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Seismic Analysis of RC Structures Using Friction Dampers

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Abstract*: Structure are mainly subjected to various types of loading conditions such as earthquake, wind loads etc. For earthquake zone areas, the structures are designed considering seismic forces. The structures which are present in higher earthquake zone area are liable to get damaged or collapse, hence to increase the safety of these structure few retrofitting techniques or additional of materials to stabilize the structures against the earthquake forces are done. And if the retrofitting techniques are adopted then cost plays an important role and possibly few spaces will be compromised depend upon the type of methods adopted. Later the structure may be strengthened by adding materials externally to transfer the lateral loads i.e. some protective devices have been developed. In modern seismic design, the damping devices are used to reduce the seismic energy and enable the control of the structural response of the structure to that1earthquake excitation. For the present study, an 10-story structure which is symmetrical in plan is modelled and analyzed using the ETABs 2015 software. The earthquake loads are defined as perIS1893-2002 (Part 1). To analyze the structure, the static and dynamic analysis method is adopted. The response spectrum function is defined to carry out dynamic analysis. To control the seismic response and to increase the stiffness of the structure, Friction dampers are provided to the structure. The results obtained and compared in the form of displacement, story drift and story shear are compared.

Keywords: Friction damper, response spectrum method, storey displacement, story drift and story shear.

I. INTRODUCTION

A natural calamity like an earthquake cause significant loss of life and destruction to property every year. A disturbance that causes shaking of earth surface due to movement at underground along fault plane or from volcanic activity is called earthquake. The seismic forces produced are harmful and lasts only for a small duration of time. Yet, humans are confused with uncertainty in terms of its time of occurrence and its nature. However with advances made in varies areas of sciences it has been learned how to pinpoint the locations of earthquake and how to accurately measure their sizes, however, this solves only one part of the problem to protect a structure. The other part is seismic design of the structures. Since from the last century, this part of problem has taken various forms, and improvements in design philosophy and methods have been done. There are two types of methods for the seismic design of structures

1) Conventional method: This is the traditional method to resist lateral force is by increasing the design capacity and stiffness. Ex- shear wall, Braced frames or Moment resisting frames.
2) Non conventional method: Based on reduction of seismic demand instead of increasing capacity. Ex- Base isolation, Dampers.

II. DAMPERS

Damper is the device which is used to absorb the vibrations caused by the earthquake in the structure. Friction dampers are the devices, which are used in the structures to dissipate or absorb the vibration caused by earthquake hazards. It is made up of steel plates which are fixed with high strength bolts. The working of this category of damper is reliable.

friction dampers are reliable, repeatable and they have expansive (rectangular hysteresis circles(loops). Fraction Dampers are passive energy dissipation devises and are basic and secure in development. Fundamentally, these comprise of arrangement of steel plates, which are extraordinarily treated to grow exceptionally friction. These plates are clipped together and permitted to slip at a predetermined load. Many years of research and testing have prompted perfecting the craft of rubbing. Their performances subsequently, require no energy source other than seismic inputs to work it.

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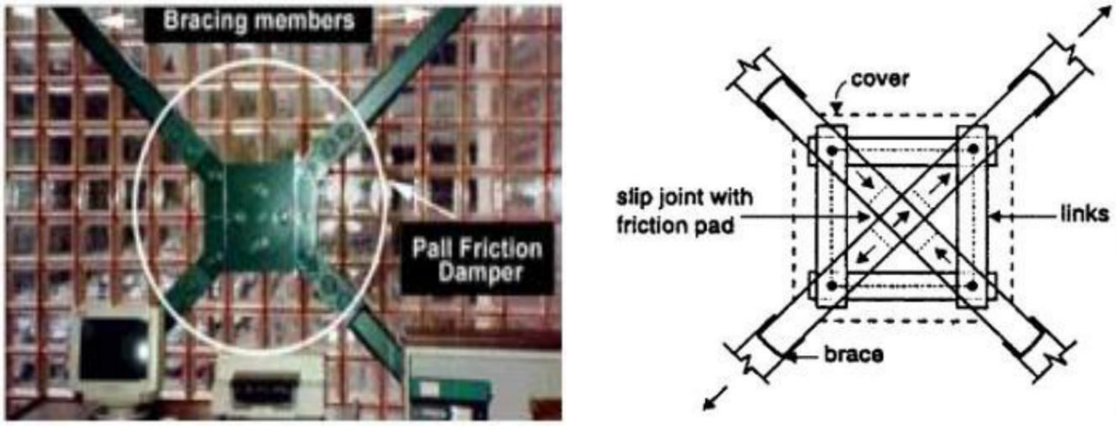

Fig 1: Friction Damper

III. OBJECTIVES OF THE STUDY

A. Following are the objectives for the present study

1) To carry out modelling & analysis of RC building with & without friction damper by using Etabs 15.1 version software & study the effect of seismic forces on these models.
2) To study the effect of placement of friction damper along the width and height of the building.
3) To carry out comparison between building with & without friction damper by response spectrum method on the basis of response properties like storey displacement, inter storey drift & storey shear.

