Seismic assessment of multistory symmetric and asymmetric buildings with and without friction dampers

Madhukaran, Dr.H.Eramma* Sandeepkumar.D.S**, Raghavendra.M.R***

Civil engineering department, UBDTCE, davanagere.

ABSTRACT- In the current study we have modeled symmetric and asymmetric buildings such as H-shape, L-shape, Long slender shape, Rectangular shape and T-shape buildings for G+5, G+10 and G+15 stories with and without friction dampers using ETABS 9.7 non-linear version software. Friction dampers act like fuses in the building. Just like fuses protect electrical circuit Friction dampers protect building by reducing the earthquake load on the buildings. In the current study we have observed that time period, lateral displacement and story drift get reduced but the story shear get increased by the use of friction dampers in the building.

Index Terms- Symmetric, asymmetric, Friction Dampers and base shear.

I. INTRODUCTION

Structural vibration control, as an advanced technology in engineering, is to implement energy dissipation devices or control systems into structures to reduce excessive structural vibration, enhance human comfort and prevent catastrophic structural failure due to strong winds and earthquakes. Structural control technology can also be used for retrofitting of historical structures especially against earthquakes. The common sense approach to vibration control of structures is with vibration damping that is added to a structure either passively or actively. The damping dissipates some of the vibration energy of a structure by either transforming it to heat or transferring it directly to a connected structure.

The friction dampers have advantages such as simple mechanism, low cost, less maintenance and powerful energy dissipation capability as compared to other passive dampers. They were found to be very effective for the seismic design of structures as well as the rehabilitation and strengthening of existing structures.

They provide a practical, economical and effective approach for the design of structures to resist excessive vibrations. However, modelling of frictional force in the damper is quite a cumbersome process, as the number of equations of motion varies depending upon the non-slip and slip modes of vibration.

A damper is a mechanical element that eliminates or progressively diminishes oscillations. It dissipates energy in the form of heat instead of storing it. The application of direct damping through friction systems permits plastic behavior by providing non-linearity while allowing the structure itself to remain elastic. The systems, carefully controlled by a sliding surface, feature a very large initial stiffness and the possibility of nearly perfect rectangular hysteretic behavior There are two main types of friction dampers in use in steel-framed buildings. Rigid frame friction dampers, providing real plastic hinges which may be replaced easily following an earthquake, and Braced frame friction dampers, which utilize diagonal bracing which slips at a predetermined stress.

Friction dampers: It has been a common practice among mechanical engineers to apply friction-based brakes to absorb kinetic energy in machines and devices. This has encouraged the development of Pall friction based damper (Chandra [6]). Pall friction dampers have successfully gone through sophisticated experimental studies on shake tables in Canada (Filiatrault [3]) and the United States (Aiken [7]). Pall friction dampers have been very attractive due to their simplicity and low cost of construction. High seismic performance of Pall's damper has been a great motivation to extend its application out of its origin to other countries, especially to United states. General structure of Pall type dampers is made up of some steel plates layed on each other with high strength bolts pressing them together, generating friction between them. Contrary to Viscoelastic systems, Pall system is not sensitive to environmental temperature and state of loading. Pall system's hysteretic behaviours are almost rectangular and completely similar to ideal elasto plastic behaviour. Due to high dissipation energy capacity and stability of hysteresis loops, Pall system seems to show higher seismic performance, than other damping systems.

Following procedure is generally used for the analysis according to IS 1893 – 2002.

i) Calculation of lumped weight.

ii) Calculation of fundamental natural period.

The fundamental natural period of vibration (Ta) in seconds of a moment resisting frame building,

$T_a = 0.075\, h^{0.75}$ (without brick infill panels)
$T_a = 0.09\, h/\sqrt{d}$ (with brick infill panels)
Where
h = Height of the building
d = Base dimension of the building at the plinth level in m, along the considered direction of the lateral force.

iii) Determination of base shear (VB) of the building.

