Proceedings of IOE Graduate Conference, 2019-Summer
Peer Reviewed
Year: 2019 Month: May Volume: 6
ISSN: 2350-8914 (Online), 2350-8906 (Print)

Seismic Performance Analysis of Steel Frame Building with Bracing and Friction Damper

Sujal Koju [a], Gokarna Bahadur Motra [b]

[a] *Department of Civil Engineering, IOE, Thapathali Campus, Tribhuvan University, Nepal*
[b] *Department of Civil Engineering, Pulchowk Campus, IOE, Thapathali Campus, Tribhuvan University, Nepal*
Corresponding Email: [a] sujal3991@gmail.com, [b] gmotra@ioe.edu.np

Abstract
Steel frame buildings are being widely constructed nowadays for various advantages over RC framed buildings like fast construction, light weight construction and large span possibility. Such construction, especially in the earthquake prone country like Nepal needs safer design methodology against seismic forces along with wind load, of which the common and effective methods are the use of bracings and dampers. Diagonal bracings and diagonal friction dampers for a ten storey building are used. Non linear time history analysis is used to compare the response between the bare frame, frame with bracing and frame with damper. This study gives the comparision of the three types of frames and shows the improvement of the seismic performance of the building using both the methods stated for the steel frame building.

Keywords
Steel Frame Building, Diagonal Bracing, Friction Damper, Nonlinear Time History Analysis

1. Introduction

When the earthquake occurs, large earthquake force acts on the structural members of the building. Conventional building are designed to resist minor to moderate earthquake following the codal provisions in design. But these types of buildings are exposed to a greater risk of damage when a major earthquake occurs. In case of high rise building there is a need to resist lots of force both by wind as well as seismic load which may not be sufficiently fulfilled by the conventional building configurations. So to resist these lateral forces, there arises the need of incorporation of additional members. The commonly used methods are the use of braced frames and the use of damping system.

In the recent major earthquakes, it is noticed that the seismic risk is increasing due to which trend in seismic design of building is changed. It is observed that losses are increased due to the seismic design of buildings using codal procedure is not able to achieve best performance during earthquake. In Nepal too, as the construction of high rise buildings has been growing, the need of proper design of building falls under prime requirement. In case of steel frame buildings too, as conventional moment resisting frames are not adequate to resisting lateral forces, the study of seismic performance of buildings with the use of bracing and dampers is necessary for a safer design.

Bracing is the system elements to resist lateral loads in a structure. The optimal type and configuration of the bracings in a building will lead to a greater improvement in the performance of the building reducing the lateral drift. Damper on the other hand are also an effective method of improving seismic performance of the structure by dissipating the seismic energy into heat energy by the friction between the moving metal parts. They are designed not to act in wind and smaller earthquake and are designed to slip during larger earthquakes prior to the yielding of the members.

From the reference of many researches, it is found that the use of bracings and dampers have great influence in the improvement of seismic performance of a building. Mcewen [1] has compared about 200 different configurations of three types of braced frame: X, chevron and diagonal to find out the optimum bracing and configurations. Pall et al[?] has modeled the diagonal bracing and friction damped chevron model for seismic rehabilitation of Eaton's building, Montreal using time history analysis that showed improved performance of dampers than bracings. Also Pall et al carried out analysis on the use of friction damper in the Canadian Space Agency Headquarter and showed the use of friction damper as efficient and economical measure to resist earthquakes [?].

Nepal have been growing its construction of various kinds of buildings and now the buildings are demanding greater heights here. Not only RC framed, but also steel framed buildings have been increasing nowadays in developed cities of nepal, especially in Kathmandu valley with increased height or number of storey. Steel Framed buildings of more than 2 to 3 storey are not seen so far. Thus, the use of the braces in the steel frame building may lead to possibility of reliable taller buildings and also the use of friction dampers, which is most probably not used in Nepal may help the country for the high rise building construction and cope with the insecurity of the multi storey steel buildings from the greater earthquakes that are occuring and are expected to occur to make the building safer for the future.

This research includes the use of diagonal bracing and diagonal friction damper in a bare moment resisting frame to compare the seismic performance of by the both methods using nonlinear time history analysis. This explains by how much the response of a conventional structure is minimised by using these members.

