to control the seismic response of two adjacent buildings which may be dynamically similar or dissimilar (based on time period of individual structure). The free space between two adjacent buildings may be utilized in order to dissipate the unwanted energy due to earthquake or heavy wind actions. Such type of arrangement also prevent pounding (collision between two adjacent buildings due to heavy impact) of two structures, which occurred in past catastrophic earthquakes such as 1985, Mexico earthquake and 1989, Loma Prieta earthquake.

II. LITERATURE REVIEW

The need to protect civil engineering structures against base excitation was felt by many researchers all over the world. Some of the prominent literature review being studied so far is listed below:

Xu, He and Ko (1999) performed formulation of the multi-degree of freedom equations of motion for fluid damper-connected adjacent multi-story buildings under earthquake excitation is presented. The ground acceleration due to earthquake is regarded as a stochastic process, and a pseudo-excitation algorithm in the frequency domain is implemented in a computer program to handle non-classical damping properties of the system. The 1940 El Centro earthquake time history is also used for dynamic analysis of the system in the time domain. The effectiveness of fluid joint dampers is then investigated in terms of the reduction of displacement, acceleration and shear force responses of adjacent buildings. Finally, an extensive parametric study is carried out to find optimum damper properties for adjacent buildings of different stiffness ratios and different heights. Results show that using fluid dampers to connect the adjacent buildings of different fundamental frequencies can effectively reduce earthquake-induced responses of either building if damper properties are appropriately selected.

Bhaskararao and Jangid (2004) they studied that Connection between adjacent buildings with dampers not only mitigates the structural response, but also avoids pounding. The structural response of two adjacent buildings connected with various types of dampers under different earthquake excitations is studied. A formulation of the equations of motion for multi-degree of freedom model of buildings connected with dampers is presented. The effectiveness of various types of dampers, viz., viscous, visco-elastic and friction dampers in terms of the reduction of structural responses (i.e., displacement, acceleration and shear forces) of connected adjacent buildings is investigated. A parametric study is also conducted to investigate the optimum parameters of the dampers for adjacent buildings of different heights. In addition, the optimal placement of the dampers, rather than providing the dampers at all the floor levels, is also studied. Results show that connecting the adjacent buildings of different fundamental frequencies by passive dampers can effectively reduce the earthquake induced responses of either building. There exist optimum damper properties for minimum earthquake response of the buildings. In addition, it is not necessary to connect the two adjacent buildings by dampers at all floors but lesser dampers at appropriate locations can also significantly reduce the earthquake response of the combined building system.

Bhaskararao and Jangid (2006) performed an Analytical seismic response of two adjacent structures, modeled as single-degree-of-freedom (SDOF) structures, connected with a friction damper are derived in closed-form expressions during non-slip and slip modes and are presented in the form of recurrence formulae. The derivation of analytical equations for seismic responses is 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 are proposed for MDOF structures and are validated with the results obtained from the analytical model considering an example of SDOF structures. The effectiveness of dampers in terms of the reduction of structural responses, namely, displacement, acceleration and shear forces of connected adjacent structures is investigated. A parametric study is also conducted to investigate the optimum slip force of the damper. The optimal placement of dampers, rather than providing dampers at all floor levels is also studied to minimize the cost of dampers. Results show 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 is appropriately selected. It is 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.

Matsagar and Jangid (2006) The seismic response of the two adjacent building including base isolation and fluid viscous damper is studied. It has been shown that the damage caused due to large bearing displacements of isolator can be reduced to a great extent by linking two base isolated buildings with fluid viscous dampers. More ever extensive parametric study has been carried out to arrive at optimum damping coefficient of dampers for various cases such as adjacent base isolated and fixed base building, two dissimilar base isolated buildings. It has also been concluded that the use of dampers between adjacent buildings is a helpful tool to control pounding.

