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EFFECT OF THE POSITION AND NUMBER OF FRICTION DAMPERS ON THE SEISMIC RESPONSE OF UNSYMMETRIC BUILDING

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ABSTRACT - *Current trends in construction industry demands taller and lighter structures, which are also more flexible and having quite low damping value. This increases failure possibilities and also problems from serviceability point of view. Now-a-days several techniques are available to minimize the vibration of the structure, out of the several techniques available for vibration control; concept of using dampers is a newer one. Supplemental damping in conjunction with appropriate stiffness offers an innovative and attractive solution for the seismic response control of structures.*

This study deals with the effectiveness of one such damper, friction damper as a passive dissipative device in structures for controlling vibration of structure and also discusses the effect of number of dampers and position of dampers in a structure. To fulfill this objective, a 25-storey L-shaped building have been modeled with five different damper location formats in ETABS subjected to El Centro earthquake record. Non-linear modal Time history method has been used and seismic zone V is considered for analysis. Base shear, storey displacement, storey drifts, storey shears, storey accelerations, forces in columns and Total energy components has been compared to find out most optimal damper location format among five different damper location formats and also to find out the effect of number of dampers. Results showed that position and number of dampers has considerable influence in the seismic performance of the structure.

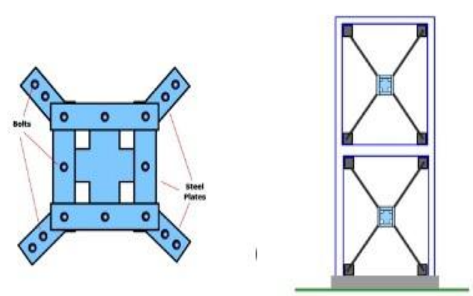
1. INTRODUCTION

The world population is growing so rapidly in recent years that there has been a resurgence of high – rise constructions in the major cities. High rise buildings have become a trend and, moreover, they have paved the way to world competition in constructing tall buildings to exhibit the symbol of power and technology possessed by its population. However, high rise buildings are subjected to vibrations. These vibrations can be due to wind loads, earthquakes, machinery vibrations and other sources of vibration. These vibrations can cause structural damage or even collapse of the structure.

In particular, during recent years earthquakes have been the main cause of structure collapse. An earthquake is a natural phenomenon of ground shaking caused by the sudden energy release inside earth and thus, it causes breaking and movement of the tectonic plates. This may contribute to create other phenomena such as tsunamis, landslides, rock falls, ground settling and liquefaction. As a matter of fact, high rise buildings are not suitable to be constructed in areas with high seismicity, if not studied and analyzed accordingly.

Friction Damper

Pall Friction Dampers are simple and foolproof in construction. Basically, these consist of series of steel plates, which are specially treated to develop very reliable friction. These plates are clamped together and allowed to slip at a predetermined load. Their performance is reliable, repeatable and they possess large rectangular hysteresis loops with negligible fade. Pall Friction Dampers are passive energy dissipation devices and, therefore, need no energy source other than earthquakes to operate it. They do not require any repair or replacement after the earthquake and are always ready to do their job.



Tension only cross brace with friction damper

Scope

The main objectives of this study can be listed as following.

a) To assess the effectiveness of friction dampers in reducing the earthquake induced response of structural systems.

b) To assess, how the variation of placement and number of dampers affect the seismic response of a frame structure, and

c) Comparison of the building performances for five different formats of placement of friction dampers in terms of base shears, storey drifts and storey accelerations etc.,

Shaik Kamal Mohammed Azam et al., (23) states that the dual structural system consisting of special moment resisting frame (SMRF) and concrete shear wall has better seismic performance due to improved lateral stiffness and lateral strength. A comparison of structural behavior in terms of strength, stiffness and damping characteristics is done by arranging shear walls at different locations/configurations in the structural framing system. The results of the study indicate that the provision of shear walls symmetrically in the outermost moment resisting frames of the building and preferably interconnected in mutually perpendicular directions forming a core will lead to better seismic performance.

