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EFFECT OF FRICTION DAMPER IN RCC FRAMED STRUCTURES ON SLOPING GROUND

Priyanka Baraker[1], M.Q.Patel[2]

[1]*PG Student, Department of Civil Engineering,*
B.L.D.E. Association's V.P.Dr.P.G.Halakatti College of Engineering and Technology, Vijayapura,

[2]*Assistant Professor, Department of Civil Engineering,*
B.L.D.E. Association's V.P.Dr.P.G.Halakatti College of Engineering and Technology, Vijayapura,

Abstract— Generally Buildings are designed to resist the strong earthquake motion. These activities will cause loss of lives, collapse or damage of structures. To resist earthquake motion structures are to be strengthened by some techniques like Base Isolation Techniques, Dampers etc. In the recent years dampers are becoming more popular because of safety of structures, vibration control of structures due to seismic hazards, and inexpensive design.
The present study includes structures with symmetrical plan and structures with horizontal irregular plan of G+7 stories on sloping ground considering earthquake Zone III with and without Friction Damper are modeled and analyzed using ETABs 2015 Computer package. The results obtained are in the form of displacement, storey drift, and storey shear for buildings with and without Friction Damper. The buildings which are having Friction Damper are safer than the buildings which are not having Damper.

Keywords— Friction Damper, Non-linear static analysis, Energy Dissipation, Seismic Response, Tall Buildings

I. INTRODUCTION

Earthquake is one of the most hazardous natural phenomena known to the mankind, which induce huge amount of lateral loads in the structures. If the structures are not designed properly to resist these lateral loads, which lead to the failure of structure, life, economic losses, and sociable sufferings [1]. Approaches of Structural design using seismic reaction control is widely allowed now a day and apparently applied in Civil Engineering. Such structural controls potentially of active, passive, straddle or demi dynamic control kind. On the other hand the using of such structural control strategy is little more inadequate in India [2]. In this paper, friction dampers are used as energy dissipater in a G+7 storey framed structure located in seismic zone III of Vijayapura and its interaction on forces is evaluated.

II. FRICTION DAMPER

Friction Dampers are passive type of energy dissipating devices they dissipates the seismic energy by virtue of the solid friction developed between two sliding surfaces. The formation of the friction damper involves connecting a series of steel plates with high strength steel bolts and steel plates will be specially treated to have sufficient friction between them. Based on the type of the bracing system in which they will be installed, the construction of the friction damper slightly varies.
By proving friction damper in to the structural system, there exists an optimal slip load that corresponds to the least response of the structure. The energy is dissipated by friction damper and is also the maximum at their optimal slip load. Generally 10-15% variation in the optimal slip load affect the response of the structure much and many of the previous studies confirms the same.
The dampers are tested in the Technical University of Denmark (DTU) and in investigated at Takenaka Corporation Research Center in Japan.

Modelling and Analysis
In this paper, G+7storey's building on Sloping ground of an angle of 8^o in presence and absence of Friction Damper is studied. The plans of these structures are regular and horizontal irregular plans having the area of 24m X 24m (Regular) and others are irregular in shape with same area (24m X 24m). Each spacing of gridlines is 4m on evenly sides in regular building plan, and irregular building plans having each spacing of gridlines are 4m evenly sides. The elevation of each storey of the structures is 3m. The overall structure height is 27.36. The frame structures are modelled in ETABs 2015 software.

Structural Properties
In this present work, the material properties of the structures are considered as below,

Table 2.1 Material Properties

1.Grade of Concrete	M_{25}
2.Modulus of Elasticity of Concrete(E)	25000 MPa
3.Grade of Steel	HYSD F_{e500}
4.Modulus of Elasticity of Steel (E)	200000MPa
5.Density of Brick	20kN/m^3
6.Poisson's ratio	0.2

Section Details of the Structures

The sectional details like size of Beam, Column, Slab and Wall are considered as below,

