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SEISMIC DAMPING IN FRAME STRUCTURES USING LEVER DAMPING MECHANISM

Energy Dissipation Techniques

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Abstract — *Fluid viscous dampers were used in a 1/3 scale three story steel structure to dissipate seismic energy. The geometric configuration of the supplemental damping was design such that it did not alter the shear and axial demand on columns. In addition, it used less width and height of the span and allowed space for architectural openings. A lever mechanism technique was used for this purpose which used comparatively smaller sized dampers. The results obtained after the experimental testing indicated approximately 48% reduction in both acceleration and drift.*

Keywords*- Viscous Dampers, Supplemental Damping, Seismic Energy, Drift, Acceleration*

I. INTRODUCTION

Different parameters such as structural design methods, intensity and duration of earthquake, geological characteristics, and quality of construction are responsible for a structural damage during a seismic event. A properly designed structure means that during an earthquake it may be damaged partially but it will not collapse. Apart from structural design methods and techniques construction practices and proper supervision on site an important role in controlling fatalities and economic losses. For example, 700 fatalities were reported due to 1906 earthquake in San Francisco, however, during 1908 Southern Italy earthquake approximately 100,000 people lost their lives. The survival rate in San Francisco (almost 98%) was greater than that of Southern Italy (33%-45%) due to the fact that most of the houses were made up of wood in San Francisco and hence light in weight. (Zebrowski, 1999).

Different methods have been used to reduce the effects of seismic events on manmade structures. Conventional and advanced techniques can be used individually or in combination to resist and/or dissipate the earthquake induced forces. Some of the conventional methods is to increase the strength of structural components, also in case of highly seismic prone area the total number of stories are compromised. To overcome the limitation of structure height some advanced techniques were developed and used in the past decades. One of such techniques is base isolation while another is known as supplemental energy dissipation.

The concept of energy dissipating techniques have been researched and applied in many fields of engineering fields and systems for instance, effect of in the field of military engineering vibrations due to weapons' firing need to be dissipated. Automotive suspensions also use the concept of shock absorption. Supplemental damping in bridges and buildings to enhance their seismic characteristics. From last few decades, passive energy dissipation and its applications in the field of civil engineering for seismic control have been under development but a rapid increase in their implementation has been observed in the mid-1990s (Symans et al., 2008). The principle function of passive energy dissipation system is to reduce the inelastic energy dissipation demand on the framing system of a structure (Constantinou and Symans 1993 and Whittaker et al 1993). For example, different types of dampers are installed in tall buildings subjected to wind loads impart 5-10% total damping, which includes only 1-3% from the structure itself (Taylor and Constantinou, 1998). Additional background and historical data on the use of supplemental damping devices in structures were provided by Taylor and Lee (1987) and Taylor and Constantinou (1994). Constantinou, et al. (1997) and Soong and Dargush (1997) report on the use of dampers within building and bridge structures.

In case of supplemental damping techniques, different types of dampers are installed in a certain configuration that will efficiently dissipate the energy from a seismic event. Some of the supplemental damping techniques used in the past are;

1 Combined-Yielding Metallic Dampers (CMDs) by combining the flexural and shear plates (Taraithia et al, 2013)
2 Scissor-jack-damper system developed by Şigaher and Constantinou, 2004 used the concept to jack and toggle braced system
3 Toggle braced system developed and tested by (check whether tested by following Authors????) Hammel 1997, Constantinou et al. 1997, and Constantinou et al. 2001
4 Aiken and Kelly, 1990 tested friction dampers installed on the chevron braces
5 Added Damping and Stiffness devices used by Bergman and Goel (1987), Whittaker (1989) and Hanson (1993)
6 Eccentrically braced steel frames for earthquakes by Roeder (1978)

The configuration used in the past are however such that they in case of a seismic event attract and add more axial and shear demand on columns for which the column sizes and/or strength requirement is greater than that required in case of unbraced structure (i.e. structure without supplemental damping). In addition, most of these configurations are such that space for architectural openings is limited.