Abhijeet Baikerikar et al., (3) study has been done to examine the effect of different cases using shear wall and bracings for the different heights, maximum height considered for the present study is 75m. The modeling is done to along with different heights on seismic parameters like base shear, lateral displacements and lateral drifts. The study has been carried out for the Zone V and all types of soils as specified in IS: 1893-2002. By locating shear walls at different positions and by comparing the results it can conclude that time period is significantly lowered after placing shear walls and bracings.

3. RESEARCH METHODLOGY

The purpose of this study is to evaluate the effect of the position and number of friction dampers on seismic behavior of high rise unsymmetrical building. The design and analysis is performed by using ETABS software. For this five RCC structures have been modeled i.e., Model 1 is without friction dampers, Model 2,3,4 have been modeled with same number of dampers i.e., 96 friction dampers at different locations and Model 5 with full dampers in all the bays i.e., 288 friction dampers.

In order to understand the seismic behavior of the building time history analysis is considered to be performed. For the purpose of analysis, Time History of El Centro earthquake data that has been recorded is considered. Once modeling is completed, it automatically generates and assigns code-based loading conditions for gravity, seismic. Then two load cases TIMEX (Time history record of El Centro in X-direction) and TIMEY (Time history record of El Centro in Y- direction) is given as dynamic loading.

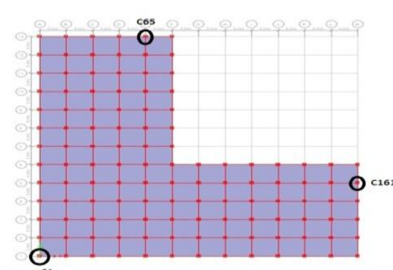
Basic parameters considered for the analysis are

1. Utility : Residential Building
2. Number of stories : 25
3. Shape of Building : L-Shape
4. Geometric details
   a. floor to floor height : 3m
   b. Column to column distance in both X and Y axis : 3m
5. Material details
   a. Concrete Grade : M30
   b. All Steel Grades: HYSD reinforcement of Grade Fe500
6. Type of Construction: RCC Framed structure
7. Column : 0.5 m X 0.5 m
8. Beams : 0.3 m X 0.6 m
9. Slab : 0.150 m
10. Live Load: 3 kN/m^2
11. Live Load contribution : 25% (as per IS:1893-2016)

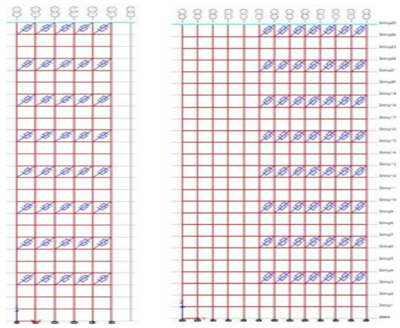
Link properties of the single diagonal tension/compression brace with friction damper.

Link Type	Plastic (Wen)
Mass (kg)	222.07
Weight (kN)	2.18
Effective Stiffness (kN/m)	152500
Effective Damping (kNs/m)	0
Yield Strength = Slip Load (kN)	450
Post Yield Stiffness Ratio	0.0001
Yielding exponent	10
Brace section	ISMB200