Table 2.2 Sectional details of the structures

1. Beam	230mmX500mm
2. Column	230mmX600mm
3. Slab Thickness	150mm
4. Wall Thickness	230mm

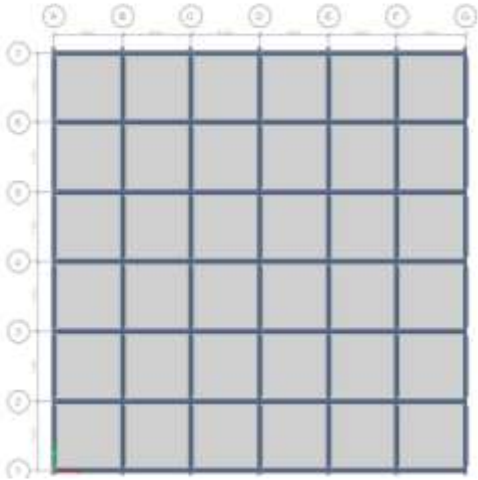

Fig.1 Plan of Model 1

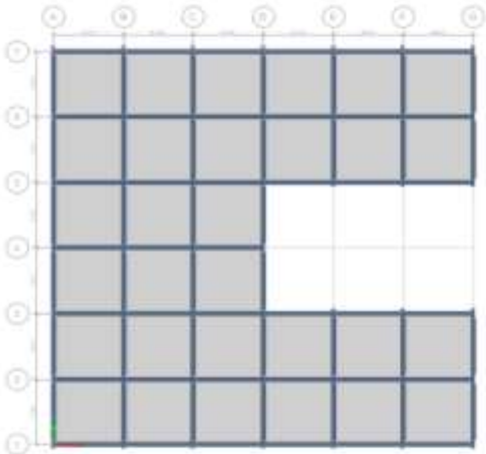

Fig.2 Plan of Model 2

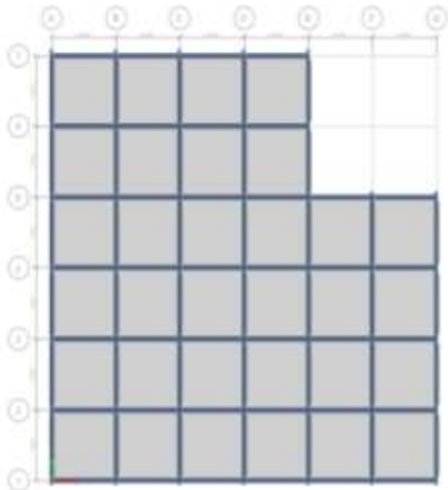

Fig.3 Plan of Model 3

III. RESULTS AND DISCUSSION

The seismic behaviour of the RCC frame structure is done by observing the parameters such as displacement, storey drift and storey shears.

Displacement

The displacement of the structure without damper is more than the structure with damper. The value of displacement is higher at the top storeys and low at bottom storey's. From the graph we can see the reduction of the displacement when the dampers are provided to the bare frame model.

The values of displacement are observed as below.

Table 3.1 Displacement in mm at X Direction

Storey	Elevation (m)	Displacement in mm					
		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
8	27.36	34.3	33.6	32.8	23	22.9	14.4
7	24.36	33.7	33	32.3	22.2	22	14.1
6	21.36	32.3	31.7	31.1	20.6	20.5	13.3
5	18.36	30.1	29.6	29.1	18.4	18.2	12.2
4	15.36	27.1	26.7	26.3	15.4	15.2	10.7
3	12.36	23.2	23	22.9	11.7	11.6	8.9
2	9.36	18.6	18.5	18.6	7.5	7.4	6.8
1	6.36	13	13.1	13.5	3.1	3.1	4.4
Base	0	0	0	0	0	0	0

