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Performance of Supplemental Viscous Damper in Eccentric Steel and RC 3D Framed Building

Bapi Mondal[1], Karabi Bharadwaj[2] and Nirmalendu Debnath[3]

[1,2]M.Tech Student N.I.T Silchar Silchar, Assam
[3]N.I.T Silchar, Silchar, Assam
E-mail: [1]mandal.bapi7@gmail.com, [2]karabi2990@gmail.com, [3]nirmalendu@civil.nits.ac.in

Abstract—*Viscous damper systems are considered as an effective passive control device for mitigating vibrations in building structures. As a passive control device, viscous dampers are not associated with any uncertainty of power-supply failure, thus performing as a robust energy dissipating device. The present study investigates the performance of linear viscous dampers in vibration-control of multi-storey building structures specially, considering control under seismic loading. In this study, a steel as well as a reinforced concrete (RC) 3D framed buildings, both having six stories, are considered. To evaluate the effect of eccentricity, three building plans like symmetric, T and L-shape are selected having similar plan-area. The models are designed and analyzed using SAP2000 based on available IS codal provisions to represent a typical building structures. Cross sectional areas for both beams and columns are kept similar across all three symmetric/asymmetric models, therefore, keeping mass of all these models similar for efficient comparison. Four cases of damper position-profile are studied varying the number and strength (damping coefficient) of dampers without varying the total damping. Three objective functions are taken into account to measure the control performance like: (a) intensity of power spectral density (PSD) (b) inter-storey drift (c) maximum top-storey displacement. In PSD analysis, reduction in the intensity of PSD (displacement based) is considered. On the other hand, time history simulation is performed using white noise (ensuring excitations with wider frequency content) to quantify top displacement and inter story drift. Comparing with the uncontrolled case, the results are obtained like: (a) maximum reduction in the intensity of PSD is about 80% for steel and 58% for RC (b) reduction in inter-storey drift is about 65% for steel and 16% for RC (c) maximum reduction of top-storey displacement is around 60% for steel and 13% for RC framed building.*

1. INTRODUCTION

In the past few decades lot of research works have been conducted to study the behavior of control systems used to lessen vibrations in structures. Passive control systems are widely preferred as these do not require any external power supply and only uses the structural motion. Supplemental viscous dampers have emerged as a viable option for the vibration control of structures. Constantinou(1986-1994) tested steel moment resisting frame and reinforced concrete building models and a steel bridge model with dampers and all exhibited improved resistance to a variety of seismic loads. Taylor & Duflot stated when fluid viscous dampers are used for seismic or wind protection, the end result is a predictable reduction of both stress and deflection in the structure. Optimal performance is dependent on the type of structure and the level of performance required. Viscous dampers are also applicable for retrofitting of structures. Kargahi & Ekwueme *(2004)* concentrated on buildings retrofitted with viscous dampers. They presented an optimization technique for selecting damper properties that incorporates the nonlinear behavior of a building. Further research was carried out taking into consideration the asymmetric plan of building. Goel (2000) examined how supplemental viscous damping can be used to control the excessive deformations in asymmetric-plan building. Dicleli & Mehta (*2006)* aimed at comparing the seismic performance of steel chevron braced frames with and without viscous fluid dampers as a function of the intensity and frequency characteristics of the ground motion and VFD parameters. Tubaldi, Barbato & Asta*(2014)* introduced an efficient methodology for assessing the seismic risk of structural systems equipped with linear and nonlinear viscous damping devices while accounting for the uncertainties affecting both seismic input and model parameters. Although viscous dampers have proved effective in reduction of structural response but the location of the passive control devices is a matter of concern. In the recent years studies have been carried out to develop the location of dampers in structures. Petti & Iuliis*(2007)* proposed a new approach to locating viscous dampers optimally in order to control the torsional seismic response of asymmetric-plan buildings. Optimal design criteria have then been carried out by evaluating the H_∞ and H_2 norms of the transfer function relating the maximum edge displacement to the input seismic excitation. Miyamoto, Gilani & Gündoğdu *(2013)* presented seismic design incorporating earthquake protection devices leads to optimal design and combination of best engineering practice and minimal cost. The research works performed showed the efficiency of viscous dampers in various fields.

2. MODELLING OF BUILDINGS

The modelling and analysis of the structure is done by using SAP200.Three types of building plans are considered to show the effect of eccentricity. Fig. 1(a) shows a typical floor plan of the building symmetric in both the axes (symmetric plan), Fig. 1 (b) shows a floor plan eccentric in X axis (T shape plan and Fig. 1(c) shows a floor plan eccentric in both X and Y axes (L shape plan).