VB = Ah x W

$$A_h = \frac{Z}{2}\frac{I}{R}\frac{S_a}{g}$$

Where,
A_h is the design horizontal seismic coefficient, which depends on the seismic zone factor (Z), importance factor (I), response reduction factor (R) and the average response acceleration coefficient (Sa/g). Sa/g in turn depends on the nature of foundation soil (rock, medium or soft soil sites), natural period and the damping of the structure.

iv) Lateral distribution of design base shear;

The design base shear VB thus obtained is then distributed along the height of the building using a parabolic distribution expression:

$$Q = V_B \frac{W_1 h_1}{\sum_{j=1}^{n} W_j h_k^{\,2}}$$

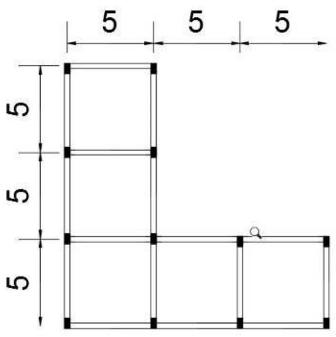
Where Q_1 is the design lateral force, W_1 is the seismic weight, h_1 is the height of the i^{th} floor measured from base and n is the number of stories in the building.

II. MODELLING AND ANALYSIS

The following load combinations are considered in the current study.

Types of analysis	Load factors	
EQUIVALENT STATIC ANALYSIS	X- Direction	0.9 DL+1.5 EQX
		1.5 (DL+EQX)
		1.2 (DL+LL+EQX)
	Y-Direction	0.9 DL+1.5 EQY
		1.5 (DL+EQY)
		1.2 (DL+LL+EQY)
RESPONSE SPECTRUM ANALYSIS	X- Direction	0.9 DL+1.5 RESX
		1.5 (DL+RESX)
		1.2 (DL+LL+RESX)
	Y-Direction	0.9 DL+1.5 RESY
		1.5 (DL+RESY)
		1.2 (DL+LL+RESY)

Among all the load combinations considered, the maximum response is observed in 1.5 (DL + EQL) combination. Therefore those values are tabulated and compared.



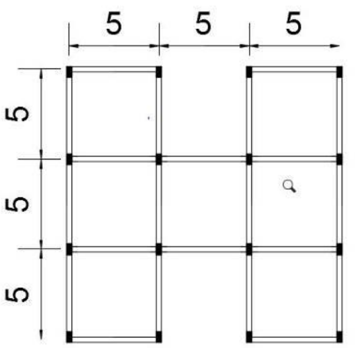
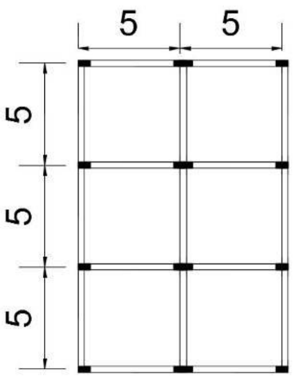
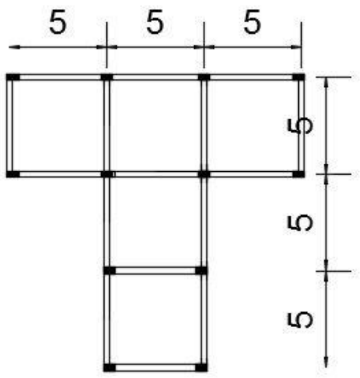


Fig. : L-shape plan. **Fig. : H-shape plan.**





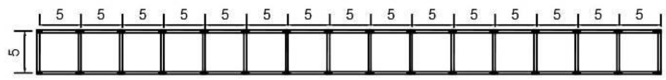


Fig. : Rectangular shape plan. **Fig. : T-shape plan.**

Fig.:Long slender shape plan.

The entire analysis has done for all the 3D models using ETABS 9.7 non-linear version software. The results are tabulated in order to focus the parameters such as time period, story shear, story drift and lateral displacement.

Input parameters

Type of building G+5, G+10 and G+15 story reinforced structure.