IV. METHODOLOGY

In the present study 10 storied reinforced concrete building have been considered. Five different models are considered. The 1st model is for RC building without friction damper , the 2nd model is for RC building with corner friction damping for all stories , 3rd model is for RC building with central friction damping for all stories, 4th model is RC building with corner friction damping for alternate stories, 5th model is for RC building with corner friction damping for bottom 3 stories, The RC frame without infill panels situated in zone IV of India having medium stiff soil is considered.

A. Loadings
1) Live load on floors = 3 kN/m^2
2) Live load on roof = 1.5 kN/m^2

B. Geometric Properties
1) Column size = 350mm x 600mm
2) Beam size = 230mm x 450 mm
3) Slab thickness = 125mm

C. Material Properties
1) Grade of concrete = M25
2) Grade of Steel = Fe500

D. Soil type : Medium (Type II)
E. Zone factor : Z = 0.24
F. Importance factor : I = 1
G. Special Moment Resisting Frame : R = 5
H. Friction damper properties
1) Stiffness = 174251
2) Damping coefficient = 5%

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I. The work started with modeling and analysis of RC building for three case.

1) The first one is analyzing of building with central damping and corner damping and comparing their results with bare frame, from this we conclude that effectiveness of placement of friction damper along width.
2) The second one is analyzing of corner damping, alternative stories, bottom 3 stories and comparing their results with bare frame, from this we conclude that effectiveness of placement of friction damper along height.
3) The third one is comparing the results of original building with effective damping building (among all damped building).

