International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 05 Issue: 04 | Apr-2018 www.irjet.net p-ISSN: 2395-0072

A Review on Optimal Positioning of X Plate Damper in Concrete Frame Building

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Abstract - *Earthquakes are the most dangerous natural disaster as they occur with no warnings. Earthquakes can impart large amount of energy to structures and can cause large deformations and vibrations resulting in their imminent failure. So there is a need for the earthquake energy to be dissipated from the structure. One of the most effective mechanism to dissipate energy in a vibrating system is by the inelastic strain of supplemental metallic elements with plastic deforming characteristics. An X- plate damper (XPD) is one such metallic device that can endure many cycles of stable yielding deformation resulting in a high level of energy dissipation or damping. In this paper the behavior of 3 bay 10 storey concrete framed buildings equipped with XPDs subjected to real time earthquake motions are simulated and optimal configuration of dampers at various storeys is investigated and a parametric study on XPDs are conducted on the optimal configuration. The most optimal damper placement locations are selected by conducting a sequential optimization procedure based on a controllability index. Nonlinear Time History Modal analysis using structural analysis package SAP2000 is used for analyzing frames.*

Key Words: SAP, Modal time history analysis, Concrete frames, optimization, XPD, controllability index

1. INTRODUCTION

Earthquakes are the most dangerous and feared upon natural disaster as they occur with no warnings. Earthquakes can impart large amount of energy to structures and can cause large deformations and vibrations resulting in their imminent failure. So there is a need for the earthquake energy to be dissipated from the structure. To this day a large number of fatalities has occurred due to the collapse of manmade structures subjected to earthquakes. A huge amount of energy is imparted to the structure at a very short duration of time making earthquake design very complex. Conventional design philosophy is based on preventing collapse by allowing structural members to absorb and dissipate the absorbed earthquake energy by allowing structural members to absorb and dissipate the absorbed earthquake energy by inelastic cyclic deformations in specially detailed regions which means that building is allowed to deform and get damaged to an irreparable extent but total collapse may not occur. In the last couple of decades, special protective systems have been developed to increase safety and reduce damage to structures during earthquakes thereby eliminating fatalities to life and reducing damage cost. These unconventional methods aim to control the structural seismic response and energy dissipation demand on the structural members by modifying the dynamic properties of the system.

Most structures are subjected to vibrations arising from wind forces, earthquake excitation, machine vibrations, or many other sources. Sometimes, especially under strong earthquake excitations, these vibrations can cause structural damage or even structural collapse. The higher the inherent or natural damping in structures, lower will be the likelihood of damage. However, for structures subjected to strong vibrations, the inherent damping in the structure is not sufficient to mitigate the structural response. In earthquake prone regions, supplemental damping is required to control the response of these structures. About this subject, many researchers have studied, developed and tested different supplemental damping techniques. The basic supplemental damping systems used in structures are passive, active and semi-active systems.

2. X- PLATE DAMPER

X-plate damper (XPD) is a passive metallic damper which can endure many cycles of stable yielding deformations during cyclic loading. It consists of thin metallic plates which dissipates energy by flexural inelastic yielding. The 'X' shape assures a constant strain variation over its entire height and ensures simultaneous and uniform yielding. During cyclic loading the metal plates are subjected to hysteretic mechanism and the plasticization of these plates absorbs and dissipates a large fraction of vibration energy imparted to the structure. Also, the additional stiffness introduced by the metallic elements increase the lateral strength of the building, resulting in subsequent reduction in deformations and damage in the main structural members. The cyclic response of yielding metallic devices is strongly nonlinear supplemented by changes in element stiffness due to the loading, unloading and reloading of yielded elements. The introduction of these devices in a structure will render it to behave nonlinearly, even if the other structural elements are designed to remain linear. It was assumed that the structural elements and the braces that support these devices remain linear when they are subjected to the real earthquake ground motions. Fig-1 represents the sectional details of a XPD.

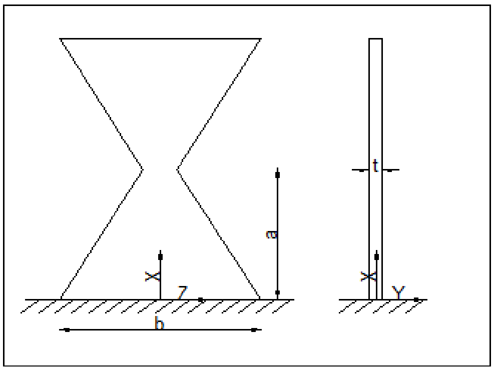

Fig -1: A typical XPD sectional details

Using beam theory, the properties of XPD are expressed as:

$$K_d = \frac{Ebt^3}{12a^3} n \tag{1}$$

$$F_y = \frac{\sigma_y b t^2}{6a} n \tag{2}$$

$$q = \frac{2\sigma_y a^2}{Et} \tag{3}$$

where, K_d is the initial stiffness, F_y is the yield load and q is the yield displacement of the XPD. E and σ_y are elastic modulus and yield stress of the damper material, respectively; a, b and t are height, width and thickness of the XPD as shown in Fig-1.