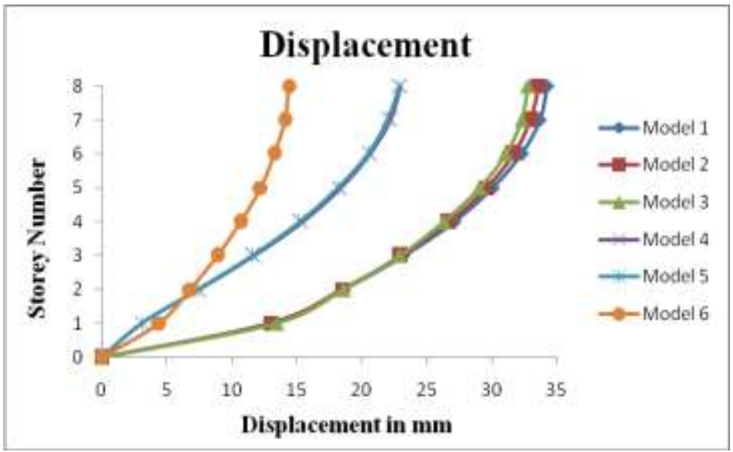

Fig 3.1 Displacement in mm at X Direction

Table 3.2 Displacement in mm at Y Direction

Storey	Elevation (m)	Displacement in mm					
		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
8	27.36	41.7	45.5	45.2	33.6	39	8.8
7	24.36	40.8	44.6	44.3	32.6	37.8	8.6
6	21.36	39.2	42.8	42.6	30.8	35.7	8.2
5	18.36	36.8	40.2	40	28.2	32.7	7.7
4	15.36	33.5	36.6	36.5	24.8	28.8	7
3	12.36	29.3	32	32	20.5	23.9	6.1
2	9.36	24.1	26.4	26.6	15.6	18.2	5
1	6.36	17.8	19.4	19.7	10.3	12	3.7
Base	0	0	0	0	0	0	0

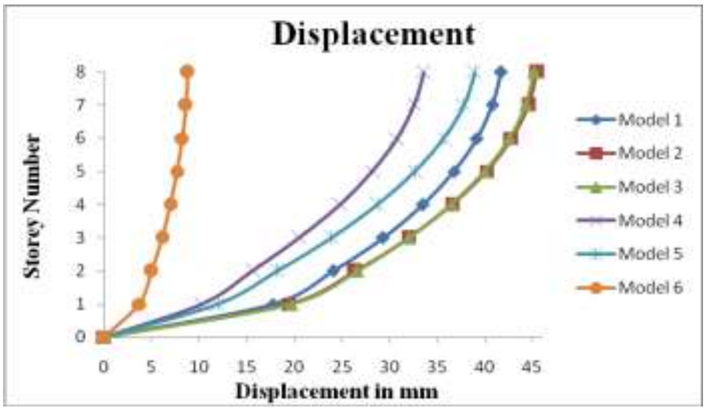

Fig 3.2 Displacement in mm at Y Direction

- From the above Tables 3.1 & &3.2 and Graphs 3.1 & 3.2 it is seen that the sttructure without damper is more displaced when compared with the structure with Friction Damper.
- Model 1, Model 2, and Model 3 without Damper are having 46.33%, 46% & 60% more displacement in X-direction compared to Model 4, Model 5, and Model 6 repectively. Model 1, Model 2, and Model 3 without Damper are having 27.2%, 22.57% & 80.72% more displacement in Y-direction compared to Model 4, Model 5, and Model 6 repectively.
- The buildings with Friction Damper are safer than the building without damper when earthquake attacks.

Storey Drift

The story drift is max at middle of the storey and min. at bottom and top storey. The results are obtained from the models with and without Friction Damper, the model with friction damper having lesser values as compared to the models without friction damper.

Table 3.3 Storey Drift in mm at X Direction

Storey	Elevation (m)	Storey Drift in mm					
		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
8	27.36	0.000197	0.000186	0.000175	0.00029	0.000295	0.000135
7	24.36	0.00046	0.00044	0.000414	0.00052	0.000521	0.000248
6	21.36	0.000734	0.000706	0.000664	0.00076	0.000757	0.000368
5	18.36	0.001008	0.000971	0.000513	0.000996	0.000989	0.000488
4	15.36	0.001281	0.001236	0.001162	0.001223	0.00121	0.000606
3	12.36	0.001554	0.0015	0.001413	0.001427	0.001405	0.000724
2	9.36	0.001897	0.001834	0.001744	0.001576	0.001543	0.000809
1	6.36	0.004306	0.004332	0.004344	0.000981	0.00099	0.001213
Base	0	0	0	0	0	0	0