2. Methodology

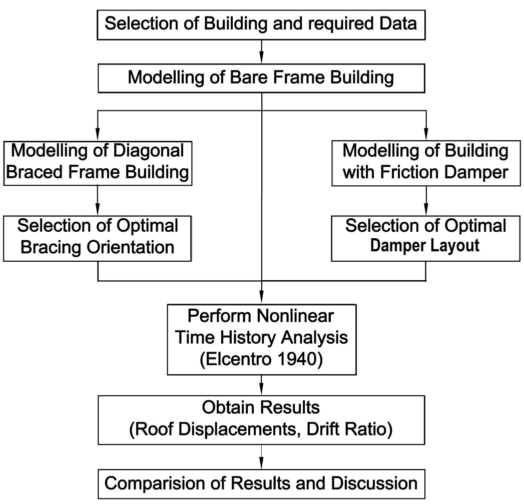

Figure 1: Flowchart for Methodology

Figure 1 shows the processes involved in the research.

Selection of Model

A hypothetical model of a ten storey steel frame building is taken of 15m x 20m, divided into bays of 5m each and height of 3m. This model is taken as existing such building was not found in Nepal. The building is assumed to have plane sides with no projections and glass partitions at exterior and interior parts, considering it as a building with commercial use.

Modelling

Modelling of the building was done in Etabs 2000V16.2.0 software developed by Computers and Softwares Inc. The steel members were used as inbuilt sections from IS codes. Column was modelled by section designer joining two I sections. Bracing members were also taken from the IS sections and model was analysed for the design of the required section. Possible configurations of bracings were analysed to determine the best placement of bracing that gives the least maximum roof displacement, taking into consideration the direction of shorter length or width of the building.

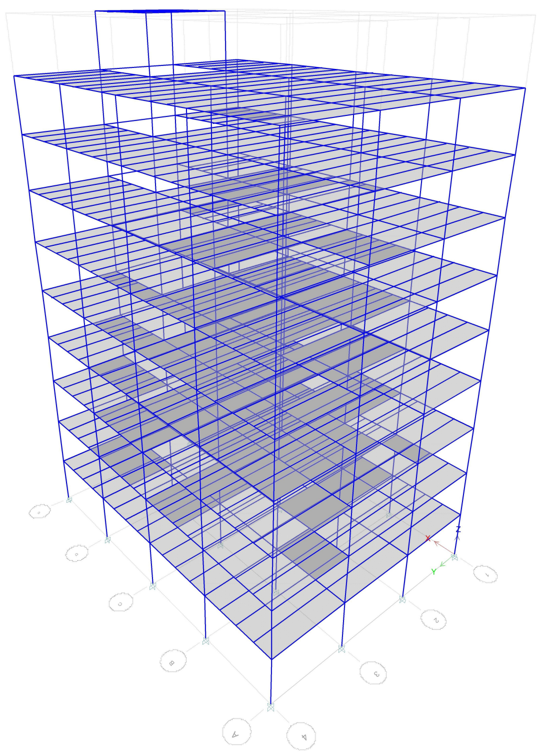

Figure 2: Model of the Building

Figure 2 shows the model of the building taken for analysis.

Table 1: Description of the Building

Description	Data
Number of Storey	10 including staircase Cover
Number of Bays in X direction	4@5m
Number of Bays in Y direction	3@5m
Columns	2xISWB600
Beams	ISWB550
Secondary Beams	ISWB300
Bracing Member	ISHB350
Deck Thickness	100mm

Table 2: Material Properties

Description	Data
Steel	FE250
Rebar	HYSD500
Modulus of Elasticity of Rebar	2E+05 N/mm^2
Concrete	M20
Modulus of Elasticity of Concrete	22360 N/mm^2
Unit weight of Rebar	78.5KN/m^3

Table 1 gives the general description of the building and Table 2 gives the description of the material properties of the building.

Nonlinear Time History Analysis:

Nonlinear time history analysis is the analysis of dynamic response of any structure which varies with the time that uses an earthquake data. The time history of Elcentro (1940) shown in Figure 3 is used to analyze the building.