3 LITERATURE REVIEW

3.1 Review on mild steel passive damping devices

Kelly et al. [1972] studied about ways to separate the load carrying function of the structure from energy absorbing function and proposed use of mild steel yielding dampers as passive devices for energy dissipation through torsion of square and rectangular bars, rolling of strips and flexure of short thick beams installed in structures.

R.G. Tyler [1978] studied the use of tapered steel cantilevers and performed various tests on these devices and proposed methods for designing them. He concluded that these devices performed as predicted and had greater energy absorbing capacity as failure approaches.

R.I. Skinner [1980] described the development of various types of hysteretic dampers developed so far and methods for selecting them accordingly for a particular application. The most recent development discussed in this paper was the lead-rubber bearing in which the properties of load-bearing and damping were combined in one unit.

Hanson et al. [1992] conducted experimental study on two-storey planar concrete frame models and compared seismic performance when retrofitted with infill wall systems, steel bracings and steel plate dampers and conclude that steel plate dampers were more efficient in increasing strength, stiffness and energy dissipation of the frame.

3.2 Review on optimization techniques

Zhang [1992] addressed practical issues associated with the application of viscoelastic dampers in structures to enhance seismic performance and a sequential procedure for optimal placement of damper was developed, based on a concept of controllability. An example on optimisation of VE dampers on 24 storey steel frame was also presented using this method. He concluded that since added viscoelastic dampers change both damping and stiffness of the original structure, the optimal damper locations did not remain same as the damper properties varied.

Gluck et al. [1996] suggested a method for optimal design and configuration of supplemental viscous dampers in multy storey buildings using optimal control theory and shown a numerical implementation of design methodology for a structural model.

Tsuji et al. [1996] proposed a guideline for effective placement of viscous dampers in a shear building whose story stiffness are determined solely by severe performance criteria under moderate design earthquakes.

Wu et al. [1997] addressed the optimal positioning of energy dissipation devices in three dimensional structures were both translational and torsional responses are of major concern. The effect of ground motion characteristics on response of the model was also studied.

Takewaki [1997] proposed a systematic method for determining the optimal damper placement to minimize the sum of amplitudes of transfer functions evaluated at the un-damped fundamental natural frequency of a structural sys-tem subjected to constraint on sum of damping coefficients of added dampers. This method could be applied to any systems that can be modelled using finite element method.

Chan [1997] studied about multi-objective structural optimization problems using genetic algorithms.

Shukla et al. [1999] studied the response of 20 storey shear frame model equipped with optimally placed viscoelastic dampers. The optimization was done using controllability index which is a measure of building's response to earthquake excitation. The damper is considered to be optimally placed in the structure where controllability index is maximum. A sequential procedure was adopted for optimal damper placement by solving random seismic response of the structure.

Shukla [1999] studied the optimal placement of viscoelastic dampers in a 20 storey shear frame by conducting a sequential optimization procedure based on a controllability index. He concluded that the scheme of the optimal placement of VEDs provides more reduction in response compared with other schemes of placement of VEDs considered in the study and the optimal placement of dampers is sensitive to the nature of excitation force and variation in parameters of viscoelastic dampers.

Arfiadi [2000] developed optimization techniques for active and passive systems under earthquake loadings. Modern control theory and genetic algorithms were used as optimization tools.

Singh [2001] proposed a way to obtain the number of viscous/viscoelastic dampers require to bring down the response of a structure to the desired level and their optimum configuration in the building structure considered. A gradient based optimization approach was considered for solving the problem. Singh [2002] also studied about optimal size and placement of viscous/viscoelastic dampers in structures using the approach of genetic algorithms.

Pezeshk et al [2003] presented a genetic algorithm based approach for optimization of structures using both continuous and discrete systems.

Lavan et al. [2004] proposed a methodology for optimal design of supplemental viscous dampers for framed structures.

3.3 Review on prevailing literatures on XPD

Bakre et al. [2006] studied about the effectiveness of XPD in minimizing the seismic response of piping systems installed in industries and nuclear/thermal power plants. Seismic performance was studied by conducting a parametric study on XPD under arbitrary ground motions. Hysteretic energy dissipation was considered to obtain optimum properties of XPD.

Pujari [2011] studied the optimum placement of steel XPDs on square shaped buildings subjected to earthquake motions. Most optimal damper location was selected from fixed location formats. To seek the optimal location of dampers, a linear combination of maxi-mum inter-storey drift and maximum base shear of the damped structure normalized by their respective un-damped counterparts has been taken as the objective function. He also conducted a parametric study on effect of variations in geometrical properties of XPDs at optimal location.

Rahul M P[2015] studied and compared various retrofitting schemes like shear walls, viscous dampers and XPDs in an open ground storey building subjected to seismic forces. The parameters affecting the performance of the dampers and the seismic response of the building were also studied.

Manchalwar [2016] compared the response of steel frames quipped with steel and aluminium XPDs.

3. CONCLUSIONS

From the above literatures it can be concluded that although considerable studies exist on optimization of viscous/viscoelastic dampers, few studies exist regarding metallic hysteretic dampers, specifically XPDs. So it has been decided to do a project on optimizing XPD location on concrete frames subjected to real time earthquake motions and thereby conducting a parametric study on XPD. Optimization is to be done by conducting a sequential optimization procedure based on a controllability index.

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