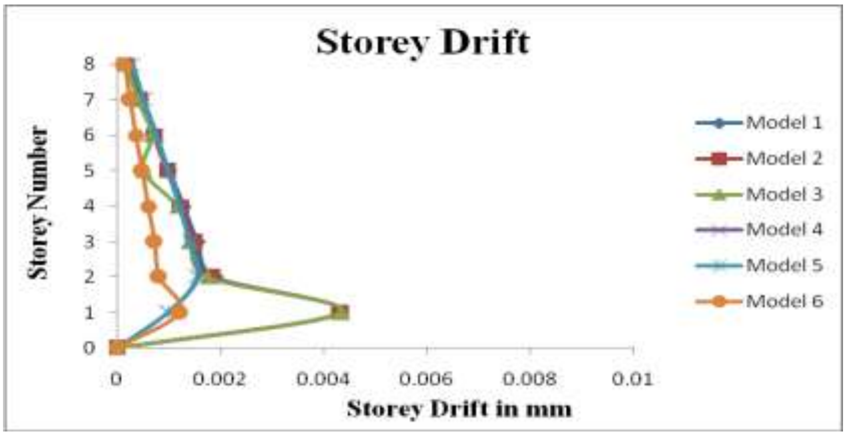

Fig 3.3 Storey Drift in mm at X Direction

Table 3.4 Storey Drift in mm at Y Direction

Storey	Elevation (m)	Storey Drift in mm					
		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
8	27.36	0.000284	0.00044	0.000306	0.000351	0.000514	7.4E-05
7	24.36	0.000534	0.000715	0.000576	0.000592	0.000772	0.000129
6	21.36	0.000819	0.001038	0.000885	0.00087	0.001074	0.000193
5	18.36	0.001109	0.001366	0.0012	0.001148	0.001379	0.000258
4	15.36	0.001401	0.001688	0.001512	0.001417	0.001675	0.00032
3	12.36	0.001708	0.002004	0.001823	0.001652	0.001969	0.000378
2	9.36	0.002127	0.002329	0.002296	0.001783	0.002144	0.000438
1	6.36	0.003307	0.003618	0.00366	0.00202	0.002354	0.000682
Base	0	0	0	0	0	0	0

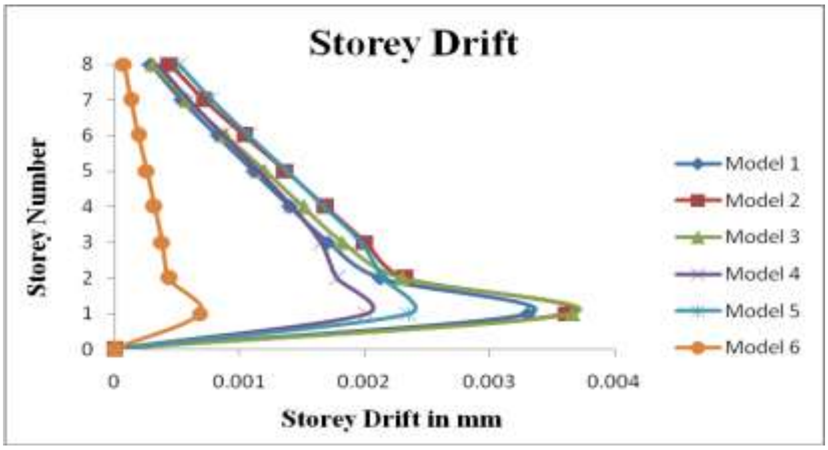

Fig 3.4 Storey Drift in mm at Y Direction

- From the graphs and tables the structure without damper has more drift as compare to the structure with Friction Damper.
- Model 1, Model 2, and Model 3 without Damper are having 23.85%, 25% & 41.83% more drift in X-direction compared to Model 4, Model 5, and Model 6 repectively. Model 1, Model 2, and Model 3 without Damper are having 19.47%, 11.35% & 78.87% more drift in Y-direction compared to Model 4, Model 5, and Model 6 repectively.

Storey Shear

By comparing Both Models without damper and with Friction Damper the storey shear will be more for Buildings without Damper.

Table 3.5 Storey Shear in kN at X Direction

Storey	Elevation (m)	Storey Shear in kN					
		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
8	27.36	113.794	129.061	79.700	101.939	88.247	50.901
7	24.36	395.212	374.928	234.219	287.710	256.366	149.581
6	21.36	656.486	620.794	388.738	473.481	424.484	248.261
5	18.36	917.760	866.661	543.258	659.252	592.603	346.941
4	15.36	1179.035	1112.527	697.777	845.023	760.721	445.621
3	12.36	1440.308	1358.394	852.296	1030.794	928.840	544.301
2	9.36	1681.631	1604.266	1006.815	1216.565	1096.958	642.984
1	6.36	1943.912	1850.122	1161.334	1402.337	1265.077	741.661