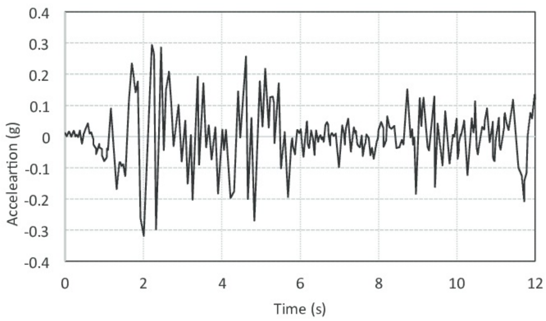

Figure 3: Time History of Elcentro earthquake(1940)

Bracing of Steel Building

Various methods of bracings are used to resist the lateral forces in a building. Most common configurations used for bracing are X Bracing, Inverted V or Chevron Bracing and Diagonal Bracing. Diagonal bracing method is adopted here and among various configurations, the zig zag configuration of the bracing was selected for the building as it showed greater reduction in the roof displacement. Also from the research of Mcewen[1], it shows that this configuration is most efficient among the diagonal braced configurations.

Design of Friction Damper

Diagonal Friction damper is used in the building modelling in Etabs 2000V16.2 as link element. Assuming this as an elastoplastic element, Wen Model is applied. The parameters for this model are as follows:
Link Type = Plastic (Wen)
Mass = M_1+M_2
Weight = M x g
Rotational Inertia R_1=R_2=R_3 = 0
Deformation DOF(Direction)=U1 (axial), Non Linear

Non Linear properties:

Effective Stiffness = Brace Stiffness = $K_e = \dfrac{AE}{L} = K$
Effective Damping = 0
Yield Strength = Slip Load
Post Yield Stiffness Ratio = 0.0001
Yielding Exponent = 10

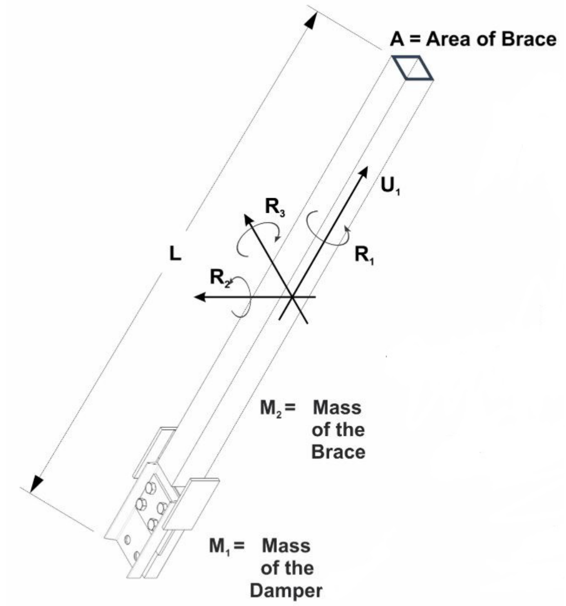

Figure 4: Wen Model Parameters for Friction Damper

Figure 4 shows the Wen Model Parameters for the Friction Damper used for the building that gives the pictorial representation of all the required parameters.

3. Results and Discussions

First, 12 different configurations of the diagonal braces were compared. Then Nonlinear Time History taking the earthquake data of Elcentro(1940) using Etabs2016 v16.2.0. Only Y direction was taken for study for simplicity and also being the direction with least dimension.