Patel and Jangid (2009) Studied the seismic performance of two adjacent dynamically similar buildings coupled with fluid viscous dampers. The analysis is carried by formulating the equations of motions using Newmark beta method. Thorough study is conducted in order to arrive at optimum damping coefficient by choosing top storey displacement, acceleration and base shear as principal damaging measure by placing dampers of same and different damping coefficient at each storey. Beyond optimum damping the responses were found to increase. Finally, in order to minimize the cost, dampers were placed at location of maximum relative velocity and responses were checked. Thus, it is finally concluded, minimum dampers at suitable locations minimize the severe responses of two adjacent buildings connected with fluid dampers.

Jankowski and Mahmoud (2016) carried out analytical study on pounding of structures by linking two shear type buildings with various elements such as link, dashpot and visco-elastic element. One building being flexible and other is stiffer, spacing between them is kept very less. Seismic loading is applied in the form of non-linear time history analysis using Newmark Beta method by solving equation of motion in a programming tool. Parametric study has been carried out in order to get the optimum parameters such as stiffness and damping constant of the link elements. It has been concluded that the use of link elements proved to control the responses of flexible building and responses remain unchanged in case of stiffer building even for high stiffness and damping of link elements. Thus, pounding of two structures in case of seismic action can be avoided with the help of such gap elements.
Chirag C. Patel(2011)
The seismic response control behavior of two similar structures connected with viscous dampers is investigated. The ground excitations considered are four different types of real earthquake ground motions. The equation of motion for the two multi-degree-of-freedom (MDOF) structures connected with viscous dampers is formulated. The numerical study is carried out for two similar MDOF structures connected by viscous dampers having same damper damping coefficient. The response control criteria considered are top floor displacement, top floor absolute accelerations and base shear force; and damper effectiveness is investigated for reduction of structural responses. A parametric study is also conducted to investigate the optimum damping coefficient of the dampers. Results show that using viscous dampers to connect the similar structures can effectively reduce earthquake-induced response of either structure by selecting appropriate damping coefficient of damper. The lesser dampers at appropriate locations can reduce the earthquake response of the coupled system.
Ming-Yi Liu*, An-Pei Wang and Hsing-Wei Tseng(2016) The objective of this paper is to investigate the dynamic characteristics of two adjacent building structures interconnected by viscous dampers under seismic excitations. The computational procedure for an analytical model including the system model formulation, complex modal analysis and seismic time history analysis is presented for this purpose. A numerical example is also provided to illustrate the analytical model. The complex modal analysis is conducted to determine the optimal damping ratio and the optimal damper coefficient of the linear viscous damper for each mode of the system. For the damper coefficient with optimal value, the responses can be categorized into under damped and critically damped vibrations. The seismic time history analysis is conducted to assess the effectiveness of the linear viscous damper for vibration control. Based on the optimal damping ratio and the optimal damper coefficient of the linear viscous damper for a certain mode of the system, compared to the peak responses, the linear viscous damper can be used to more effectively suppress the root-mean-square responses of the two adjacent buildings.
Elif Cagda Kandemir-Mazanoglu (2017) This paper investigates optimum viscous damper capacity and number for prevention of one-sided structural pounding between two adjacent buildings under earthquake motion. The buildings assumed as shear-type structures are modeled by using lumped mass stiffness technique. Impact forces due to pounding is simulated by nonlinear elastic spring approximation called Hertz model. A parametric study is conducted by varying storey number and stiffness of buildings in addition to the capacity of the viscous dampers. Pounding force and supplemental damping ratio for each case are presented based upon newly defined non-dimensional natural frequency parameter ratio. An optimization procedure for determination of viscous damper capacity is developed based on modified supplemental damping ratio equation. Results are compared with each other to clarify the effect of variation in building parameters on pounding forces and viscous damper capacity

III. CONCLUSION

Following conclusions have been made by thoroughly studying the past literature review. Fluid dampers if connected between adjacent buildings of different fundamental frequencies can effectively reduce earthquake-induced responses of either building if damper properties are appropriately selected. It is an important tool to control the pounding phenomenon between adjacent buildings.

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