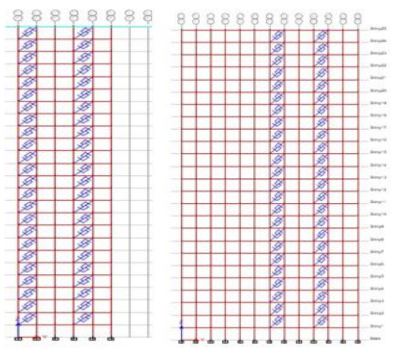
4. MODELS IN ETABS



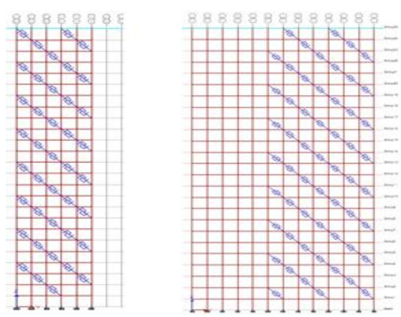
Plan View of Building



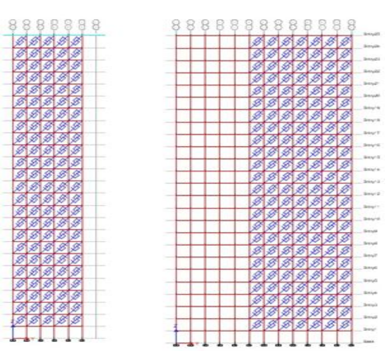
Building with friction dampers in every two alternate floors (MODEL 2)



Building with friction dampers in every two alternate bays (MODEL 3)



Building with friction dampers at zigzag location (MODEL 4)



Building with friction dampers in all the bays. (MODEL 5)

Note: In all the models Dampers are placed in Elevation Grid M&13 And F&6.

4. RESULTS & DISCUSSION

4.1 Modal participating mass ratios

Modal participating mass ratios (MODEL 1)

Case	Mode	Period	Frequency	Sum UX	Sum UY	Sum RX	Sum RY	Sum RZ
		sec	cyc/sec					
Modal	1	3.138	0.319	0.2682	0.2682	0.0771	0.0771	0.2408
Modal	2	3.085	0.324	0.6591	0.6591	0.1877	0.1877	0.2408
Modal	3	2.793	0.358	0.7849	0.7849	0.2176	0.2176	0.7921
Modal	4	1.01	0.99	0.8287	0.8287	0.4003	0.4003	0.8285
Modal	5	0.998	1.002	0.8892	0.8892	0.656	0.656	0.8285
Modal	6	0.921	1.086	0.9031	0.9031	0.7335	0.7335	0.9034
Modal	7	0.561	1.782	0.9203	0.9203	0.7676	0.7676	0.9047
Modal	8	0.56	1.786	0.9383	0.9383	0.8046	0.8046	0.9047
Modal	9	0.437	2.287	0.943	0.943	0.8195	0.8195	0.9192
Modal	10	0.394	2.54	0.952	0.952	0.8524	0.8524	0.9192
Modal	11	0.335	2.986	0.9633	0.9633	0.8904	0.8904	0.9251
Modal	12	0.298	3.351	0.9695	0.9695	0.9067	0.9067	0.9251
Modal	13	0.215	4.657	0.9765	0.9765	0.9292	0.9292	0.9251
Modal	14	0.176	5.667	0.9892	0.9892	0.9652	0.9652	0.9279
Modal	15	0.12	8.354	0.9967	0.9967	0.9877	0.9877	0.9279

Modal participating mass ratios (MODEL 2)

Case	Mode	Period	Frequency	Sum UX	Sum UY	Sum RX	Sum RY	Sum RZ
		sec	cyc/sec					
Modal	1	3.025	0.331	0.391	0.391	0.1106	0.1106	0
Modal	2	2.939	0.34	0.7275	0.7275	0.2014	0.2014	0.1141
Modal	3	2.748	0.364	0.7876	0.7876	0.2148	0.2148	0.7956
Modal	4	0.974	1.026	0.8496	0.8496	0.4733	0.4733	0.7956
Modal	5	0.955	1.047	0.9034	0.9034	0.7184	0.7184	0.8069
Modal	6	0.902	1.109	0.9065	0.9065	0.7397	0.7397	0.9086
Modal	7	0.544	1.838	0.9245	0.9245	0.7776	0.7776	0.9086
Modal	8	0.541	1.847	0.9421	0.9421	0.8127	0.8127	0.9087
Modal	9	0.384	2.607	0.9506	0.9506	0.8453	0.8453	0.9097
Modal	10	0.382	2.616	0.9594	0.9594	0.8777	0.8777	0.9097
Modal	11	0.29	3.45	0.9653	0.9653	0.8933	0.8934	0.9097
Modal	12	0.28	3.573	0.9735	0.9735	0.9165	0.9165	0.9132
Modal	13	0.209	4.781	0.9796	0.9796	0.9365	0.9365	0.9132
Modal	14	0.151	6.627	0.9901	0.9901	0.9699	0.9699	0.9152
Modal	15	0.118	8.482	0.9976	0.9976	0.9925	0.9925	0.9152