Table 3.6 Storey Shear in kN at Y Direction

Storey	Elevation (m)	Storey Shear in kN					
		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
8	27.36	299.273	312.146	250	271.552	225.180	57.588
7	24.36	883.989	906.798	734.885	766.422	741.318	169.232
6	21.36	1468.386	1501.449	1219.703	1261.292	1227.457	280.876
5	18.36	2052.782	2096.099	1704.521	1756.162	1713.595	392.520
4	15.36	2637.177	2690.748	2189.339	2251.031	2199.733	504.163
3	12.36	3221.572	3285.397	2674.157	2745.901	2685.871	615.806
2	9.36	3761.353	3880.049	3158.975	3240.771	3172.01	727.447
1	6.36	4345.886	4474.824	3643.793	3735.641	3658.370	839.137

- The storey shear force will be more in structure without damper as compared to the structure with Friction Damper.
- Model 1, Model 2, and Model 3 without Damper are having 25.74%, 31.62% & 36.13% more shear in X-direction compared to Model 4, Model 5, and Model 6 repectively. Model 1, Model 2, and Model 3 without Damper are having 13.54%, 19.45% & 76.97% more shear in Y-direction compared to Model 4, Model 5, and Model 6 repectively.

Location of Hinges for Buildings and their Performance point

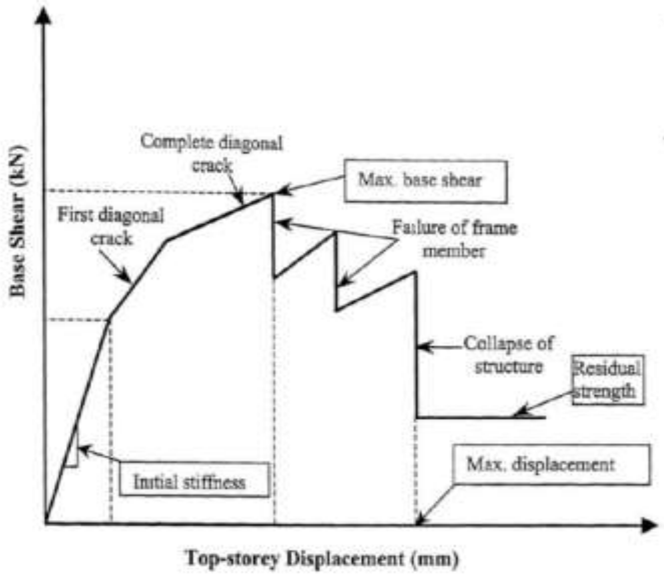

Fig 4 Typical pushover curve

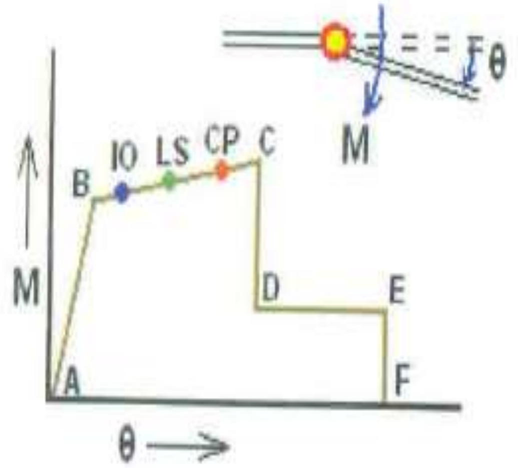

Fig 5 Typical flexural hinge

Pushover analysis is a method of applying incremental lateral load to the structure until the formation of plastic hinge, cracks, yielding and failure of various structural components occurs so that it can be rectified. The performance point shows the performance of the structure during seismic activities.

A representative flexural hinge is to be shown in Fig. 5'AB' represents the linear range commencing the unloaded status (A) to its effect yield (B), duplicate by means of an inelastic but linear response of condensed stiffness as of B to C. CD shows a spontaneous reduction in load resistance duplicate by the reserve capacity DE and to end with, complete extent loss of conflict from E to F.

These hinges enclose non-linear state clear as 'Immediate Occupancy' (IO), 'Life Safety' (LS) and 'Collapse Prevention' (CP) within the ductile region (BC). Structures as a whole also have these states explained on the basis of drift limits.

