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EFFECT OF FRICTION DAMPER ON SEISMIC PERFORMANCE OF MULTI-STOREYED FRAME STRUCTURE IN HIGH RISE BUILDING-A REVIEW

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Abstract-

An earthquake is a spontaneous event of shaking ground caused by the passage of seismic waves through earth's rock. Over the centuries they have been responsible for millions of deaths and extensive damages to the property. Now-a-days high rise buildings have become a trend and, moreover, they have paved the way to world competition in constructing tall buildings to exhibit the symbol of power and technology possessed by its population. Structures are mainly subjected to various types of loading conditions such as earthquake, wind loads etc. For earthquake zone areas, the structures are designed considering seismic forces. The structure which are present in higher earthquake zone area are liable to get damaged or collapsed, hence to increase the safety of these structure few protective systems are in the form of seismic isolation system and supplementary energy dissipating device are used to stabilize the structures against the earthquake and wind forces. The mechanical devices are incorporated into the frames of the structure and absorb the energy from the earthquake reduces the drift as well as effect on the critical components of the structures. From the literature study it is concluded that they include different types of dampers like metallic dampers, viscous dampers, viscoelastic dampers, friction dampers etc. however there have been few investigations for the combinations of dampers, its advantages are discussed and a detailed review is carried out. By using the mechanical dissipating devices, it has been found effective and their application form focus of the study.

Keywords— ***friction damper, response spectrum analysis, high rise building, seismic protective systems.***

Introduction

Earthquake in the simplest terms can be defined as Shaking and vibration at the surface of the earth resulting from underground movement along a fault plane. The vibrations produced by the earthquakes are due to seismic waves. Seismic waves are the most disastrous one. However, modern high-rise buildings and tall structures cannot conveniently be geared up with these techniques. The safety and serviceability of any structure is thus endangered with the increasing elevation. As per the standard codes, a structure that can resist the highest earthquake that could possibly occur in that particular area can be called as an earthquake resistant structure. However, the most efficient way of designing earthquake resistant structure would be to minimize the deaths as well as minimize the destruction of functionality of the structural element. The most disastrous thing about earthquake is its unpredictability of time and place of occurrence. These possess a great challenge to the economy and safety of structure. From the past and few present records, the world has experienced number of destroying earthquakes, causing in number of increase the loss of human being due to structural collapse and severe damages to structure. Because of such type of structural damages, during seismic (earthquake) hazards clearly explains that the buildings / structures like residential buildings, public life-line structures, historical structures and industrial structures should be designed to seismic force design and very carefully to overcome from the earthquake hazards. The approach in structural design using seismic response control device is now widely accepted for structure and frequently used in civil engineering field. Structural control concept into a workable technology and such devices are installed in structures.

SEISMIC PERFORMANCE OF HIGH RISE BUILDINGS

The structures of high-rise building with different heights behave differently under earthquake loadings. The maximum axial load, shear and bending moments occur at ground columns. So, the effect of earthquake decreases as intensity of earthquake is reduced. The effects of earthquake are not proportional to the building height, for example, the axial load increases as the number of floors is reduced. Therefore, different building systems will behave differently and the response of the buildings are more depending on their natural period.

DAMPING DEVICE

A flexible structural element of the damping system that dissipates energy due to relative motion of each end of the device. Damping devices include all pins, bolts, gusset plates, brace extensions, and other components required to connect damping devices to the other elements of the structure. Damping devices may be classified as either displacement dependent or velocity dependent, or a combination there of, and may be configured to act in either a linear or nonlinear manner**.**

DAMPING SYSTEM

The collection of structural elements that includes all the individual damping devices, all structural elements or bracing required to transfer forces from damping devices to the base of the structure, and the structural elements required to transfer forces from damping devices to the seismic force resisting system.

OBJECTIVE OF STUDY

The main aim of this research is to generate fundamental research information on the seismic performance of building structural system installed with different dampers

- To improve the seismic response by installing the optimum number of dampers.
- Study the effect of important parameter such as location and configuration of the dampers.
- To find the most effective damper location by altering the damper location and configuration
- Use the research findings to propose more effective damping system for seismic mitigation.

METHODOLOGY ADOPTED

Static Seismic Coefficient method, Response spectrum analysis as well as force coefficient method will be employed to models to analyse and investigate the effects of different damping systems in the seismic response of the structure.

The purpose of this study is to evaluate the effect of the different position and different configuration of friction dampers on seismic behaviour of high-rise building considering seismic and wind effect using (IS code 1893-2002), (IS code 875-1987) and (IS code 456-2000) in ETABS software.

Equivalent Static Analysis

The equivalent static analysis procedure is essentially an elastic design technique. It is, however, simple to apply than the multi-model response method, with the absolute simplifying assumptions being arguably more consistent with other assumptions absolute elsewhere in the design procedure.