Modal participating mass ratios (MODEL 3)

Case	Mode	Period	Frequency	Sum UX	Sum UY	Sum RX	Sum RY	Sum RZ
		sec	cyc/sec					
Modal	1	3.036	0.329	0.3899	0.3899	0.1117	0.1117	0
Modal	2	2.972	0.337	0.7223	0.7223	0.2049	0.2049	0.1145
Modal	3	2.752	0.363	0.7842	0.7842	0.2183	0.2183	0.7896
Modal	4	0.976	1.024	0.8459	0.8459	0.4732	0.4732	0.7896
Modal	5	0.96	1.042	0.9017	0.9017	0.718	0.718	0.7989
Modal	6	0.9	1.112	0.9037	0.9037	0.7345	0.7345	0.9043
Modal	7	0.545	1.835	0.922	0.922	0.7726	0.7726	0.9043
Modal	8	0.543	1.842	0.9399	0.9399	0.808	0.808	0.9044
Modal	9	0.392	2.55	0.9475	0.9475	0.8365	0.8365	0.9087
Modal	10	0.382	2.618	0.9567	0.9567	0.8696	0.8696	0.9087
Modal	11	0.297	3.37	0.9659	0.9659	0.8964	0.8964	0.9142
Modal	12	0.289	3.458	0.9721	0.9721	0.9129	0.9129	0.9142
Modal	13	0.209	4.794	0.9789	0.9789	0.9349	0.9349	0.9142
Modal	14	0.162	6.166	0.9902	0.9902	0.9696	0.9696	0.9179
Modal	15	0.117	8.53	0.9973	0.9973	0.9909	0.9909	0.9179

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Modal participating mass ratios (MODEL 4)

Case	Mode	Period	Frequency	Sum UX	Sum UY	Sum RX	Sum RY	Sum RZ
		sec	cyc/sec					
Modal	1	2.984	0.335	0.4026	0.3782	0.1079	0.1144	1.28E-05
Modal	2	2.924	0.342	0.7469	0.746	0.2086	0.2083	0.0726
Modal	3	2.717	0.368	0.7863	0.7858	0.2168	0.2163	0.7928
Modal	4	0.968	1.033	0.8501	0.8456	0.4641	0.4818	0.7928
Modal	5	0.945	1.058	0.9048	0.9043	0.7305	0.7313	0.797
Modal	6	0.893	1.12	0.9053	0.9048	0.7365	0.7373	0.9072
Modal	7	0.54	1.85	0.9263	0.9203	0.7688	0.7809	0.9072
Modal	8	0.538	1.858	0.9409	0.9405	0.8092	0.8099	0.9075
Modal	9	0.398	2.51	0.9472	0.947	0.8336	0.8339	0.9148
Modal	10	0.38	2.635	0.9563	0.9559	0.8659	0.8671	0.9148
Modal	11	0.306	3.27	0.9652	0.9664	0.8978	0.8946	0.9215
Modal	12	0.288	3.475	0.9721	0.9717	0.9118	0.9131	0.9215
Modal	13	0.208	4.816	0.9782	0.979	0.9356	0.933	0.9215
Modal	14	0.165	6.059	0.9904	0.99	0.9684	0.9699	0.9247
Modal	15	0.117	8.58	0.9972	0.9973	0.9906	0.9902	0.9247

Modal participating mass ratios (MODEL 5)