V. MODELLING AND ANALYSIS

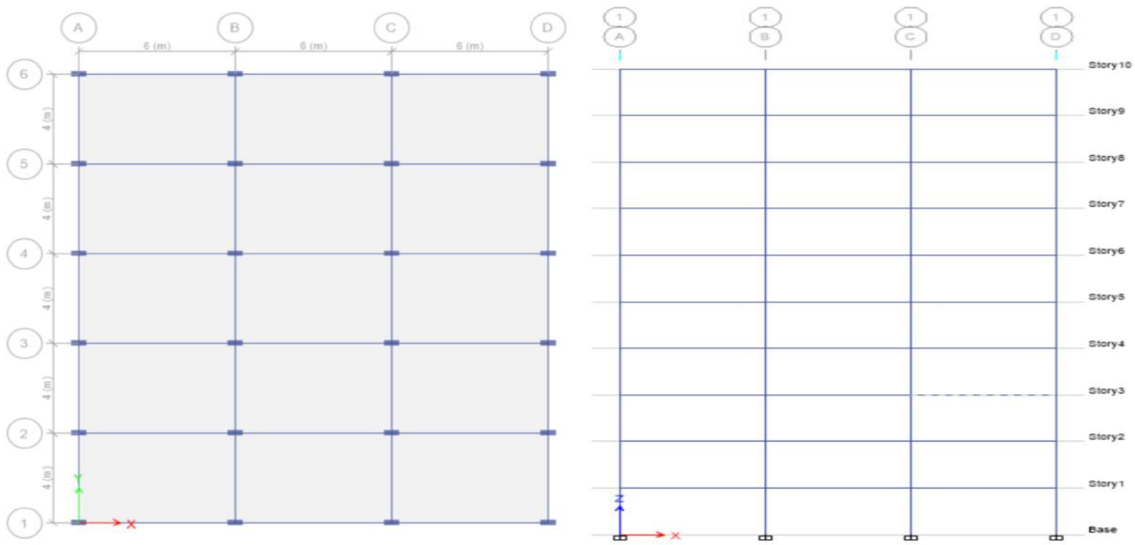

Figure 2: RC building without friction dampe

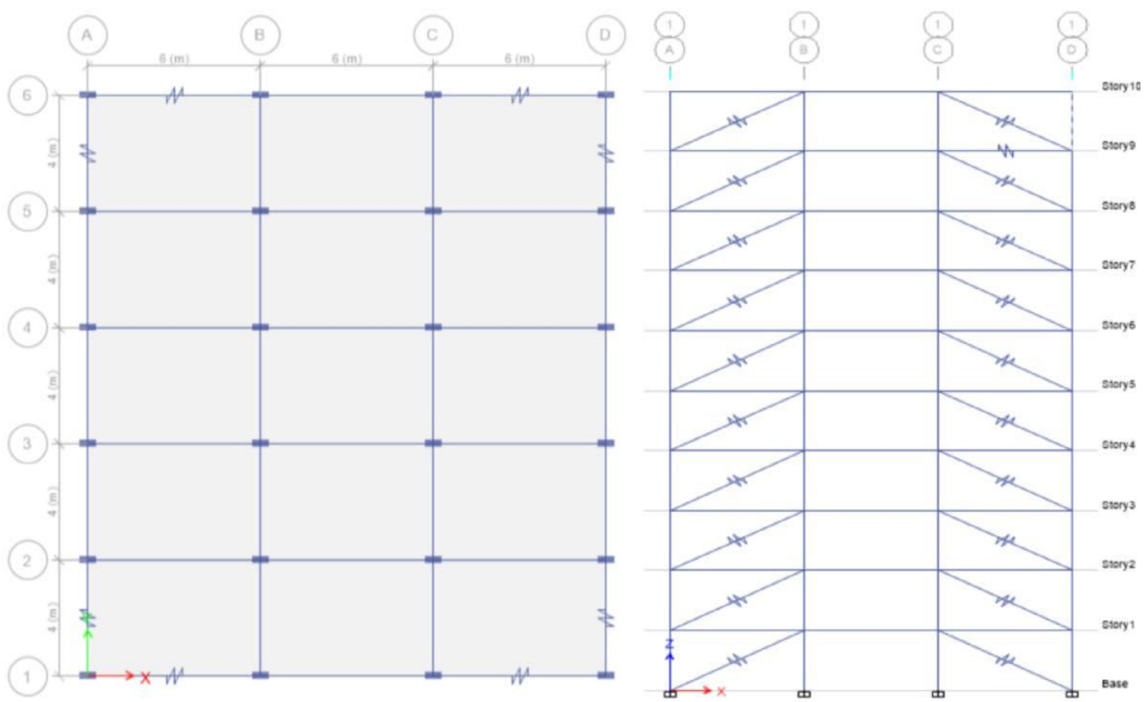

Figure 3: RC building with corner friction damping for all stories

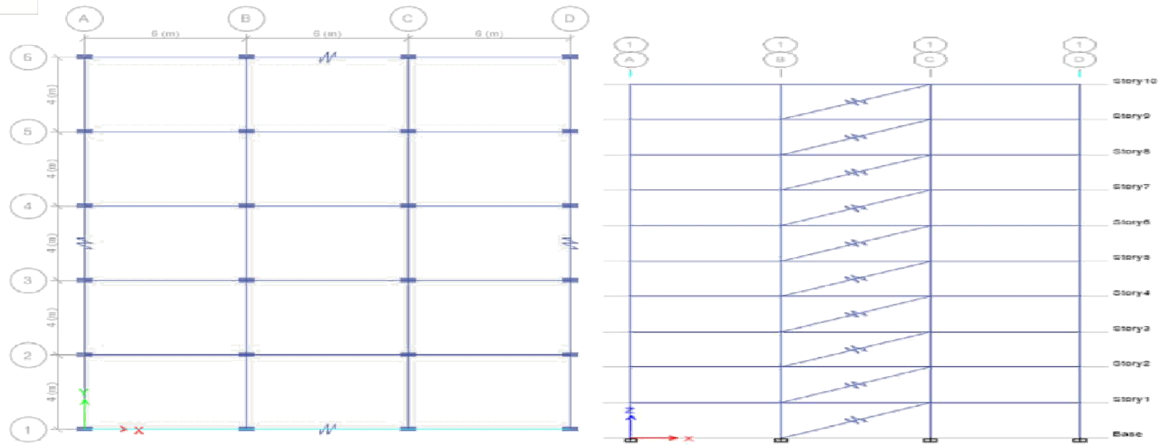

Figure 4: RC building with central friction damping for all stories

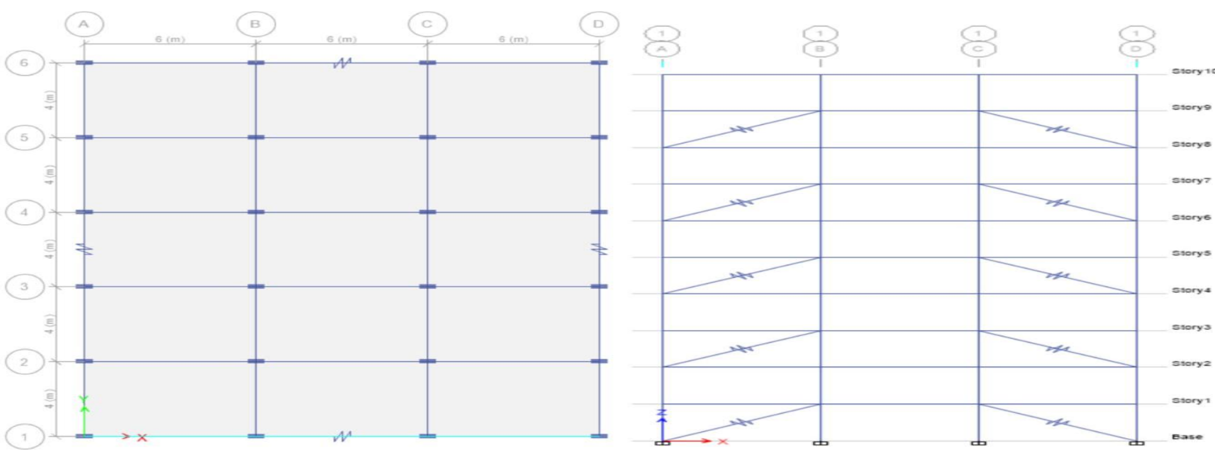

Figure 5 RC building with corner friction damping for alternate stories

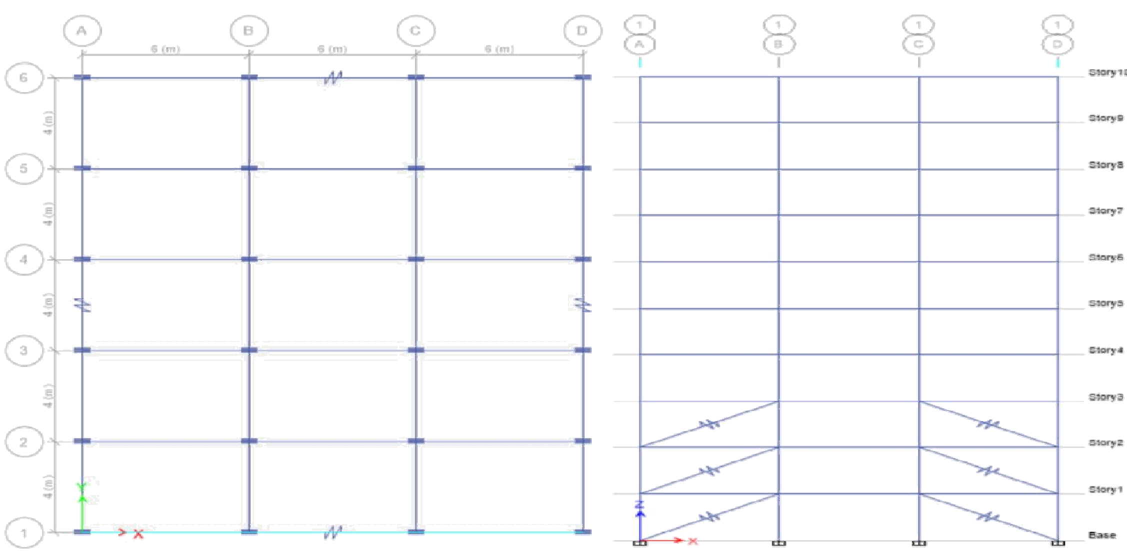

Figure 6 RC building with corner friction damping for bottom 3 stories

VI. RESULTS AND DISCUSSIONS

A. Effect of Friction damper along the Width:

To study the effect of placement of Friction damper along the width, the different cases that are taken into consideration to understand are,

1) *RTEM (rectangular exterior middle bays):* Friction damper are placed in all the exterior middle bays. A total of 4 Friction dampers will be there in each floor.
2) *RTEC (rectangular exterior corner bays):* Friction damper are placed in all the exterior corners. A total of 8 Friction dampers will be there in each floor.

B. Effect of Friction damper along the height

To study the effect of Friction damper along the height, analysis was already done on rectangular models of ten stories. From the previous results it is concluded that, effective placement friction damper along width among (RTEM & RTEC) & it is taken for further study.

The different cases that are taken into consideration to understand the effectiveness along the height are

C. Friction damper distributed uniformly
D. Friction damper on alternative stories
E. Friction damper on 1st three stories

1) *Storey displacement:*

i) *Along width:* From the above the graph it has been observed that, the percentage reduction of story displacement along X direction with respect to the bare frame for RTEM is 37% and for RTEC is 49%.