Linear viscous dampers are placed in four position profiles. The total supplemental damping per panel is taken as 1800 N-sec/cm for both RC and steel building frame. The RC building is assumed to have an internal damping of 5% and for steel building frame the value reduces to 2%. The total supplemental damping is distributed to a number of dampers based on position profile.

Case I: Uncontrolled model

In this case no damper is provided in any of the panels.

Case II: Uniform model

In this case dampers are provided in each panel and all the stories in both X and Y directions.

Case III: Triangular model

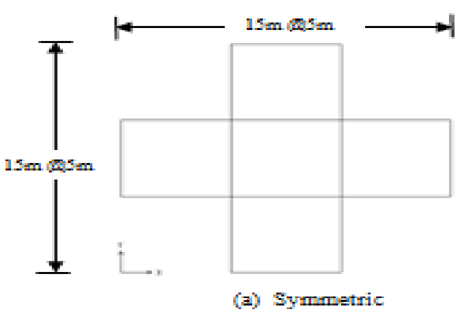
The damping profile is obtained as triangular by uniformly varying the damping coefficient from top to bottom with zero damping at the top floor and maximum damping at the ground floor applied in both X and y directions.

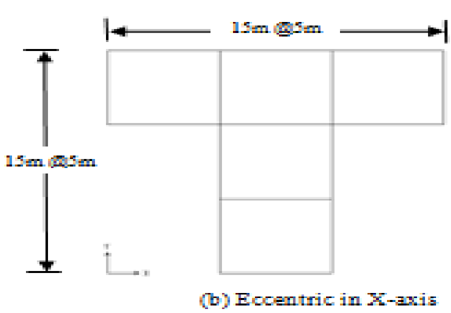
Case IV: Lower rectangular

In this case dampers are provide only in bottom three stories and the damping coefficient is kept constant in both X and Y axes.

Case V: Lower triangular

The dampers are placed in a similar manner as in case IV but uniformly varying the damping coefficient to obtain the lower triangular profile.





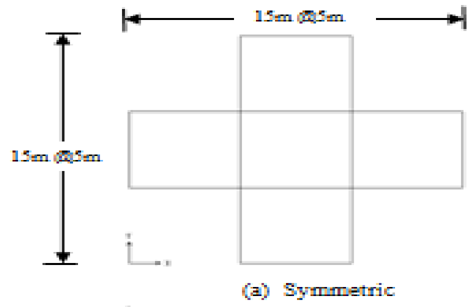


Fig. 1: Typical floor plans of the buildings

3. RESULTS

Several sets of numerical results have been obtained. The focus of this study is especially on the effect of the position of dampers on the buildings and the effect of eccentricity considering control under seismic loading. Three objective functions are taken to evaluate the displacement PSD, inter-story drift and roof displacement.

3.1. Displacement PSD

The following graphs show the results obtained from PSD analysis in SAP2000 of the RC and Steel framed building. The effect of eccentricity is showed for the best position profile. The percentage reduction of displacement PSD for all the damping profile cases with compared to uncontrolled cases is as follows:

3.1.1 Displacement PSD of RC framed building

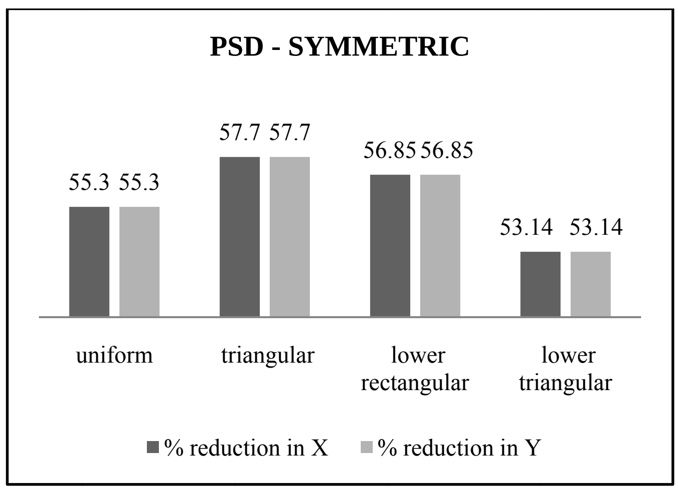


Fig. 2 (a) % reduction of PSD displacement in symmetric plan

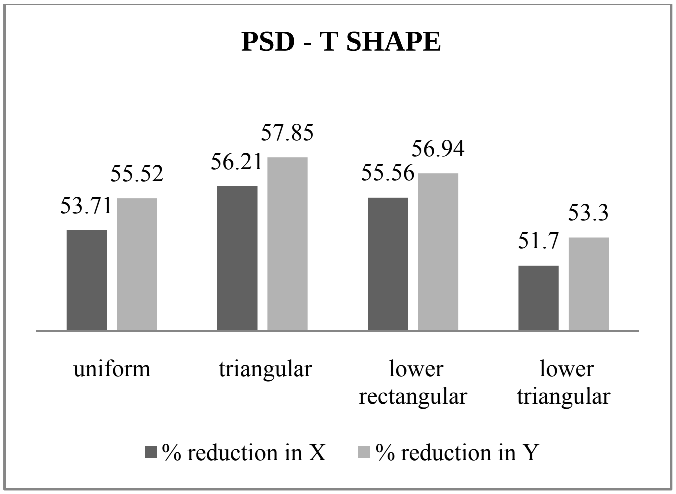


Fig. 2 (b) % reduction of PSD displacement in T shape plan

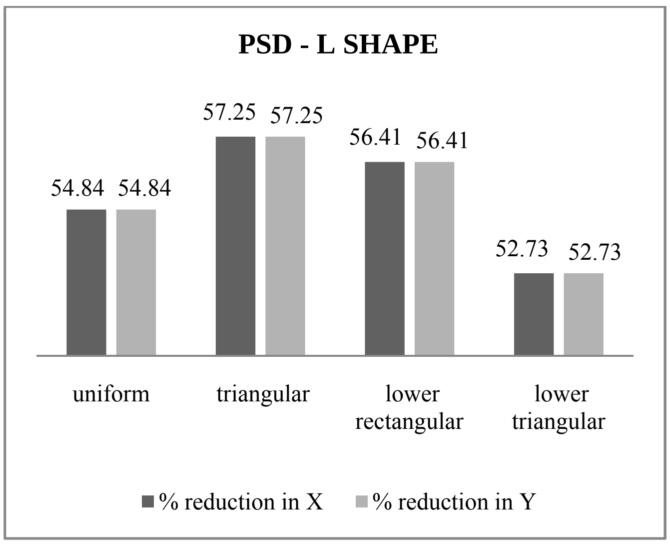


Fig. 2 (c) % reduction of PSD displacement in L shape plan

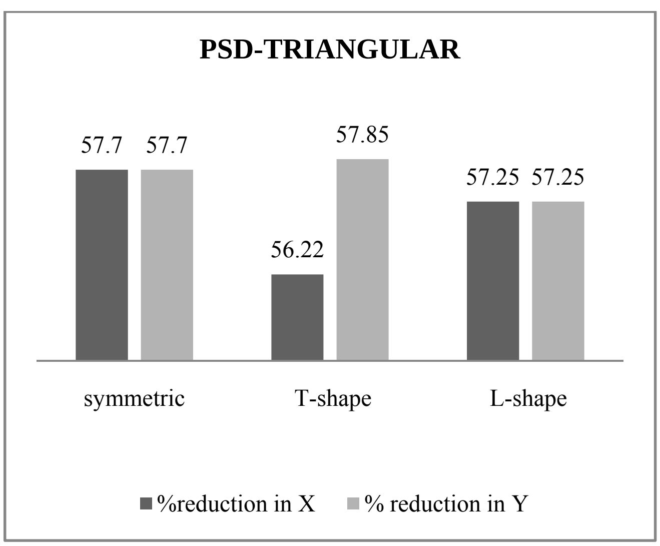


Fig. 3: Effect of Eccentricity of triangular damping profile

3.1.2 Displacement PSD of Steel framed building

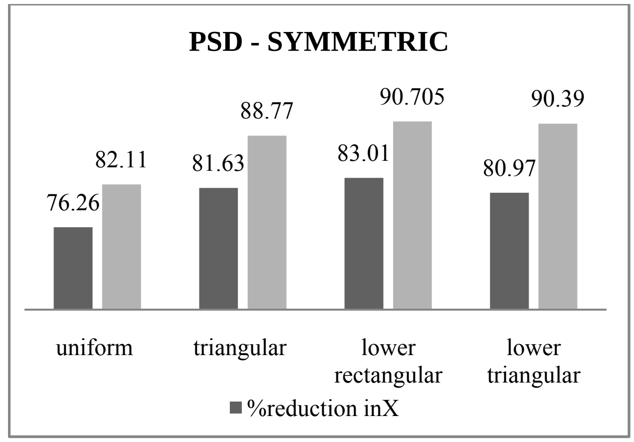


Fig. 4: (a) % reduction of PSD displacement in symmetric plan