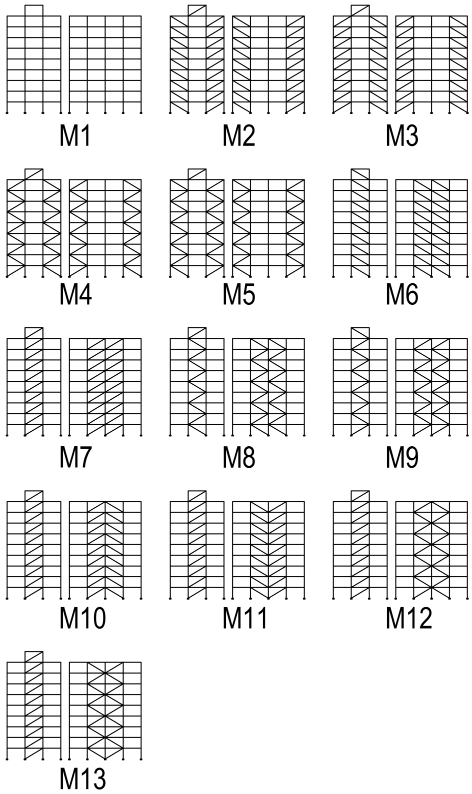

Figure 5: Different Configurations of Bracing Compared for Displacement

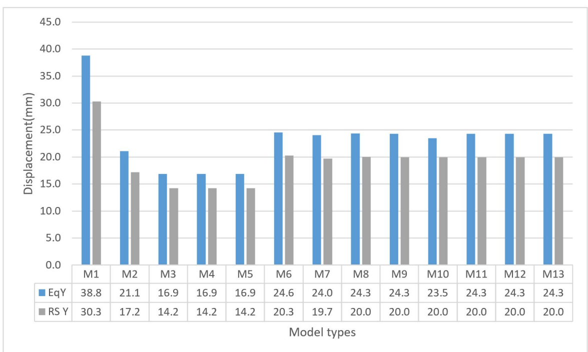

Figure 6: Displacement graph for Seismic Coefficient and Response Spectrum Methods at Y direction

Response spectrum analysis was used to find the optimum configuration of the bracing placement having least displacement. Results were considered for the displacement in Y-direction having least dimension for the configurations shown in Figure 5.

From the bar graph in Figure 6, it can be seen that the bracings placed at the exterior part showed relatively greater effectiveness than that placed in the centre. Thus for further comparision, Model M3 is selected.

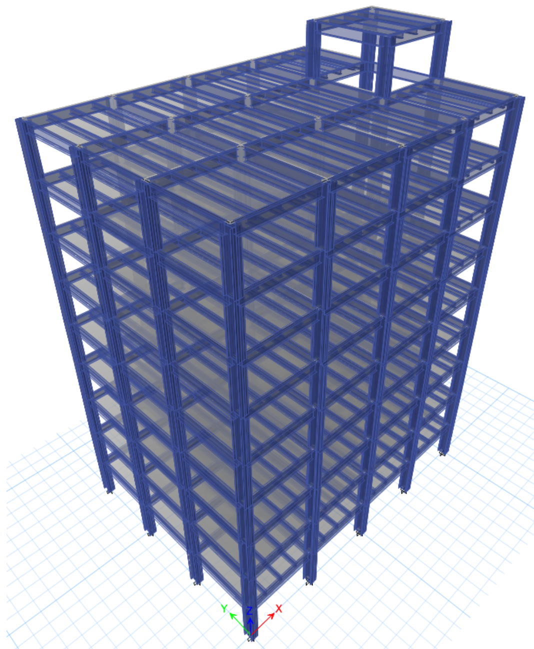

Figure 7: Bare Framed Building Model

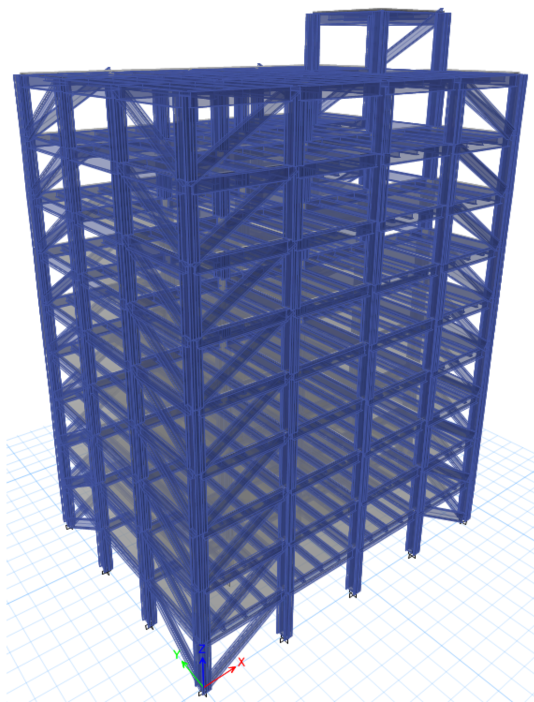

Figure 8: Braced Framed Building Model (M3)