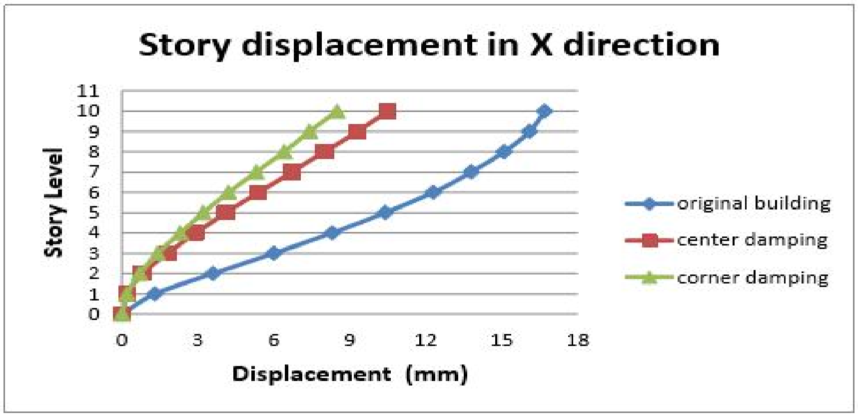

Fig 7: Comparison of Displacement along width

ii) *Along height.*

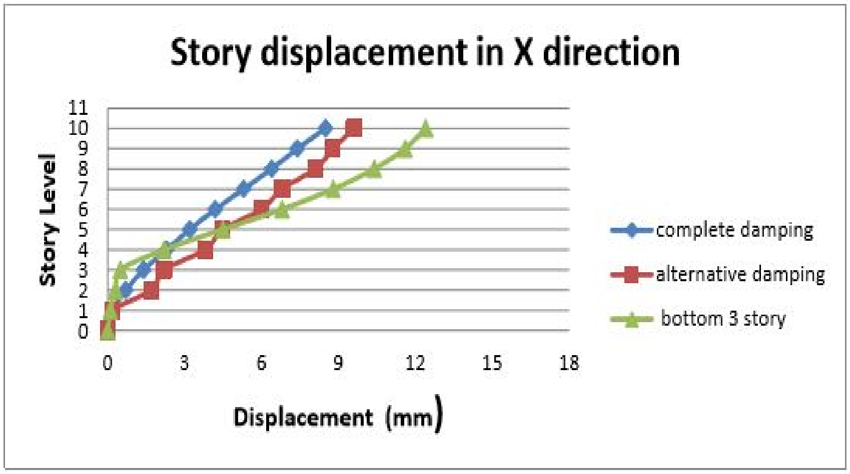

Fig 8: Comparison of Displacement along height.

From the above the graph it has been observed that, the percentage reduction of story displacement along X direction with respect to the bare when FD were placed Uniformly, alternative stories and 1st three stories are 49%, 42.5% and 27.7% respectively.

2) *Storey drift:* The difference between the horizontal displacement of two adjoining stories above or underneath of the structure is known as the story drift.

The values of the story dreft of the building modules are noted in underneath table for maximum load combinations. The story drift is less at bottom and upper story and maximum at middle story. The values obtained from the model with damper have lesser value compared to the bare frame model.

i) *Along width:* From the table and graph we can observe that:

ii) The values of drift are more at mid-story i.e. at 3 & 4 stories and less at top and bottom story.

iii) The percentage reduction in story drift at mid- stories with respect to the bare frame for RTEM was 62% and for RTEC was 71%.

iv) The percentage reduction in story drift at bottom- stories with respect to the bare frame for RTEM was 82% and for RTEC was 81%.

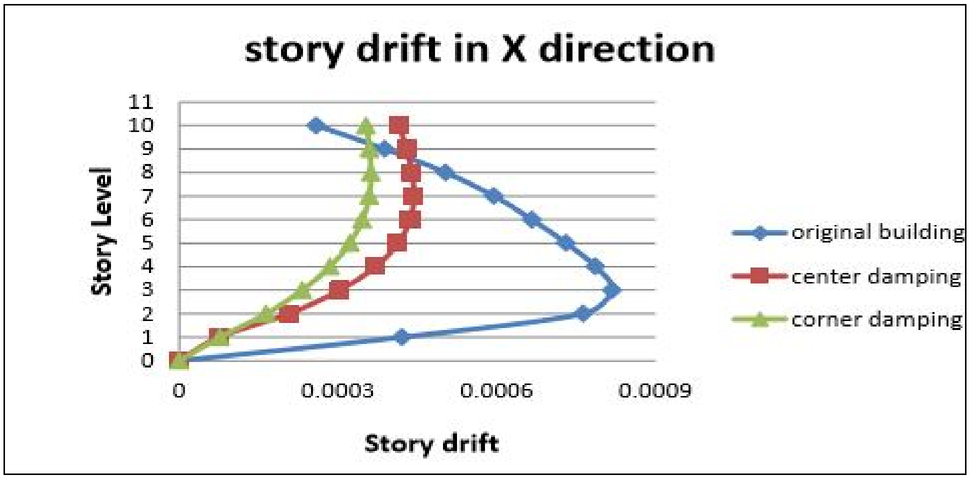

Fig 9: Comparison of Story Drift along width

Story	Elevation (m)	Story Drift in X direction (mm)		
		Original Building	center damping	Corner Damping
0	0	0	0	0
1	3	0.000421	0.000075	0.000077
2	6	0.000764	0.000207	0.000164
3	9	0.000818	0.000303	0.000232
4	12	0.000787	0.000371	0.000285
5	15	0.000731	0.000413	0.000322
6	18	0.000667	0.000436	0.000346
7	21	0.000594	0.000443	0.000359
8	24	0.000503	0.000439	0.000362
9	27	0.000388	0.000429	0.00036
10	30	0.000259	0.000415	0.000353

Table 1: Story Drift along width (mm)

F. Along height.

From the table and graph we can observe that

1) The story drift is less at bottom and upper story and maximum at middle story.
2) By observing the above graph values of friction damper model are less as compared to without friction damper model.