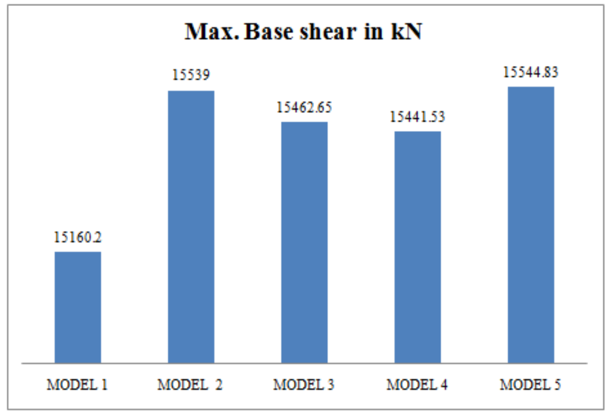
Case	Mode	Period	Frequency	Sum UX	Sum UY	Sum RX	Sum RY	Sum RZ
		sec	cyc/sec					
Modal	1	2.92	0.342	0.3882	0.3882	0.1137	0.1137	0
Modal	2	2.742	0.365	0.7022	0.7022	0.193	0.193	0.1729
Modal	3	2.485	0.402	0.7859	0.7859	0.2168	0.2168	0.7919
Modal	4	0.924	1.082	0.8507	0.8507	0.4717	0.4717	0.7919
Modal	5	0.901	1.11	0.895	0.895	0.6929	0.6929	0.8101
Modal	6	0.806	1.241	0.9076	0.9076	0.7414	0.7414	0.91
Modal	7	0.52	1.922	0.9214	0.9214	0.7679	0.7679	0.916
Modal	8	0.511	1.957	0.94	0.94	0.8082	0.8082	0.916
Modal	9	0.423	2.366	0.9472	0.9472	0.829	0.829	0.9325
Modal	10	0.358	2.796	0.9564	0.9564	0.8618	0.8618	0.9325
Modal	11	0.306	3.263	0.9675	0.9675	0.901	0.901	0.9352
Modal	12	0.271	3.692	0.9735	0.9735	0.9173	0.9173	0.9352
Modal	13	0.196	5.092	0.9799	0.9799	0.9383	0.9383	0.9352
Modal	14	0.164	6.081	0.9913	0.9913	0.9712	0.9712	0.9369
Modal	15	0.112	8.932	0.9975	0.9975	0.9901	0.9901	0.9369

4.2 Comparison of Time periods of five models for different modes

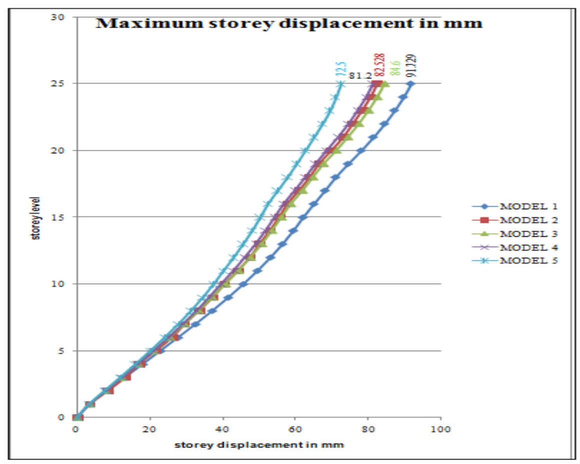
Comparison of Time Periods of Five Models for Different Modes

Case	Mode	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5
		Period	Period	Period	Period	Period
		sec	Sec	sec	sec	Sec
Modal	1	3.138	3.025	3.036	2.984	2.92
Modal	2	3.085	2.939	2.972	2.924	2.742
Modal	3	2.793	2.748	2.752	2.717	2.485
Modal	4	1.01	0.974	0.976	0.968	0.924
Modal	5	0.998	0.955	0.96	0.945	0.901
Modal	6	0.921	0.902	0.9	0.893	0.806
Modal	7	0.561	0.544	0.545	0.54	0.52
Modal	8	0.56	0.541	0.543	0.538	0.511
Modal	9	0.437	0.384	0.392	0.398	0.423
Modal	10	0.394	0.382	0.382	0.38	0.358
Modal	11	0.335	0.29	0.297	0.306	0.306
Modal	12	0.298	0.28	0.289	0.288	0.271
Modal	13	0.215	0.209	0.209	0.208	0.196
Modal	14	0.176	0.151	0.162	0.165	0.164
Modal	15	0.12	0.118	0.117	0.117	0.112