Therefore, a new configuration named as "sliding lever mechanism technique" was developed which is arranged such that it would not increase axial demand and shear demand on columns yet at the same time making more space available for architectural opening and symmetry. To check the seismic performance of the new idea a three story steel structure model (1/3 Scale) was tested on shake table for different earthquake records. The results showed a reduction of approximately 48% in both stories displacements and accelerations when dampers were installed using new geometric configuration.

II. ANALYTICAL MODEL

The analytical model was used to determine sizes of structural members as well as their structural response without using of supplemental damping. Finite element based software SAP2000 was used for linear modal time history analyses. Stiffener were used to make a connection between column, base plate and beams, therefore all these joints were modelled as rigid connections. After running the analysis, the fundamental time period and frequency of the structure was 1.01 Sec and 0.99 Hz respectively.

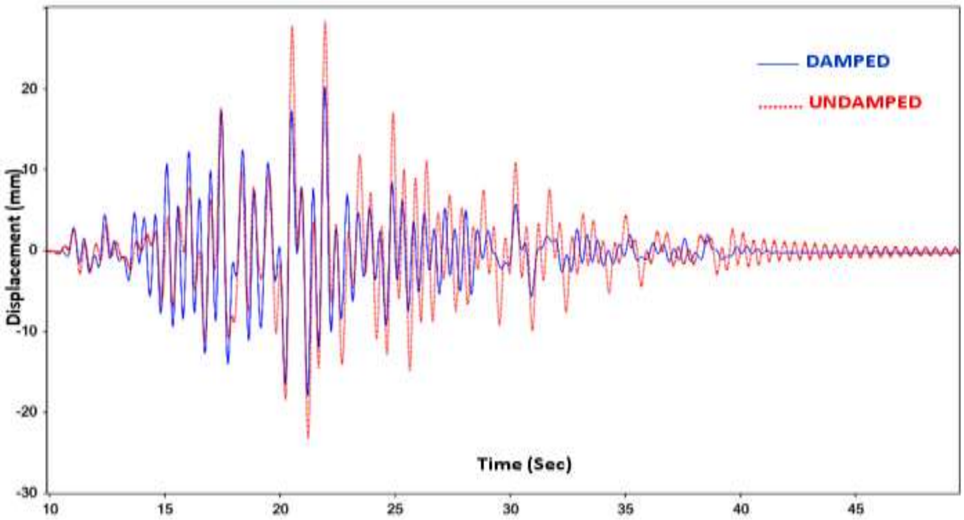
III. MATERIALS AND METHODS

Steel tube sections of 2mm thickness and A36 material were used to fabricate the main frame structure (column and beams) of the experimental model. The model consisted of two identical frames of three story at a scale 1/3 and tied together by tie beams. The tie beams had the same section as that of main frame. The two frames were tied at each story. The planner grid of the columns was selected based on the size and grid of bolting holes in the shake table available. The selection of member sizes, number of stories and masses on each story were aimed to achieve a range of time period and lateral drift that would be a reasonable representation of actual steel building and also to have a distinguishable graphical comparison of the damped and undamped structural responses. Another smaller frame was installed inside each main structural frame to provide a rigid mount for accessories that would be used in damping mechanism. Fluid viscous dampers were used in the model to dissipate seismic forces.

Two types of previous earthquake records with varying levels of g from 0.1g to 1g were tabulated to test the model. The experimental model was tested for two previous earth records of Imperial Valley (USA) October 15, 1979 and Kashmir (Pakistan) October 8, 2005 the accelerograms.

IV. RESULTS AND DISCUSSION

Accelerations and displacements were directly recorded using accelerometers and displacement transducers. The result data was then processed and filtered using interactive graphics worksheet DADiSP 2002. Structural responses like base shear, accelerations, displacements were then plotted against each other as shown;



The values of peak roof displacements of the model with and without using sliding lever mechanism technique were then plotted against each other as shown in the above figure

V. CONCLUSION

The dampers when installed in a new geometric configurations known as sliding lever mechanism technique reduced the overall seismic response of the experimental model. By comparing the results obtained it can be concluded that this configuration is most suitable for structures with smaller drifts.

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