Story	Elevation (m)	Story Drift in X direction (mm)			
		original building	Corner damping	alternative damping	bottom 3 story
0	0	0	0	0	0
1	3	0.000421	0.000077	0.000056	0.000032
2	6	0.000764	0.000164	0.000516	0.000063
3	9	0.000818	0.000232	0.00019	0.000085
4	12	0.000787	0.000285	0.000542	0.000583
5	15	0.000731	0.000322	0.00026	0.000767
6	18	0.000667	0.000346	0.00052	0.000776
7	21	0.000594	0.000359	0.000285	0.000689
8	24	0.000503	0.000362	0.000443	0.000581
9	27	0.000388	0.00036	0.000283	0.000448
10	30	0.000259	0.000353	0.00027	0.000303

Table 2: Story Drift along height (mm)

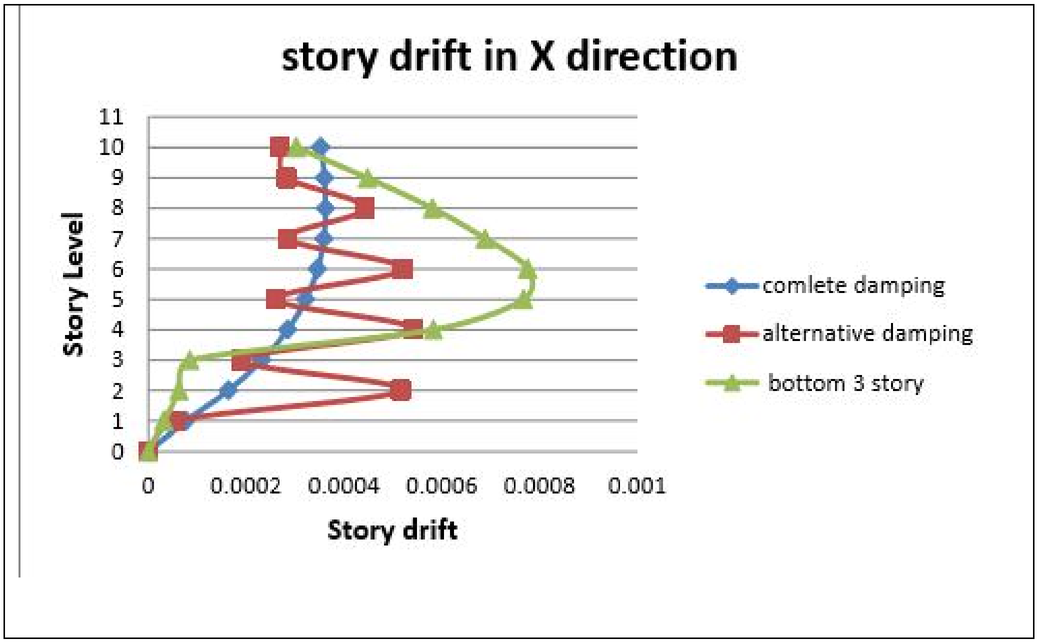

Fig 10: Comparison of Story Drift along height

3) Story Shear (kN):

G. Along width

From the below graph,

1) By observing the above values story shears in case of model with corner damping are more than model with central damping as compare to bare frame.
2) The value of the story shear has been linearly decreases as height of the story increases.

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Story	Elevation (m)	Story shear in X direction (mm)		
		original building	center damping	Corner damping
0	0	0	0	0
1	3	412.8021	637.2899	804.5367
2	6	399.321	628.003	796.5542
3	9	374.8072	604.175	772.7162
4	12	345.3981	567.9427	732.7831
5	15	316.8424	522.963	679.5025
6	18	288.1976	472.1845	614.8871
7	21	257.6932	415.2633	538.7084
8	24	218.6587	349.0846	446.7954
9	27	166.933	266.3838	331.6644
10	30	94.3705	152.3192	182.7262

Table 3: Story shear along width X direction (kN)