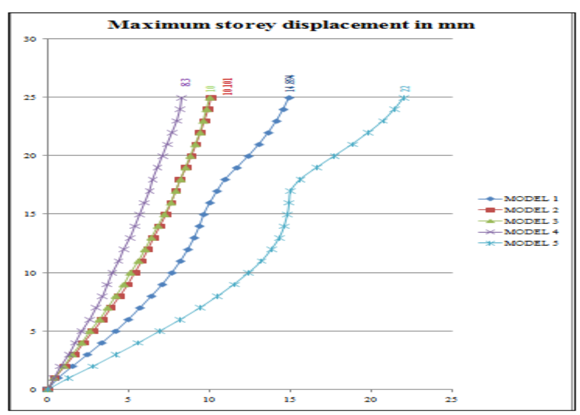
4.3 Base shear



4.4 Storey displacements

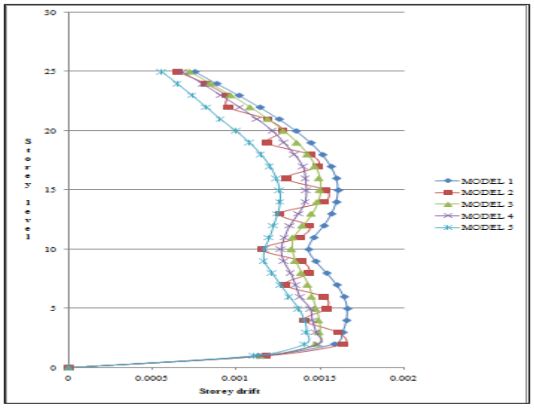


Storey displacement vs. storey level in X- direction & Y-direction for Load case: TIMEX AND TIMEY respectively.

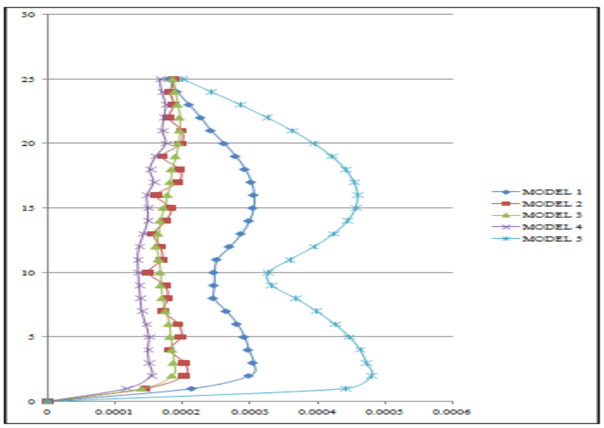


Storey displacement vs. storey level in X- direction and Y-direction for Load case: TIMEY and TIMEX