Height b/w the floor	3.0 m
Ground floor height	3.0 m
Wall thickness	300 mm
Unit weight of R.C.C **(IS 875-1987, P-1)**	25 kN/m^3
Unit weight of bricks **(IS 875-1987, P-1)**	18 kN/m^3
Grade of concrete (M20)	20 N/mm^2
Grade of steel (Fe415)	415 N/mm^2
Size of beam	230x450 mm
Size of column	900x900 mm
Thickness of slab	150 mm
Live load	3 kN/m^2
Floor finishes	1.25 kN/m^2

III. RESULTS AND DISCUSSIONS

TIME PERIOD

The time taken (in seconds) for each complete cycle of oscillation (i.e., one complete back-and-forth-motion) is the same and is called Fundamental Natural Period T of the building. Value of T depends on the building flexibility and mass; more the flexibility, the longer is the T, and more the mass, the longer is the T. In general, taller buildings are more flexible and have larger mass, and therefore have a longer T.

No. of stories **L**	Time period in seconds	
	With damper	Without damper
G+5	0.4976	1.0422
G+10	1.0403	1.9894
G+15	1.7219	3.0961

Table : Natural time period for L -shaped buildings.

No. of stories **Longslender**	Time period in seconds	
	With damper	Without damper
G+5	0.4608	1.0396
G+10	0.9382	1.8647
G+15	1.4824	2.704

Table : Natural time period for Long slender shaped buildings.

No. of stories **H**	Time period in seconds	
	With damper	Without damper
G+5	0.5292	1.0461
G+10	1.1158	1.9295
G+15	1.8631	2.9079

Table : Natural time period for H shaped buildings.

No.of stories **Rectangular**	Time period in seconds	
	With damper	Without damper
G+5	0.4886	1.1071
G+10	1.1333	2.087
G+15	2.0589	3.2413

Table : Natural time period for Rectangular shaped buildings.

No. of stories **T**	Time period in seconds	
	With damper	Without damper
G+5	0.6008	1.044
G+10	1.268	1.962
G+15	2.0952	3.0126

Table : Natural time period for T-shaped buildings.

The above tables provides the comparison of Time Period for G+5, G+10 and G+15 storied building with and without friction dampers for H-shape, L-shape, Rectangular shape, Long slender shape and T-shape buildings. Fundamental natural period T is an inherent property of a building. Any alterations made to the building will change its T, that can be observed from above tables.

LATERAL DISPLACEMENT

Lateral displacement or drift of a reinforced concrete frame building under earthquake loading is a critical parameter for structural evaluation or design. The magnitude of lateral displacement indicates the damage state and the vulnerability of the building. The below figures provides lateral displacement obtained for all shape buildings that is H-shape, L-shape, Long slender shape, Rectangular shape and T-shape buildings for equivalent static method and response spectrum method with and without friction dampers.

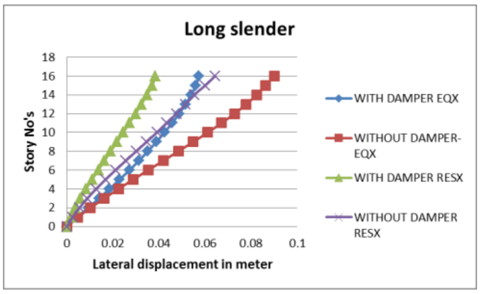


Fig. : Lateral displacement for Long slender shaped building for 1.5(DL+EQL)

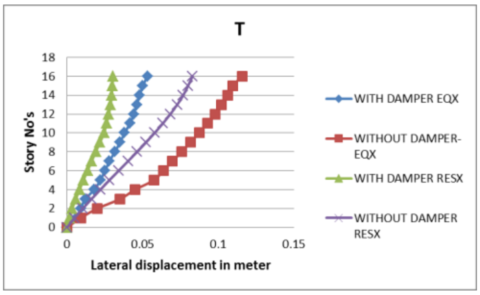


Fig. : Lateral displacement for T shaped building for 1.5(DL+EQL)