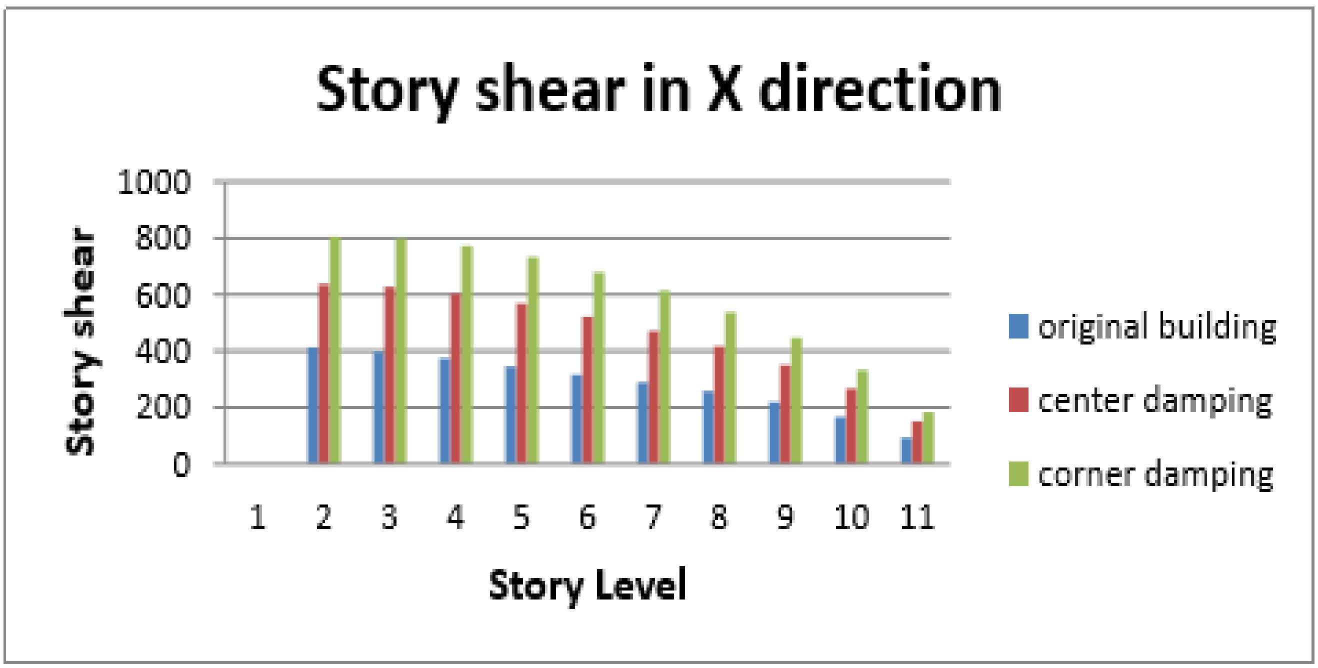

Fig 11: Comparison of Story shear along width

H. Along height.

From the above graph,

1) By observing the above values story shears in case of model with corner damping are more than other damped modules as compare to bare frame.
2) The value of the story shear has been linearly decreases as height of the story increases.

Story	Elevation (m)	Story shear in X direction (mm)			
		original building	Corner damping	alternative damping	bottom 3 story
0	0	0	0	0	0
1	3	412.8021	804.5367	689.7178	453.6553
2	6	399.321	796.5542	684.2879	443.7267
3	9	374.8072	772.7162	649.4922	427.427
4	12	345.3981	732.7831	613.216	406.4959
5	15	316.8424	679.5025	560.1459	379.8738
6	18	288.1976	614.8871	506.6141	344.9967
7	21	257.6932	538.7084	437.1834	302.169
8	24	218.6587	446.7954	362.1065	254.6494
9	27	166.933	331.6644	259.4066	193.5903
10	30	94.3705	182.7262	143.0155	117.1171

Table 4: Story shear along height

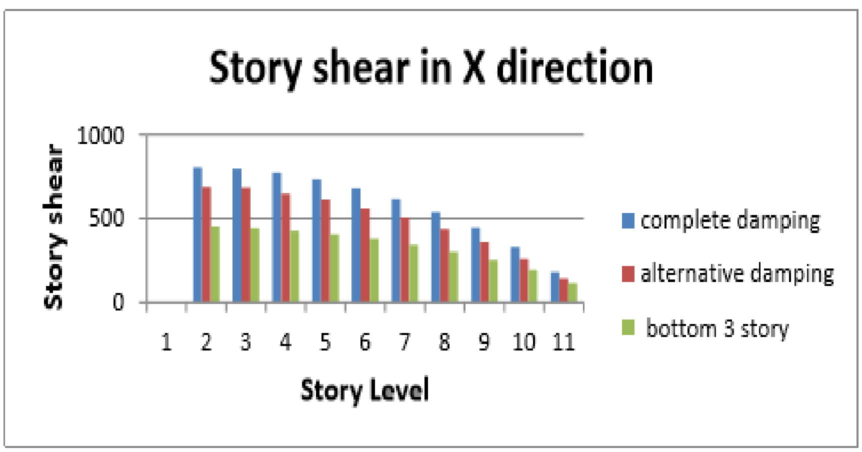

Fig 12: Comparison of Story shear along height

VII. CONCLUSIONS

A. Effectiveness of friction damper along the Width

1) From the dynamic responses of the buildings, it can be concluded that, placing of friction damper at the external corners on all four sides is effective when compare to central damping. Effectiveness of friction damper along the Height:
2) The story displacements and inter story drifts are minimized most effectively by placing the friction damper along the corner at all stories compare to models having corner dampers at alternative , bottom 3stories.