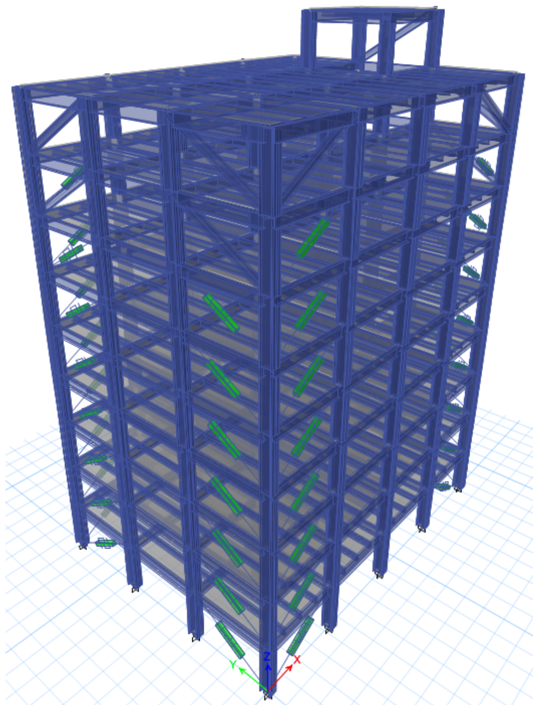

Figure 9: Building Model with Friction Damper

Figure 7 shows the bare moment resisting frame building, Figure 8 shows the framed building with diagonal bracings and Figure 9 shows the building with diagonal friction damper.

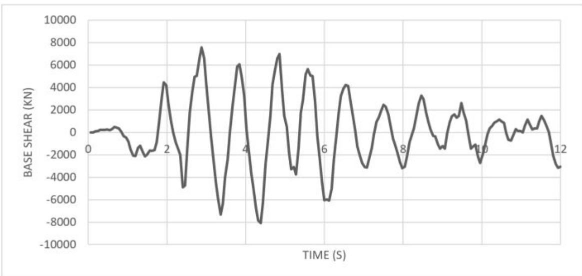

Figure 10: Base Shear for Model M1

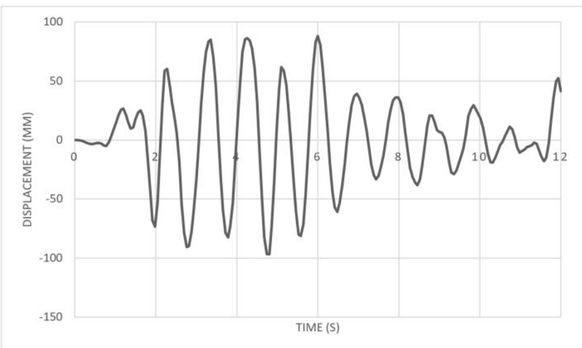

Figure 11: Displacement for Model M1

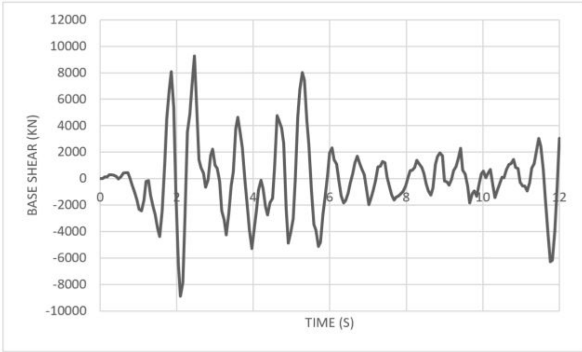

Figure 12: Base Shear for Model M3

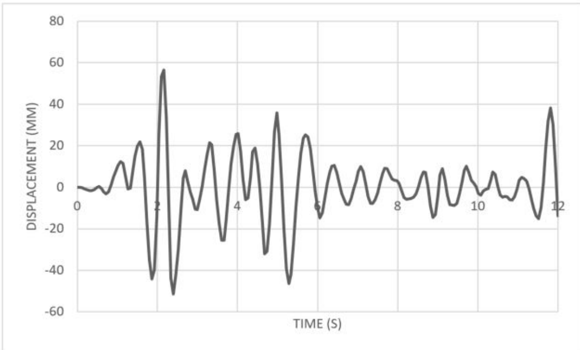

Figure 13: Displacement for Model M3

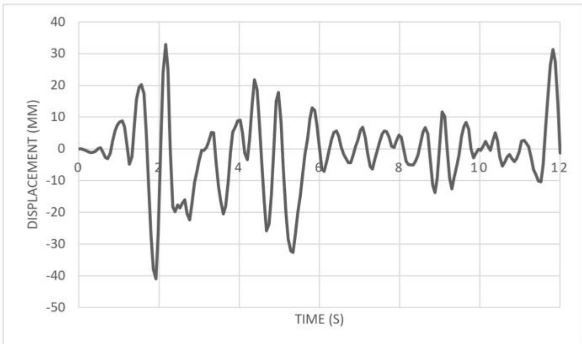

Figure 15: Displacement for Model with Friction Damper

Figure 10 shows the base shear of the model M1, Figure 11 shows the displacement for model M1, Figure 12 shows the base shear for model M3, Figure 13 shows the displacement of model M3, Figure 14 shows the base shear of the model with friction damper and Figure 15 shows the displacement of the model with friction damper under the excitation of the time history data of Elcentro(1940) earthquake.