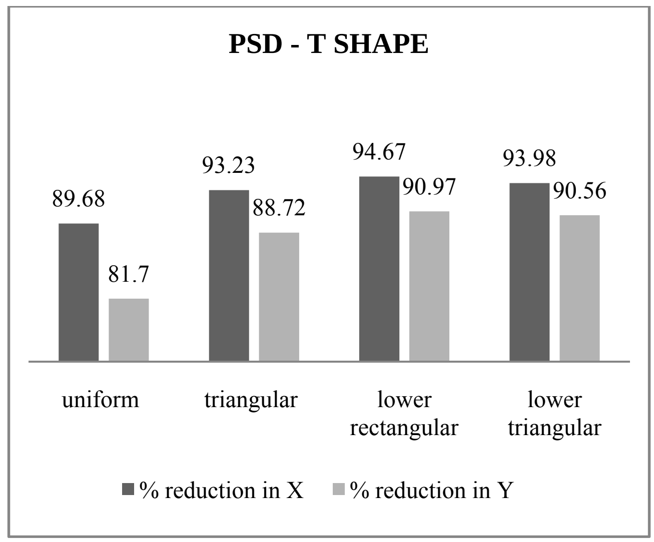


Fig. 4: (b) % reduction of PSD displacement in T shape plan

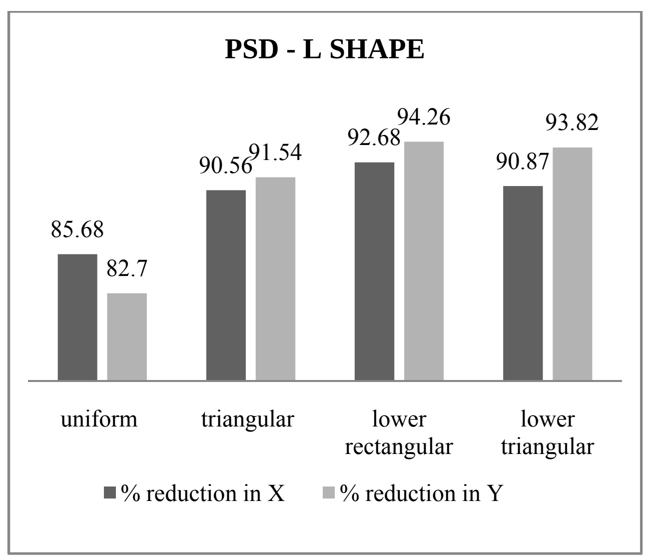


Fig. 4: (c) % reduction of PSD displacement in L shape plan

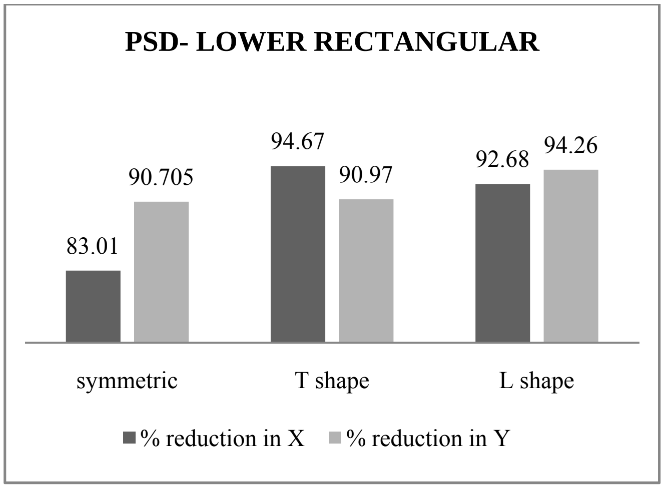


Fig. 5: Effect of Eccentricity of lower rectangular damping profile

3.2 Inter-story drift

The maximum of mean inter-story drift is obtained from linear time history analysis using white noise (0.01sec time step) excitation. The percentage reduction of inter-story drift for all the damping profile cases with compared to uncontrolled cases is as follows:

3.2.1 Inter-story drift of RC framed building:

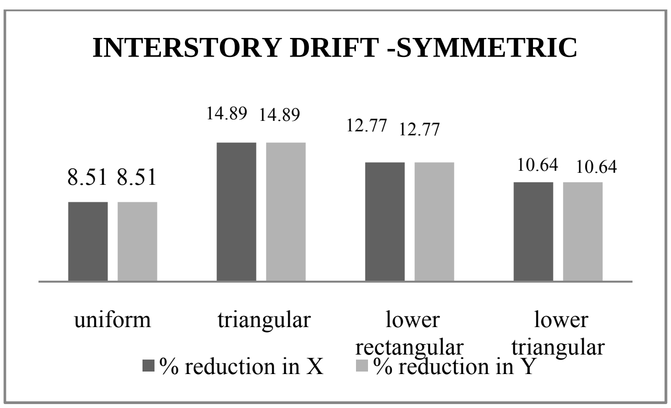


Fig. 6 (a) % reduction of inter-story drift in symmetric plan

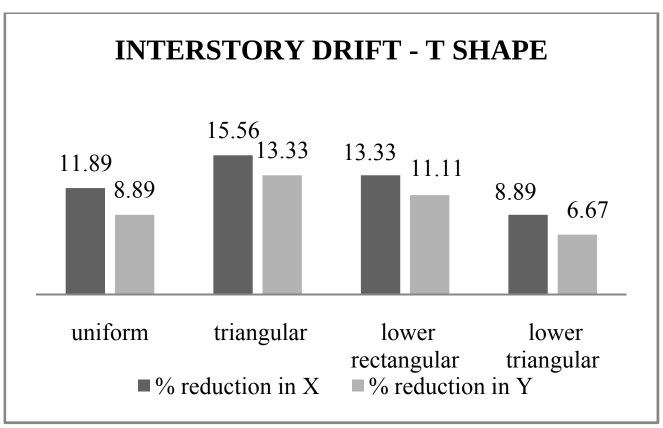


Fig. 6 (b) % reduction of inter-story drift in T shape

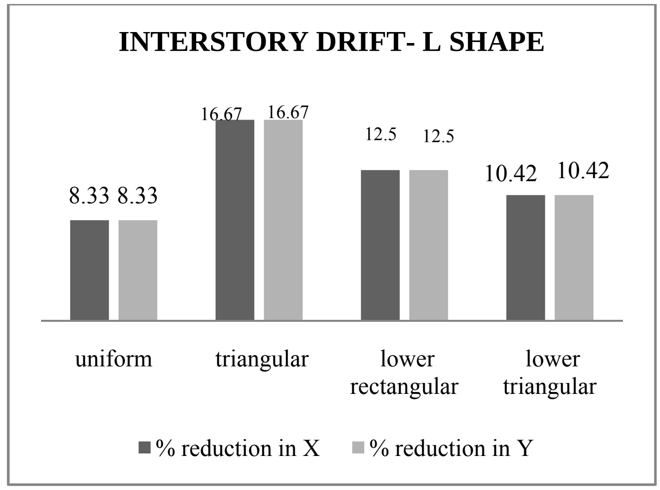


Fig. 6: (c) % reduction of inter-story drift in L shape plan

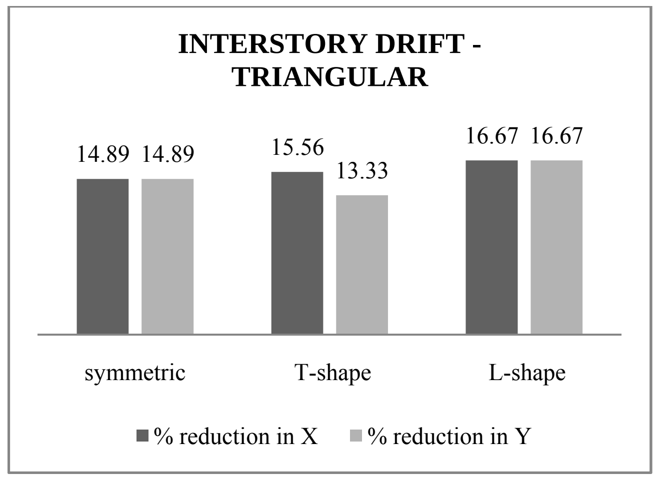


Fig. 7: Effect of Eccentricity of triangular profile

3.2.1 Inter-story drift of Steel framed building:

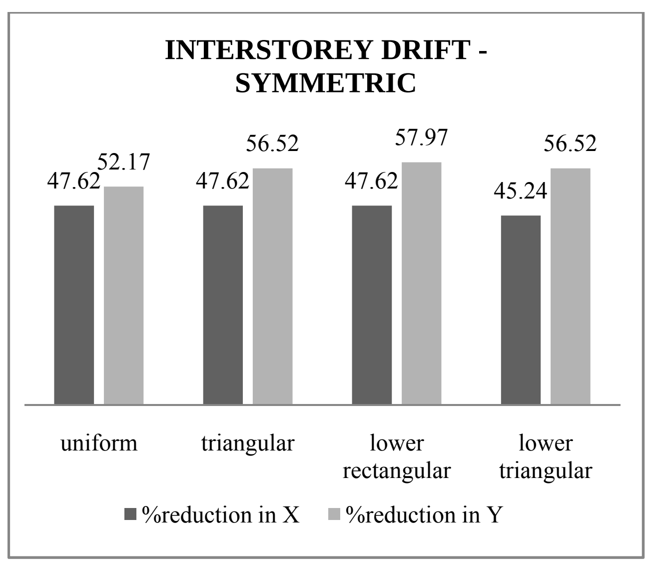


Fig. 8: (a) % reduction of inter-story drift in symmetric plan