In Table 3.7, the Location of Hinges for Model 1, Model 2, Model 3,Model 4, Model 5and Model 6 without and with Friction damper and with fixed base along X direction on sloping ground by Pushover analysis is shown

Table 3.7 Location of Hinges for Buildings and their Performance point at X Direction

Model No.	Monitored Displacement in mm		Base Force kN	A-B	B-C	C-D	D-E	>E	A-IO	IO-LS	LS-CP	>CP	Total
1	Ultimate	112.8	2284.61	4648	182	0	0	14	4732	84	14	14	4844
	Yield	34.3	1414.39	4830	14	0	0	0	4844	0	0	0	4844
2	Ultimate	119.2	2478.46	4278	158	0	12	0	4348	64	24	12	4448
	Yield	33.6	1275.61	4436	12	0	0	0	4448	0	0	0	4448
3	Ultimate	119.6	2405.90	4286	156	8	2	0	4356	66	20	10	4452
	Yield	31.7	1170.68	4448	4	0	0	0	4452	0	0	0	4452
4	Ultimate	105.2	8035.91	4992	368	0	0	0	5753	3	0	0	5360
	Yield	22.9	1958.11	5360	0	0	0	0	5360	0	0	0	5360
5	Ultimate	105.6	7693.66	4673	288	0	0	0	4956	0	0	4	4960
	Yield	22.9	1865.56	4960	0	0	0	0	4960	0	0	0	4960
6	Ultimate	140.6	7477.21	4232	604	0	0	0	4684	88	0	64	4836
	Yield	10	747.64	4836	0	0	0	0	4836	0	0	0	4836

In Table 3.8, the Location of Hinges for Model 1, Model 2, Model 3,Model 4, Model 5and Model 6 without and with Friction damper and with fixed base along Y direction on sloping ground by Pushover analysis is shown

Table 3.8 Location of Hinges for Buildings and their Performance point at Y Direction

Model No.	Monitored Displacement in mm		Base Force kN	A-B	B-C	C-D	D-E	>E	A-IO	IO-LS	LS-CP	>CP	Total
1	Ultimate	59.3	6571.59	4640	204	0	0	0	4706	138	0	0	4844
	Yield	7.4	3767.75	4842	2	0	0	0	4844	0	0	0	4844
2	Ultimate	57.2	3766.19	4254	192	0	2	0	4290	106	36	16	4448
	Yield	6.3	3688.62	4446	2	0	0	0	4448	0	0	0	4448
3	Ultimate	42.4	3356.32	4276	174	0	2	0	4314	102	26	10	4452
	Yield	6.6	3673.13	4450	2	0	0	0	4452	0	0	0	4452
4	Ultimate	8.6	12875.83	5157	203	0	0	0	5356	0	0	4	5360
	Yield	3.3	4379.84	5360	0	0	0	0	5360	0	0	0	5360
5	Ultimate	6.7	11389.93	4810	150	0	0	0	4956	0	0	4	4960
	Yield	3.1	4512.03	4960	0	0	0	0	4960	0	0	0	4960
6	Ultimate	2.4	5890.73	4752	84	0	0	0	4834	0	0	2	4836
	Yield	0.4	845.86	4836	0	0	0	0	4836	0	0	0	4836

- From the above tables 3.7 and 3.8, it can be seen that Model 4 Model 5 and Model 6 in X-Direction have more base force i.e. 28.46%, 31.12%, and 32.17% at ultimate stage compared to Model 1 Model 2 and Model 3. Similarly in Model 4 Model 5 and Model 6 in Y-Direction have more base force i.e. 51.03%, 33.06%, and 56.97% at ultimate stage by Pushover analysis.
- By comparing Model 1, Model 2, and Model 3 with Model 4, Model 5, and Model 6, within the life safety range the hinges are formed at ultimate stage is 100% in Model 4, Model 5, and Model 6 which are having Friction Damper.

IV. CONCLUSIONS

After analysis, results are compared and are concluded as follows

- By using Friction Damper to the structures it gives the decreasing values of displacement, story drift, and story shear.
- The displacements of the structures without friction damper are more than the structures with friction damper, and they get reduced 46% to 80% with using friction damper.
- While comparing structures without friction damper and with friction damper, the storey drift will be reduces 24% to 78%
- The storey shear will be more when the structures are with friction damper while comparing structures without friction damper.
- The shear force will be reduced by 25% to 76% when structure with Friction Damper.
- The structure with friction damper is safer than the structure without damper.
- They provide safety against the strong earthquake load and reduce the damage of the structure.

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