Seismic Performance of Building using Accordion Metallic Damper

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Abstract – *Passive energy dissipation have been used so far to dissipate the unwanted energy due to earthquake and heavy wind actions. The complete failure of the structures that has occurred in the past due to catastrophic earthquakes may be avoided with the use of such devices. The study is concerned with the use of accordion metallic dampers that uses hysteretic energy to dissipate the unwanted energy due to earthquake. It consists of corrugated thin walled tubes installed as a brace connection in the frame. The axial deformation of the accordion damper enhances the lateral buckling capacity and results in maximum reduction of the damaging measures. The study emphasizes the use of such dampers and in depth analysis will be performed In order to assess the nonlinear performance of the dampers installed in the building.*

Keywords- Metallic damper, lateral buckling capacity, nonlinear performance.

INTRODUCTION

During the last decades, many researches have been concerned about the development of supplemental passive energy absorption devices especially hysteretic metallic dampers. In this regard, many different types of these devices have been developed for different purposes with different capacities and potentials. Thin-walled tubes are considered to be the most common shape and probably the oldest shape utilized in impact energy absorption. Plastic energy can be dissipated in thin-walled metallic tubes in several modes of deformation, including: inversion, splitting, lateral indentation, lateral flattening and axial crushing. From the point of view of energy absorption capacity, it was found that axial crushing of circular tubes provides one of the best devices.

An axially crushed circular tube can undergo one or more of three distinct deformation modes: Euler buckling, concertina mode of deformation, and diamond mode. Present study will be based on the nonlinear performance of dampers subjected to base excitation, the method of analysis will be time history analysis (nonlinear dynamic analysis) and nonlinear static pushover analysis to determine the capacity of the building equipped with metallic dampers.

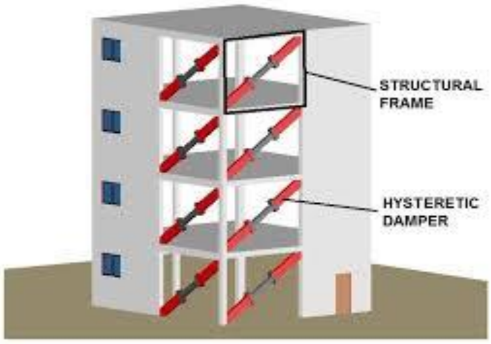

Fig.1-Use of metallic dampers in building (Google search)

Fig. 1 shows the elevation of building equipped with hysteretic damper. Takewaki, 1997 studied optimal damper placement to minimize the sum of amplitudes of the transfer functions evaluated at the undamped fundamental natural frequency of a structural system subjected to a base excitation. Batra, 2005 studied Thin-walled circular cylindrical shells are used widely as energy absorbing devices since they are inexpensive, efficient and reliable. Tyler, 1978 presented the results of tests carried out on tapered steel energy dissipaters are given, together with the design methods which have evolved. By employing a taper, the metal along its length is utilized for energy absorption to the fullest extent, which makes for a compact device which has found application in a stepping chimney at Christchurch and in a bridge in Dunedin. Climent, 2011 focused on the application of hysteretic EEDs to the seismic retrofit of buildings. In order to develop cost-effective retrofit solutions. The reduction in the critical damaging measures such as storey drift, top storey displacement, acceleration reveals the formidable potential of such metallic devices which uses hysteretic energy to dissipate the earthquake energy. Moreover, optimal damper placement results in maximum reduction thus the efficiency is enhanced. Number of trials are required in order to assess the optimal damper positions. Lastly, area of the hysteresis curve of damper gives the energy dissipated by the dampers.

Methodology

The equation of motion for an N-degree of freedom system equipped with hysteretic metallic damper subjected to base motion is given by

$$M\ddot{u}(t) + C\dot{u}(t) + Ku(t) + F(t) = -M\ddot{u}_g r$$

Where M, C and K are the mass matrix, damping matrix and stiffness matrix of the system, of size N x N respectively and F (t) is the restoring force vector for the metallic damper as per Wen's model; u (t) is the column vector of the story displacements relative to the ground, r is a column vector of ones and üg (t) is the ground acceleration.