The assumptions involved in the method are:

- Major contribution made to base shear is by fundamental mode of the building.
- The total building mass is considered as against the model mass used in dynamic analysis.

Response Spectrum Analysis

It is a linear dynamic analysis. A response spectrum is a plot of the maximum response amplitude (displacement, velocity or acceleration) versus time period of many linear single degree of freedom oscillators to a give component of ground motion. The resulting plot can be used to select the response of any linear SDOF oscillator, given its natural frequency of oscillation. One such use is in assessing the peak response of buildings to earthquakes.

Response spectrum is one of the useful tools of earthquake engineering for analysing the performance of structures especially in earthquakes, since many systems behave as single degree of freedom systems. Thus, if we can find out the natural frequency of the structure, then the peak response of the building can be estimated by reading the value from the ground response spectrum for the appropriate frequency. In most building codes in seismic regions, this value forms the basis for calculating the forces that a structure must be designed to resist (seismic analysis).

Force Coefficient Method

It is a non-dimensional coefficient such that the total wind force on a body is the product of the force coefficient, the dynamic pressure due to the incident design wind speed and the reference area over which the force is required.

LITERATURE REVIEW

- ***J.Vaseghi, S.Navaei, B.Navayinia, F.Roshantabari (2009)*** performed analytical investigation on "A parametric assessment of friction damper in eccentric braced frame". In this paper, the behaviour of eccentric braced frame (EBF) is studied with replacing friction damper (FD) in confluence of these braces, in 5 and 10-storey steel frames. For FD system, the main step is to determine the slip load. For this reason, the performance indexes include roof displacement, base shear, dissipated energy and relative performance should be investigated. In nonlinear dynamic analysis, the response of structure to three earthquake records has been obtained and the values of roof displacement, base shear and column axial force for FD and EBF frames have been compared. The results demonstrate that use of the FD in frames, in comparison with the EBF, substantially reduces the roof displacement, column axial force and base shear. The obtained results show suitable performance of FD in higher storey structure in comparison with the EBF.

- ***Naveet Kaur, V. A. Matsagar, and A. K. Nagpal (2012)*** performed analytical investigation on "Earthquake response of mid-rise to high-rise buildings with friction dampers". In this work earthquake response of mid-rise to high-rise buildings provided with friction dampers is investigated. The steel buildings are modelled as shear-type structures and the investigation involved modelling of the structures of varying heights ranging from five storeys to twenty storeys, in steps of five storeys, subjected to real earthquake ground motions. Three basic types of structures considered in the study are moment resisting frame (MRF), braced frame (BF), and friction damper frame (FDF). Mathematical modelling of the friction dampers involved simulation of the two distinct phases namely, the stick phase and the slip phase. A dynamic time history analysis was carried out to study the variation of the top floor acceleration, top floor displacement, storey shear, and base-shear. Further, energy plots were obtained to investigate the energy dissipation by the friction dampers. It is seen that substantial earthquake response reduction is achieved with the provision of the friction dampers in the mid-rise and high-rise buildings. The provision of the friction dampers always reduces the base-shear. It is also seen from the fast Fourier transform (FFT) of the top floor acceleration that there is substantial reduction in the peak response; however, the higher frequency content in the response has increased. For the structures considered, the top floor displacements are lesser in the FDF than in the MRF; however, the top floor displacements are marginally larger in the FDF than in the BF.

- ***A.V. Bhaskararao, R.S. Jangid*** performed analytical investigation on "Seismic analysis of structures connected with friction dampers". In this work, analytical seismic responses of two adjacent structures, modelled 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. However, 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. It is found that the proposed two numerical models are predicting the dynamic behaviour of the two connected SDOF structures accurately. Further, 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. In addition, 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. Further, 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.

- ***Amir Shirkhani, Naser Shabakhty, Seyed Roohollah Mousavi (2014)*** performed analytical investigation on "The influence of friction damper device on the performance of steel moment frames". In this study friction damper device belongs to those passive control systems made according to friction mechanism. Since, friction is a great source of energy dissipation; it is used in structures in order to decrease the structure response against wind and earthquake load. In this paper, steel moment frames with 3, 7 and 12 stories equipped with the mentioned damper is investigated under seismic analysis. Finally, it is concluded that by adding dampers, the reduction percentage of roof displacement of frames will be decreased by increasing the number of stories. It is also concluded that 7 stories frame equipped with dampers has a better performance.