From the above data, it can be clearly seen that there is the reduction in the displacement in the braced frame than than bare frame and the maximum reduction in the response is in the building incorporated with friction

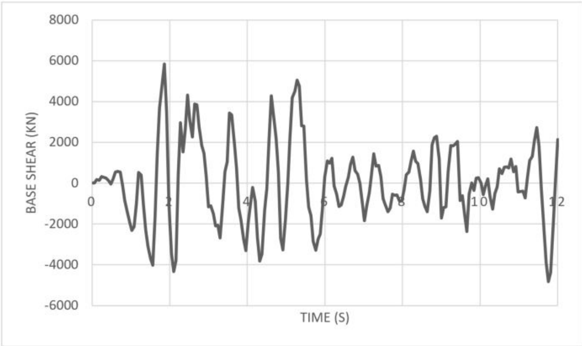

Figure 14: Base Shear for Model with Friction Damper

damper. Also, the base shear is increased in case of braced frame due to increased stiffness but reduced in the case of friction damped frame due to damping.

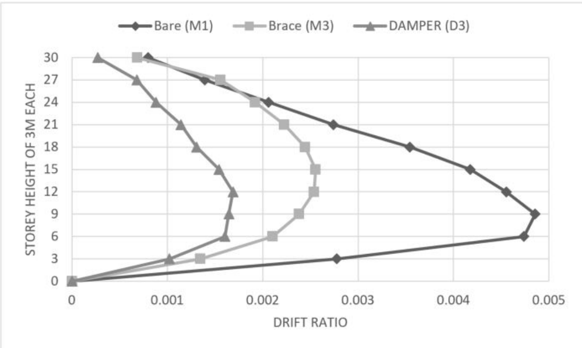

Figure 16: Drift Ratio for Bare, Braced and Damped Brace Frame

The curve in Figure 16 shows the reduction in the drift ratio in the cases where bracing and friction damper is used. The drift ratio is comparatively reduced in case of braced frame and more in case of damped braced frame.

4. Conclusion

A ten storey building was analysed using different configurations of bracing and use of friction damper. Following conclusions are obtained from the analysis:

- The time period of the building decreases as the bracing or damper are used due to the increased stiffness in the building.
- The use of Bracing configuration also effects the seismic response of the building.
- Use of bracing showed the decrement in the displacement to about 40 percent and drift to about 50 percent.
- Use of friction damper showed the decrement in the displacement to about 60 percent and drift to about 65 percent.
- Incorporation of friction damper seems more efficient in reducing the seismic effect on a building.

5. Future Enhancements

The efficiency of a building and the reduction in the response of a structure can be compared more by using various other methods of bracing system like inverted V, K bracing and cross bracing. Also analysis of the building using other types of friction dampers and even viscous damper can be done to obtain more results on the efficient and economic method of seismic energy dissipation in a building.

References

[1] Nicholas F. Mcewen. Optimal bracing type and layouts to minimise lateral drift in high-rise steel frame buildings subjected to high winds in sap2000. Technical report, 2011.

[2] Bungale S. Taranath. *Structural Analysis and Design of Tall Buildings*. McGraw-Hill Book Company, 1988.

[3] M.EERI and M. E. E. R. I. S. Cherry A. Filiatrault. Seismic response control of buildings using friction dampers. *Earthquake Spectra*, pages 447–466, 1993.

[4] A. R. Kambekar Gayatri Thakre. Effect of steel bracings in steel structure. *International Journal of Scientific & Engineering Research*, 8, 2017.

[5] A. S. C. E. Avtar S. Pall Members and Cedric Marsh. Response of friction damped braced frames. 1982.

[6] R. Tina Pall Avtar Pall. Performance-based design using pall friction dampers- an economical design solution. 13th World Conference on Earthquake Engineering, 2004.

[7] Seismic design with friction dampers.

[8] Pall friction dampers design.

[9] Is 875 part i, ii and iii.

[10] ”criteria for earthquake resistant design of structures”, part-1 general provisions and buildings, 2002.