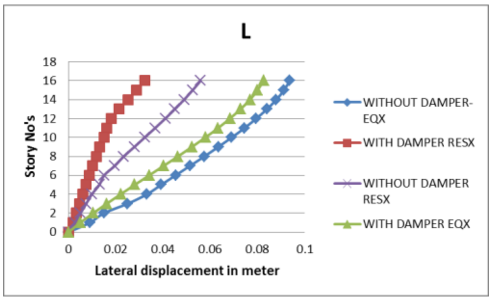


Fig. : Lateral displacement for L shaped building for 1.5(DL+EQL)

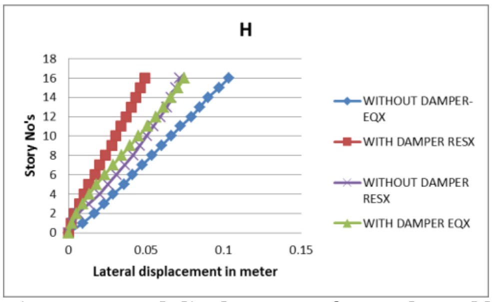


Fig. : Lateral displacement for H shaped building for 1.5(DL+EQL)

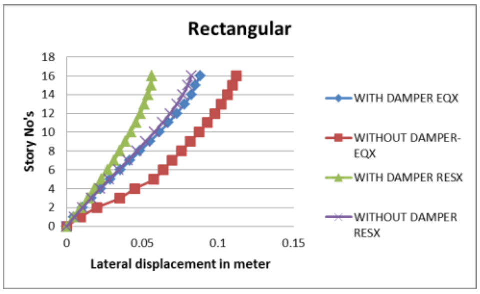


Fig. : Lateral displacement for Rectangular shaped building for 1.5(DL+EQL)

It is observed that, the maximum displacement is increasing from first story to last one. It's clear that the static analysis gives higher values for lateral displacement of the stories rather than Response spectrum methods of analysis, especially in higher stories.

From the above graphs, for H-shape we notice that Lateral displacement of the roof of the building without friction damper is 0.012m for Equivalent static method whereas for building with friction damper it is 0.007 m. Hence there is a reduction of 41.67%, for L-shape we notice that Lateral displacement of the roof of the building without friction damper is 0.09m for Equivalent static method whereas for building with friction damper it is 0.008 m. Hence there is a reduction of 11.11%, for Longslender-shape we notice that Lateral displacement of the roof of the building without friction damper is 0.095m for Equivalent static method whereas for building with friction damper it is 0.05 m. Hence there is a reduction of 47.39%, for Rectangle-shape we notice that Lateral displacement of the roof of the building without friction damper is 0.012m for Equivalent static method whereas for building with friction damper it is 0.08 m. Hence there is a reduction of 33.33% and for T-shape we notice that Lateral displacement of the roof of the building without friction damper is 0.115m for Equivalent static method whereas for building with friction damper it is 0.05 m. Hence there is a reduction of 56.52%. We can notice that addition of friction dampers in the building reduces story displacement.

STORY DRIFT

Story drift is the drift of one level of a multistory building relative to the level below. Story drift is the difference between the roof and floor displacements of any given story as the building sways during the earthquake, normalized by the story height. The Story Drift obtained for Equivalent static method and response spectrum for all shaped buildings that is H-shape, L-shape, Long slender shape, Rectangular shape and T-shape buildings with and without friction Dampers are plotted in graphs below.

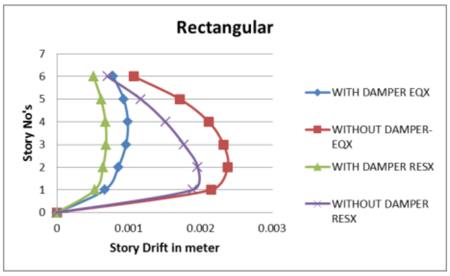


Fig. : Story Drift for Rectangular shaped building for 1.5(DL+EQL) combination.

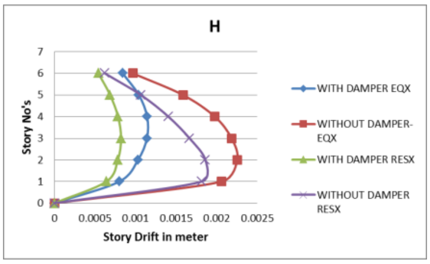


Fig. : Story Drift for H shaped building for 1.5(DL+EQL) combination.