- ***S S Sanghai and P Y Pawade (2014)*** performed analytical investigation on "Effect of position and number of friction dampers on seismic response of frame". This paper deals with effect of position and number of friction dampers on response of 2D frame. To fulfill this objective, two bay & five storey 2D frame is analysed using software SAP2000. The study is carried out using two, three and four number of friction dampers with different locations keeping slip load & stiffness constant. As the behaviour of friction damper is elasto-plastic, the Non-Linear Time History Analysis of all the frames is done using El Centro ground motion record. To study the effect of number and position, percentage energy dissipated in accordance with energy induced in the frame, fundamental time period, base shear, and joint displacement and member forces is considered. The results have showed that number and placement of damper influences significantly the structural response. A large number of dampers do not always lead to best benefit in terms of energy dissipation. It was found that the location of damper which tuned the building with respect to input acceleration dissipates maximum percentage of input energy.

- ***Shameena Khannavar, M.H.Kolhar, Anjum Algur (2017)*** performed analytical investigation on “Seismic analysis of RC structures using friction dampers”. The structure are mainly subjected to various types of loading conditions such as earthquake, wind loads etc. For earthquake zone areas, the structures are designed considering seismic forces. The structures which are present in higher earthquake zone area are liable to get damaged or collapse, hence to increase the safety of these structure few retrofitting techniques or additional of materials to stabilize the structures against the earthquake forces are done. In modern seismic design, the damping devices are used to reduce the seismic energy and enable the control of the structural response of the structure to that earthquake excitation. For the present study, a 10-story structure which is symmetrical in plan is modelled and analysed using the ETABs 2015 software. The earthquake loads are defined as perIS1893-2002 (Part To analyse the structure, the static and dynamic analysis method is adopted. The response spectrum function is defined to carry out dynamic analysis. To control the seismic response and to increase the stiffness of the structure, Friction dampers are provided to the structure. The results obtained and compared in the form of displacement, story drift and story shear are compared. Using friction dampers, the forces in building get reduced such as drift, displacement.

- ***Usha K, Dr. H. R. Prabhakara (2017)*** performed analytical investigation on “Studies on effect of friction dampers on the seismic performance of RC multi-storey buildings”. Among all the natural disasters such as flood, earthquake, drought, tornadoes, hurricanes the least understood and the most destructive one is earthquake. Since, they cause plenty of injuries and economical losses leaving behind a series of signs of panic. Necessity to implement seismic codes in building design, the earthquakes is like wake-up call. For this a better method of analysis such as static analysis, dynamic analysis and time history analysis has to be adopted for performing the structures seismic risk assessment. This dissertation work according to IS 1893 (Part 1): 2002 code provisions the structures are analysed by Equivalent Static method, Response Spectrum method and Time History method. The modelling and analysis is done with SAP 2000 v 14 software and the results that is, seismic parameters such as Time period, Base shear, Lateral displacement and Inter storey drift are tabulated and then comparative study of structures with and without Friction dampers has been done. The obtained analysis shows that use of the FD in frames, substantially reduces the roof displacement, and storey drift. The obtained results show suitable performance of FD in higher storey structure.

- ***L S Minsili, Zhong Tieyi and Xia He (2018)*** performed analytical investigation on “Design and vibration control by friction dampers in truss bridges”. In this thesis, various types of control methods have been proposed from passive to active systems and a number of hybrid methods combining both of them have found a major interest. It is likely that many devices can be used for energy dissipation, however, with an appropriate installation, friction devices introduce a simple and inexpensive solution and have been massively applied to buildings and related structures while there is no particular application in bridge superstructures. Due to negative effects attributed to the rise of acceleration in some structural elements, their massive application has been rejected by many contractors. The objective of this work is to give a simple analytical method of controlling bridges vibration by means of slotted bolted friction connections based on experimental studies by M. Constantine’s and other researchers. A first stage analysis is done on a through truss bridge with a sinusoidal excitation and later, as an application, simulations are done with a running train and earthquake excitations. The obtained analytical results show the effectiveness of friction dampers installed in the superstructure of a bridge and exhibit in the same time the needs to modulate the rate of energy dissipation by adjustment of the friction characteristics to meet the expected requirements.

CONCLUSION

According to the previous studies and researches, the application of different kinds of dissipation devices especially friction dampers have been discussed and presented.

- Building with dampers well reduced seismic quantities more as compared to building with bracing.

- It was found that the presence of dampers tremendously influences the stiffness of structures. At high stiffness of dampers, the building behaved as rigidly connected and at low or zero stiffness the building returned to unconnected condition. As the no. of story decreased the overall stiffness of building increased, to counter act this damping stiffness was reduced relative to the higher no of story. Whereas continuous decrease in effective stiffness of dampers showed increase in story drift and base shear.

- The controlling devices reduce damages and also increase the structural safety, serviceability and prevent the building from collapse during the earthquake.
- The damping devices reduced the story drifts, base shear, absolute acceleration and the roof accelerations considerably when installed in a tall building.
- The optimization of the damping system leads to significant savings in the cost of the supplemental damping system.

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