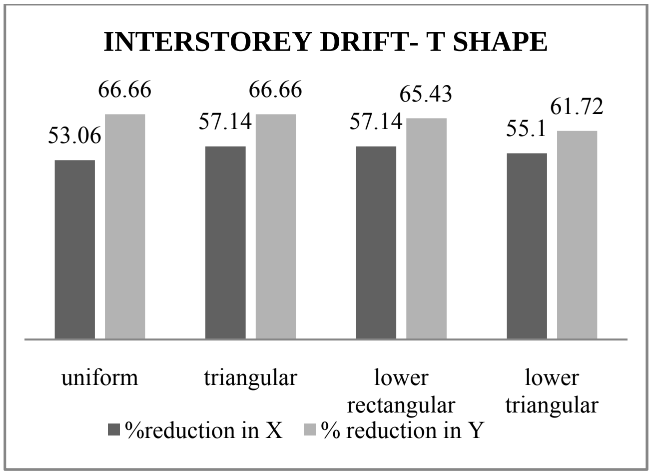


Fig. 8: (b) % reduction of inter-story drift in T shape plan

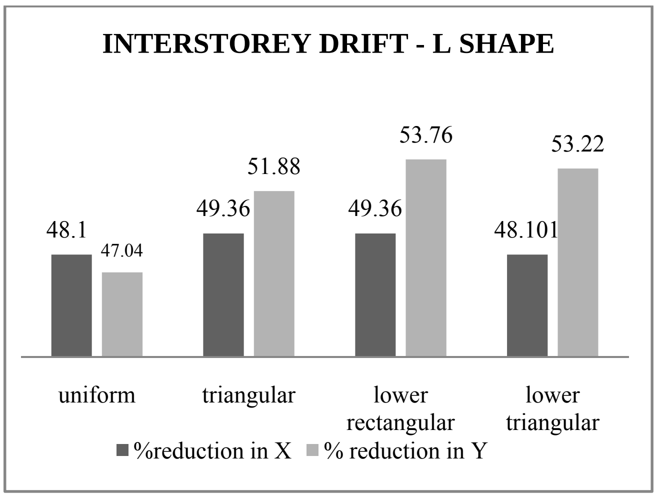


Fig. 8: (c) % reduction of inter-story drift in L shape

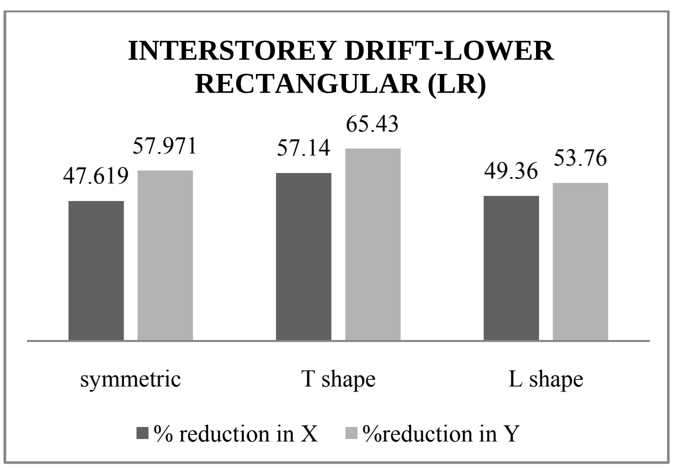


Fig. 9: Effect of Eccentricity of LR damping profile

3.3 Roof Displacement:

Average roof displacement also obtained from linear time history analysis using white noise (0.01sec time step) excitation. The percentage reduction of top displacement for all the damping profile cases with compared to uncontrolled cases is as follows:

3.3.1 For RC framed building:

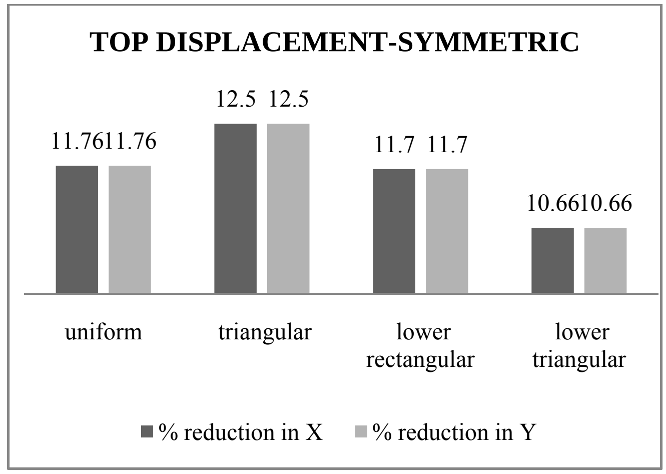


Fig. 10: (a) % reduction of top displacement of symmetric plan

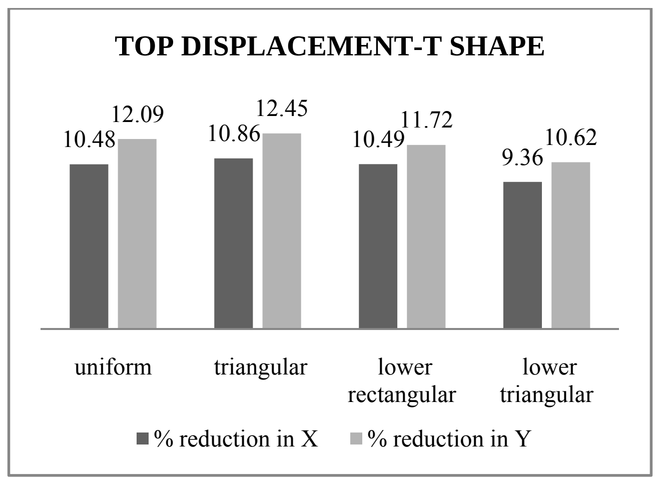


Fig. 10: (b)%reduction of top displacement of T shape

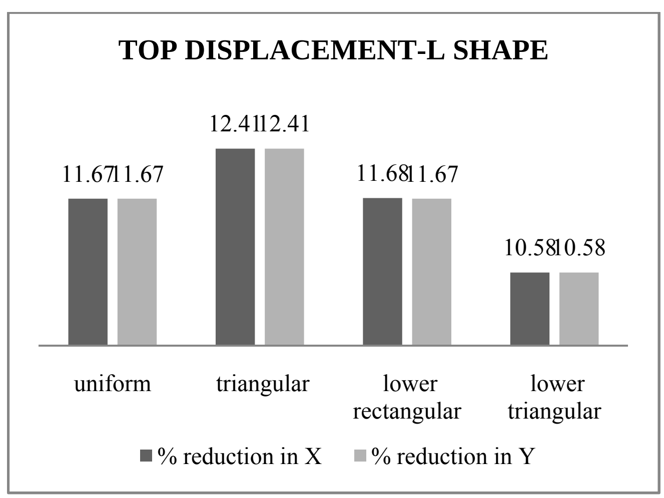


Fig. 10: (c)%reduction of top displacement of L shape

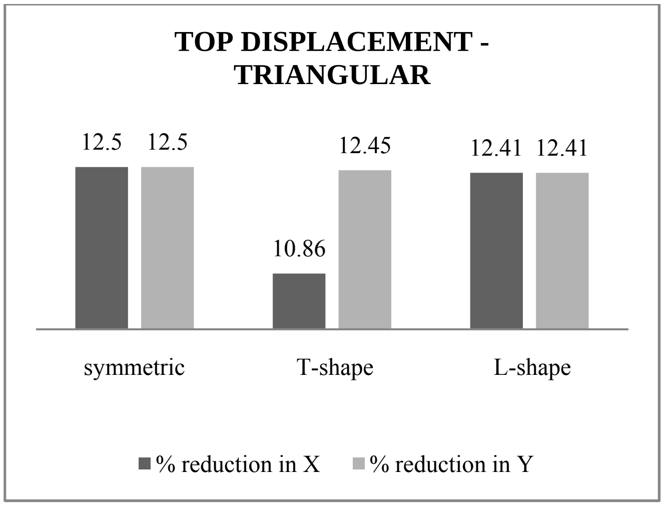


Fig. 11: Effect of Eccentricity of triangular profile

3.3.2 For Steel framed building

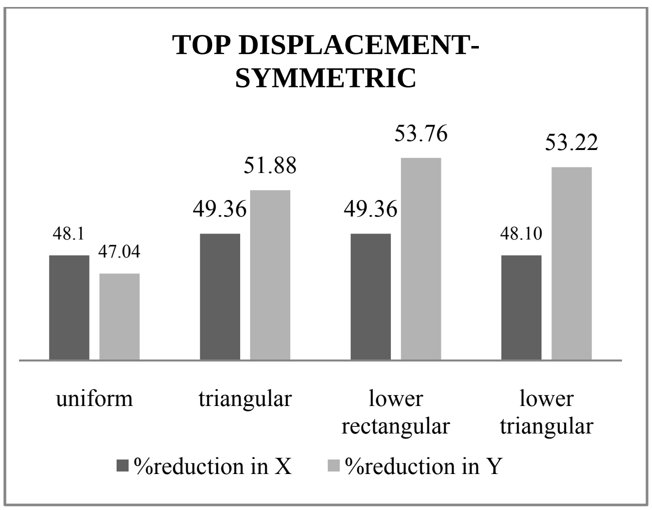


Fig. 12: (a) % reduction of top displacement of symmetric plan

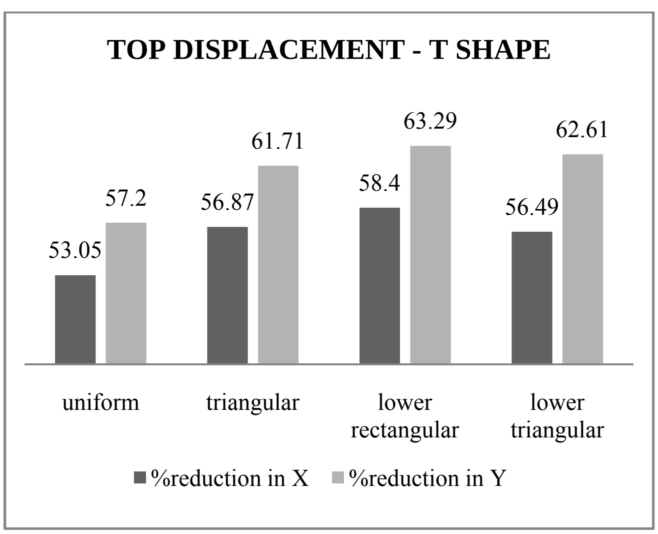


Fig. 12: (b) % reduction of top displacement of T shape plan

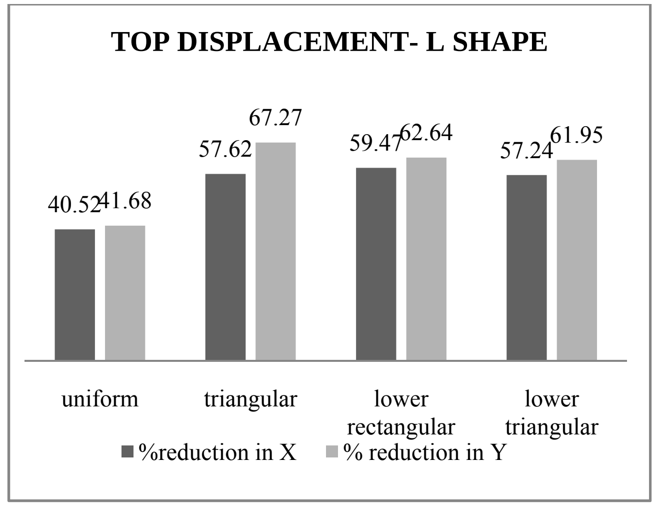


Fig. 12 (c) % reduction of top displacement of L shape plan

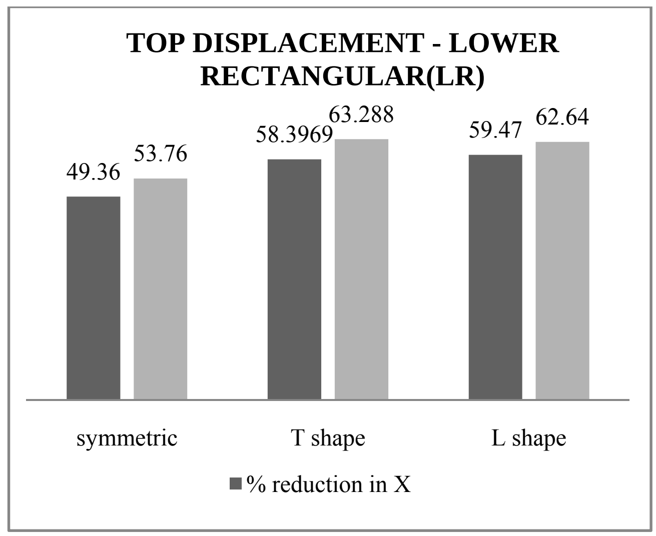


Fig. 13: Effect of Eccentricity of LR profile

4. CONCLUSION

From the present study it is observed that

1. Supplemental fluid viscous dampers are effective in reduction of structural response for both RC and steel framed buildings. Comparing with the uncontrolled case, the results are obtained like: (a) maximum reduction in the intensity of PSD is about 80% for steel and 58% for RC (b) reduction in inter-storey drift is about 65% for steel and 16% for RC (c) maximum reduction of top-storey displacement is around 60% for steel and 13% for RC framed building.
2. The location of damper in structure influences the performance of viscous dampers. Better performance is obtained by providing more damping strength at the lower stories. Triangular damper position-profile and lower rectangular damper position-profile shows better

performance for all the three objective functions in RC and steel framed building respectively.

3. Eccentricity of building plan also affects the overall performance of viscous damper. The effectiveness reduces as eccentricity increases in case of RC framed building but in case of steel framed building the variation in eccentricity is distinct in all the cases.

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