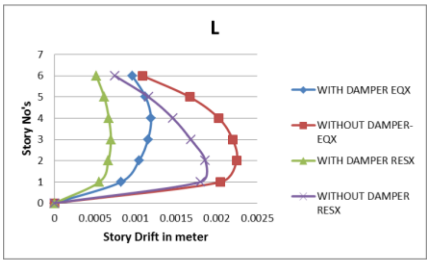


Fig. : Story Drift for L shaped building for 1.5(DL+EQL) combination.

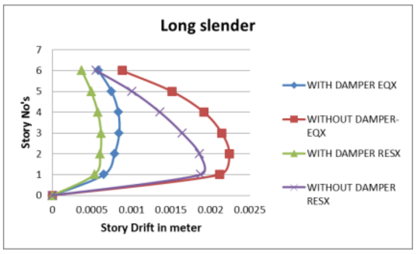


Fig. : Story Drift for Long slender shaped building for 1.5(DL+EQL) combination.

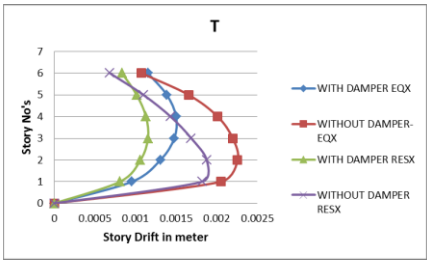


Fig. : Story Drift for T shaped building for 1.5(DL+EQL) combination.

It's clear that the static analysis gives higher values of Story Drift rather than Response spectrum methods of analysis. Static analysis provides almost real results hence we have to consider them during design.

From the above graphs, for H-shape we notice that Story drift of the roof of the building without friction damper is 0.001m for Equivalent static method whereas for building with friction damper it is 0.0008 m. Hence there is a reduction of 20%, for L-shape we notice that Story drift of the roof of the building without friction damper is 0.0012m for Equivalent static method whereas for building with friction damper it is 0.001 m. Hence there is a reduction of 16.7%, for Long slender-shape we notice that Story drift of the roof of the building without friction damper is 0.0009m for Equivalent static method whereas for building with friction damper it is 0.0007 m. Hence there is a reduction of 22.22%, for Rectangular-shape we notice that Story drift of the roof of the building without friction damper is 0.0012m for Equivalent static method whereas for building with friction damper it is 0.0009 m. Hence there is a reduction of 25% and for T-shape we notice that Story drift of the roof of the building without friction damper is 0.0014m for Equivalent static method whereas for building with friction damper it is 0.0012 m. Hence there is a reduction of 14.3%.

According to IS 1893 : 2002 (part 1) clause 7.11.1 the story drift in any story due to the minimum specified design lateral force, with partial load factor of 1.0 shall not exceed 0.004 times the story height. And the values we got are well within the limits.

We can notice that addition of friction dampers in the building reduces story drift.

VI. CONCLUSION

1. It is obvious that increases in energy dissipation of structural systems is an essential strategy to withstand the effect of probable earthquakes. Due to limited energy dissipation

capacity of actual steel material, friction connections with unlimited energy dissipation capacity observed in cyclic tests, maybe considered as a favourite alternative for conventional structural systems.

2. The friction dampers are found to be very effective in reducing the earthquake responses of the adjacent connected structures

3. The natural time period goes on increasing as the building height goes on increasing and also when we provide friction dampers in the building the Natural time period of the building decreases.

4. From the above tables it is evident that when the story height goes on increasing the Base Shear increases and also whe we provide Friction Dampers, the Base Shear increases.

5. Due to presence of friction dampers the lateral displaceme of the building got reduced.

6. Due to presence of friction dampers the Story Drift of th building got reduced.

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Madhukaran, Assistant professor, UBDTCE, Davanagere

Dr.H.Eramma, Associate professor, UBDTCE, Davanagere

Sandeepkumar.D.S, student, UBDTCE, Davanagere

Raghavendra.M.R, student, UBDTCE, Davanagere