According to Bouc-Wens model the restoring force is expressed as

$$F(t) = \alpha \frac{F_y}{U_y} u(t) + (1-\alpha) F_y z(t)$$

$$F(t) = F_e(t) + F_h(t)$$

Where, $F_e(t) = \alpha \frac{F_y}{U_y} u(t)$

$$F_h(t) = (1-\alpha) F_y z(t)$$

$$K_e = \frac{F_y}{U_y}, \quad \alpha = \frac{K_p}{K_e}$$

Ke and Kp is initial and post-yielding stiffness of system, Fy and Uy is the yield force and yield displacement of the system and over dots denotes the derivative with respect to time. For small values of 'n' the transition from elastic to the post-elastic branch is smooth, while for large values that transition is abrupt.

Problem Statement

For nonlinear analysis of metallic dampers, a 3D, seven storey rectangular and Square shaped building is considered having plan as 12 x 7 m and 9 x 9 m. height of each storey is same i.e. 3 m. The slab thickness is 125 mm. The dimensions of beam and column is given in table 1. Outer wall thickness is 230 mm.

Table 1-Size of beam and column

Beam	Size (mm)	Column	Size (mm)
B	250x 300	C	250 x 350

The live load of 3 KN/m2 is considered on the building. The modelling of the building is done with the help of FE based software SAP 2000. The nonlinear time history analysis is used to analyze the metallic dampers. It has been recommended by many authors to perform nonlinear analysis for assessment of such hysteretic dampers. Figure 2 shows the 3D view of rectangular and square shaped building.

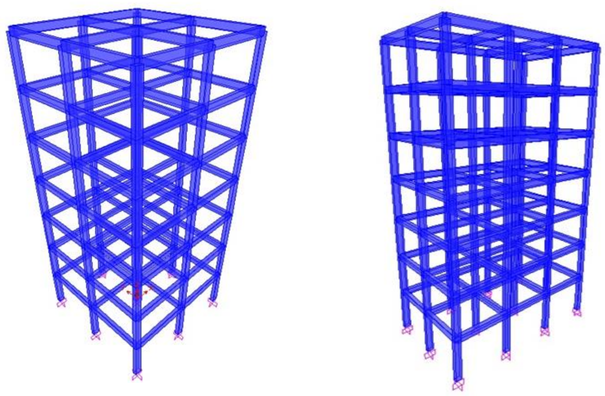

Fig. 2- 3D view of square and rectangle building

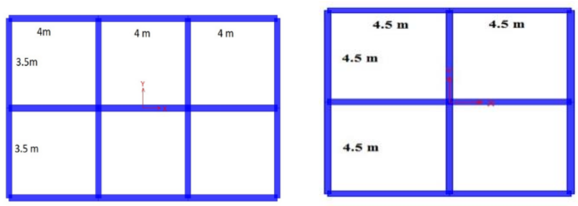

Fig. 3- Plan of Rectangular and Square building

The base excitation is simulated by using two real ground motions, taken from PEER ground motions, which are in the form of text file and is fed to SAP 2000. The details of the ground motions are given in table 2. Table 3 shows the properties of metallic damper used in the analysis

Table 2- Details of Earthquakes

Time history	Magnitude	Source
San fernando earthquake	0.13 g	NICEE

Parkfield Earthquake	0.15 g	NICEE

Properties of Single AMD

Initial Stiffness	30,000kN/m
Post Stiffness	Kp=250 kN/m
Post yield strength ratio	α=0.083
Yield force	28kN
Yielding exponent	1.0

Results and Interpretation

The intrusion of dampers results in reduction of critical damaging measures due to earthquake. It has been observed that with the application of dampers, top storey displacement and inter-storey drift is minimized from 30 to 40%. The comparative analysis is shown for both the buildings in the form of bar chart. Fig. 4 shows the comparison with and without damper for square shaped building.