4.5 Story Drift

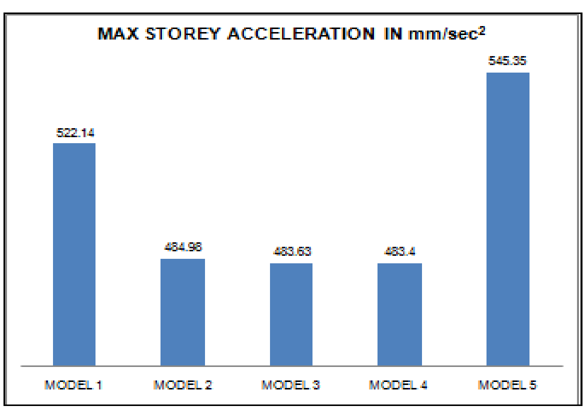


Storey drift in X & Y- directions for Load case: TIMEX & TIMEY respectively

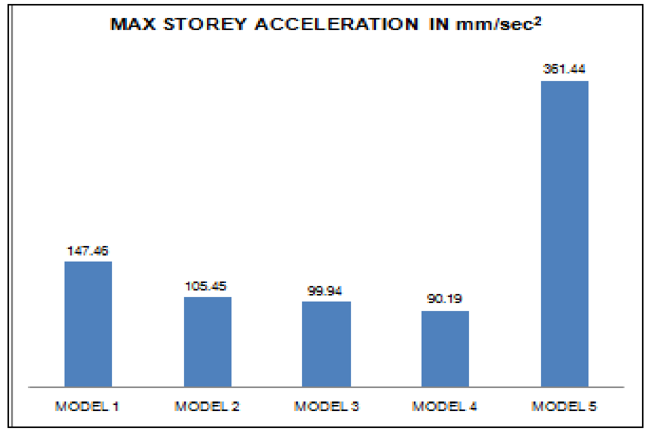


Storey drifts vs. storey level in X & Y- direction for Load Case: TIMEY & TIMEX respectively

4.6 Storey acceleration

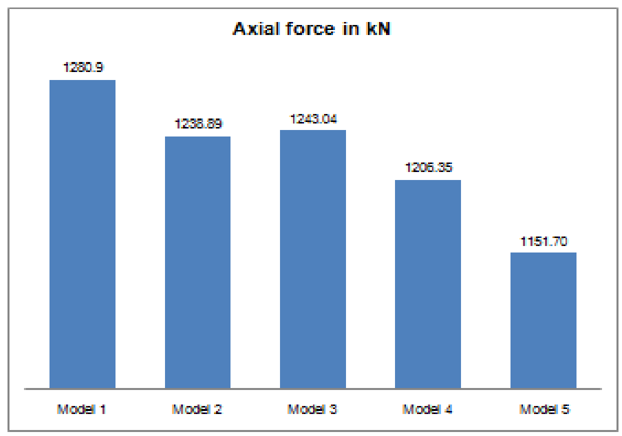


Comparison of Storey acceleration in X and Y- direction for Load case: TIMEX and TIMEY respectively

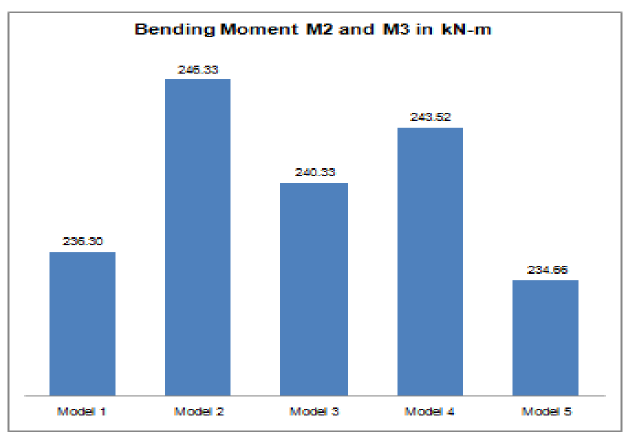


Comparison of Storey acceleration in X & Y- direction for load case: TIMEY & TIMEX respectively.