3) When dampers are provided at corner throughout the building, the story displacement has been reduced by 49% and 45% in X and Y direction respectively compared to bare frame.
4) When dampers are provided at corner throughout the building, the story drift has been reduced at middle story by 71% and 68% in X and Y direction respectively compared to bare frame.
5) When damper are provided the story shear has been decrease linearly as height of the story increases compared to bare frame.
6) From above result and discussion it is concluded that corner damping for all stories is most effective placement of friction damper among all these models (corner damping, central damping, alternative damping & bottom 3 stories)

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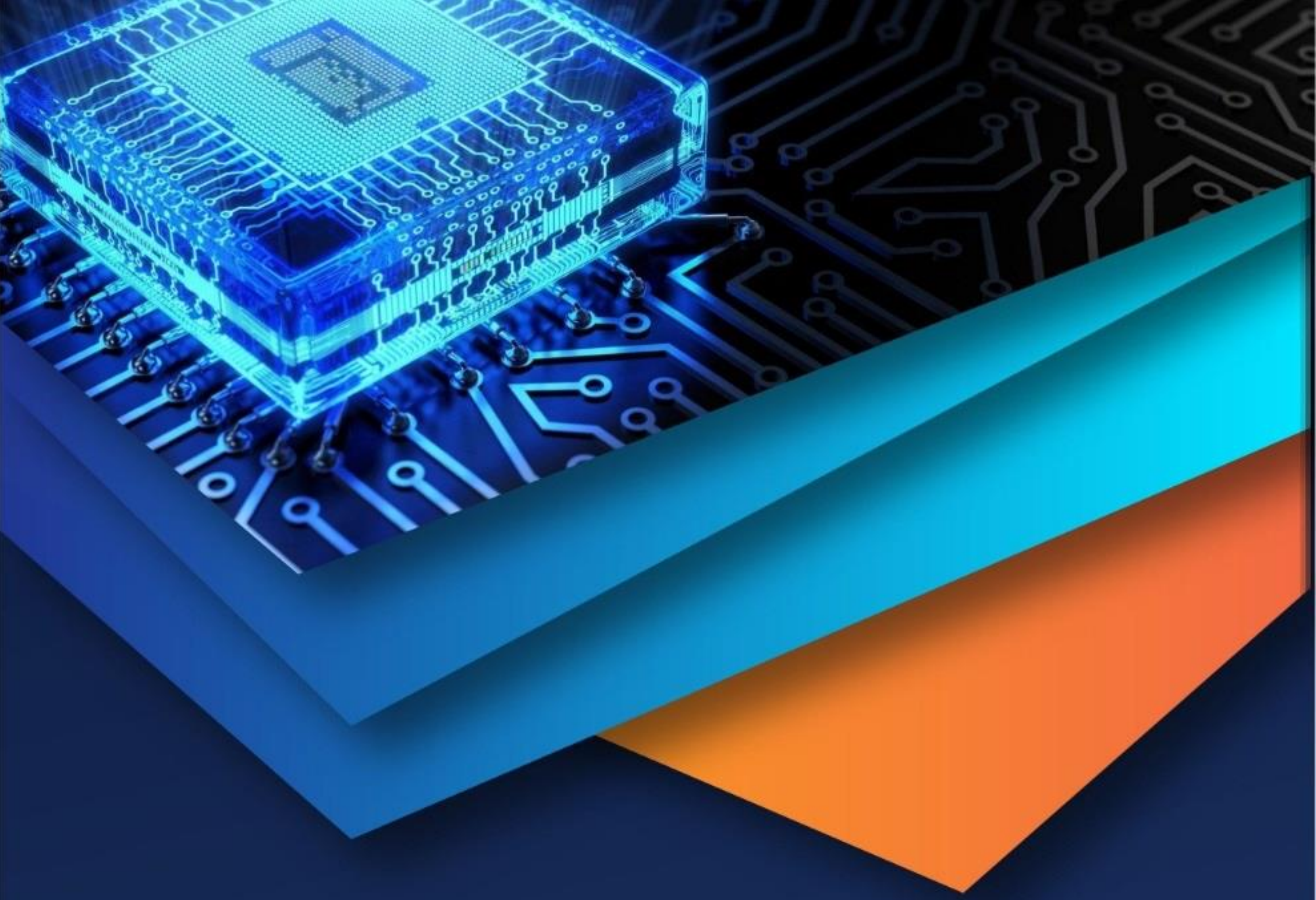

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