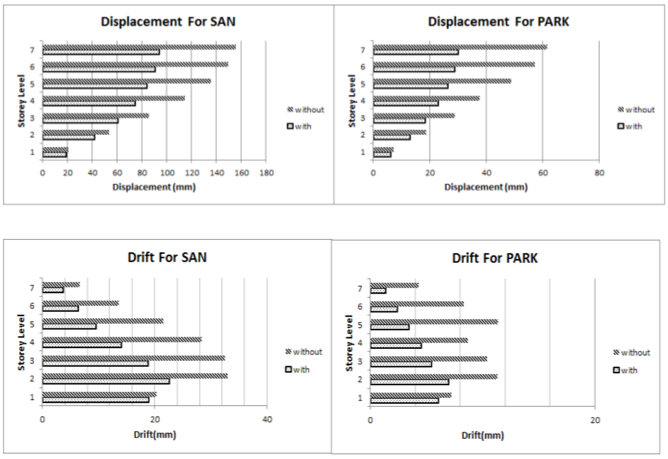

Fig. 3- Comparison for square building

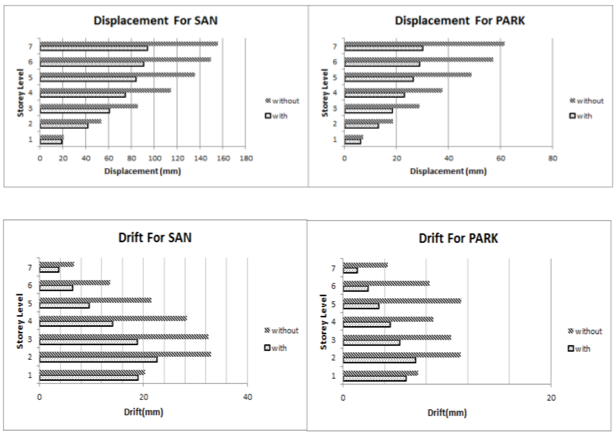

Fig. 4- Comparison for rectangular building

Lastly in order to understand the working of metallic damper, the hysteretic curve of damper is studied, which is the plot of force Vs curve. Fig. 5 shows the curve for square and rectangle deformation curve. The nonlinearity of the damper is indicated with the help of hysteretic shaped building.

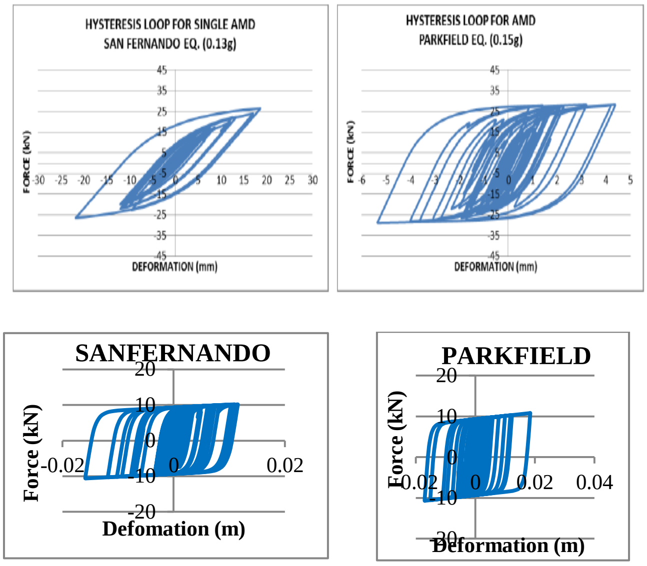

Fig.5- Hysteretic loops of AMD for rectangle and square shaped building

CONCLUSION

The existence of damper in the structure reduces the seismic response of the structure. Wen's model is a perfect model to study and understand the behavior of the metallic damper. Due to damper displacement and inter-story drift at various floors shows significant reduction. With damper, shear force and bending moment of all columns can reduce up to (55) % Reduction in axial force is very small as compared to reduction in shear force and bending moment in all columns at top storey. Response quantitates of the building reduces with increase in the initial stiffness (yield stiffness) of damper. From hysteresis loops dissipation of energy can be observed. But it is not possible to provide damper at each storey thus, it is necessary to optimize the damper location which gives more reduction for given numbers of damper. Hence, location optimization study may be performed such dampers which minimizes the cost of dampers, such damper is eco-friendly and easily available

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