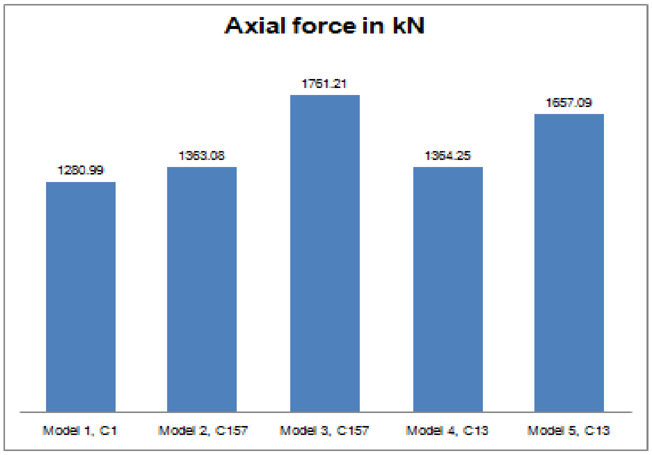
4.7 Forces in Columns



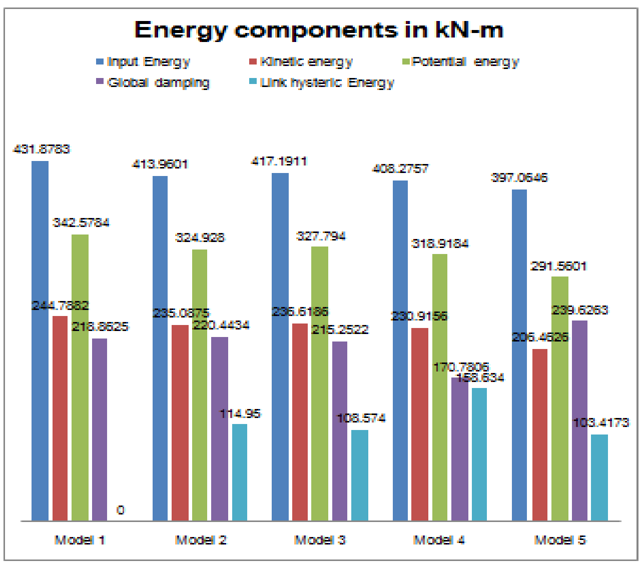
Comparison of Axial force of column C1



Comparison of Bending Moment M2 and M3 of columns C161 and C65 respectively for five Models



Comparison of maximum axial force



Comparison of different Energy components

5. CONCLUSIONS

Following conclusions are made from the present study.

1. The results of this investigation show that the response of the structure i.e, time period, storey displacement, storey drift and storey acceleration can be reduced by using friction damper.

2. It has been found that Time period of the structure got reduced with the introduction of friction dampers in the structure. Building with full dampers in all bays (Model 5) has got lowest time period.

3. Among buildings with same number of dampers but at different locations i.e., Model 2, 3 and 4. Building with zigzag location of dampers (Model 4) has got lowest time period.

4. It has been found that effect of dampers in building in reducing the Maximum base shear is insignificant as buildings with dampers i.e., Model 2, 3, 4 and 5 got high base shear values when compared to building without dampers (Model 1). Among buildings with same number of dampers at different locations (Model 2, 3 and 4) Model 4 got slightly lower maximum base shear value.

5. Maximum storey displacements also reduced with the introduction of dampers. Model 5 has got lowest maximum storey displacement. However, among buildings with same number of dampers at different locations (Models 2, 3 and 4), Model 4 has lowest maximum storey displacements.

6. It has been observed that storey drifts have been reduced with buildings having friction dampers and it has been found that buildings having same number of dampers got different drift values. So, it clearly shows that response of the structure varies with the location of the dampers.

7. Storey shears are also increased for buildings with dampers when compared to building without dampers same as in case of Base shears. This increase in base shear and storey shears can be attributed to the increase in mass of the structure with the introduction of dampers.

8. Storey acceleration decreases with addition of dampers but excessive dampers will not reduce the maximum storey accelerations.

9. Maximum Axial forces in any column increases with introduction of dampers. This is again because of addition of dampers weight of the structure increases and also some dampers are in Non-slip mode due to their location, thus they behave as bracing members because of this building becomes stiffer, hence axial forces in the columns increases.

10. Percentage of Dissipation of Input energy in the building has been increased with the addition of Friction dampers. The percentage dissipation of input energy through hysteretic behavior is maximum for Model 4.This increase in percentage dissipation through link hysteretic behavior depends upon location of friction damper.

Scope for further study

The following are suggestions for further research in this area:

1. The method of optimizing the location of the dampers within the structure can be further investigated.

2. The study can be extended to the steel structures also.

3. The study can be extended for earthquake induced structural pounding between insufficiently separated buildings.

4. The study can be compared with other dissipation techniques like base isolation.

5. The study can be extended for wind loads also.

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