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ANALYSIS OF COUPLED BUILDING USING HORIZONTAL VARIABLE FRICTION DAMPER

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Abstract

Earthquakes are the most devastating natural threat to buildings under seismic excitation. Structures in close proximity are susceptible to pounding. Previous earthquakes have caused significant structural damage to adjacent buildings due to their impact. In order to address these issues, researchers have investigated the usage of control devices in various interconnected building control systems. In the present study, the effectiveness of friction dampers in reducing the response of structure is evaluated. The purpose of this research is to determine optimistic performance under damper placement using ETABS. The purpose of this research is to investigate the coupled building response using horizontal friction dampers. We perform a comparative analysis between individual and coupled buildings with various damper placement. The current study focuses on a 10 storey and 14 storey RCC building with rectangular columns & rectangular form that was assessed in ETABS 2016 in zone-III on medium grade soil using a friction damper. ETABS has evaluated three distinct scenarios of building with alternative, double alternative and throughout damper. Research conducts response spectrum analysis and nonlinear time history analysis. EI centro earthquake time series data was used in the research. The results obtained are compared in the form of displacement, storey drift, time period and base shear. Based on the project research It is concluded that time period storey displacement and storey drift will be more in individual buildings as compared to friction damper coupled building whereas the base shear will be more in couple building as compared with individual building.

Keywords- *Coupled building, Individual building, Horizontal friction damper, Time history.*

1. 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 control of structural vibrations produced by earthquake or wind excitations can be done by various means such as modifying rigidity, masses, damping or shape and by providing passive or active control forces. Structural was introduced as an approach to provide solutions to those problems of mitigating the structural response against pulse excitation. Since from the last century, this part of problem has taken various forms, and improvementsin design philosophy and methods have been done. There are two types of methods for the seismic design of structure:

1. Conventional method: This is the traditional method to resist the lateral force 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: Control System (Base Isolation, Dampers)

. The purpose to provide control system is to take care of the seismic forces and its effects on the structure can be reduced up to certain degree so that the remaining vibrational energy can be resisted by the structure itself. The reduction of structural response caused by dynamic effects has become a subject of intensive research and it has been noted that the larger the energy dissipation capacity then there will be smaller amplitude of vibration and vice versa.

Friction Damper

Friction dampers are devices that use dry friction to dissipate energy of a system in order to limit its vibratory response. They work by keeping in contact two surfaces that move relative to each other in order to generate friction. That basic concept has been around for a very long time. An example is the use of leaf springs in horse-drawn carriages in the eighteenth century. Contemporary research dating back to 1930 proposes a mathematical formulation for such a damper. When compared to other means to attenuate vibration, friction dampers stand out by their noteworthy advantages. To name a few, they work in harsh environments and in the absence of electric or hydraulic power; they adapt to a wide excitation bandwidth without tuning; and they can act simultaneously along multiple directions. Consequently, they are used in a variety of applications. Their most common use is in buildings, as a means to prevent damage caused by earthquakes.

Friction damping can be referred to as frictional damping or Coulomb damping. When the damping comes from the material itself or from a system about which no clear information of the inner dynamics is known, the terms hysteretic damping, complex stiffness, and structural damping may refer to the same phenomenon of dissipation by friction.

The relative motion at the point of contact of a friction damper can be linear or relative, and the contacting surfaces can have curved or planar topologies. Combination with other damping technologies such as eddy currents, viscous dampers, and tuned mass dampers is also common. In such cases, the damper is often said to be semi-active

Jian yang Xu et al. (2020) presented a novel friction damper for enhancing Mortise-Tenon joint cyclic response at many levels of seismic motion. To evaluate the suggested damper, quasi-static cycle tests are undertaken on five reinforced joints and one contrast joint constructed by Pinups Silvestre's in exact conformity with ISO-16670. Reinforced joints show less Tenon pullout, bigger bearing capacity and initial stiffness, reduced strength and stiffness deterioration, and better energy dissipation capacity. Increasing friction pad coefficients and clamping force improves Mortise-Tenon earthquake performance. To get the best reinforcing effect, use friction pads with a coefficient of 0.4 and bolts with a pre-tension strain of 0.03. Reinforced joints are deformable. A rigorous finite element modelling technique is followed by validation experiments to better understand the mechanical behaviour of the reinforced connections presented here. Yonge Wang et al. Traditional structures, even with conventional SCED bracing, may experience severe deformations and high mode effects after a big earthquake, resulting to understory drift in higher stories. To meet the criteria of resilience, bigger post-yield stiffness, and higher energy dissipation, a new brace with pretension basalt fiber-reinforced polymer (BFRP) tendons and variable friction dampers (VFDs) was created. Theoretical analysis of VFD variable stiffness and sliding force. Then, quasi-static studies were performed on two VFD and two SC-VFD braces. SC-VFD brace has similar energy dissipation capabilities as VFD brace but reduced residual displacement and equal viscous damping ratio. More disc springs in series reduce axial forces and post-yielding stiffness, reducing energy dissipation. C.L. Ng et al. This work investigates semi-active coupling management of a building complex utilising variable friction dampers to mitigate seismic reactions. First, a building complex with variable friction dampers is modelled under seismic excitation. Variable friction dampers may function successfully with linear quadratic Gaussian control algorithms as a global-feedback controller. Local-feedback controllers include viscous and Reid friction controllers, modulated homogeneous friction controllers, and non-sticking friction controllers. A 20-story main building and 3-story podium structure are utilised as a numerical example to show semi-active coupling control and compare local-feedback and global-feedback controllers. The narrative drifts and acceleration responses of each controller for the building complex with single or multiple friction dampers are evaluated under different ground movements. Numerical findings reveal that semi-active coupling management reduces both structures' seismic responses. As there isn't much research on this area, we're studying horizontal friction dampers.

3. METHODOLOGY

Aim of the study is to Determine optimistic performance under damper location using ETABS software. For that we have taken a multi-story G+8 and G+12 story RCC structure were included for the investigation. In plane, the structure is symmetrical. The building has a bay width of 5m in X and 8m in Y and a story height of 3m. The height of the ground level is 3 meters. Response spectrum analysis and the time history approach are used in the ETABS programmer for analysis. A G+8 and G+12story multi-story building in Zone III on medium grade soil is evaluated, and the displacement and acceleration of the structure with and without walls owing to various load combinations are determined. IS1893:2002 response spectrum approach is used for seismic analysis.

The objective of the study is to Investigate the coupled building response using horizontal of damper. From that we will conduct a Comparative study of between individual and coupled building.

The following factors are taken into account while modelling the G+8 and G+12story structures, as stated in the table below

1.	Number of story	G+8 and G+12story
2.	Floor height	3m
3.	Size	25X 32 m
4.	Slabs	200 mm
5.	Grid spacing X direction	5m in each direction
6.	Grid spacing Y direction	8m in each direction
7.	Size of column	600mm×600mm
8.	Size of beam	450mm×750mm

9.	Types of soil	Medium soil
10.	Damper type	Horizontal variable friction damper
11.	Seismic zone	III
12.	Zone factor	0.16
13.	Response of spectra As per IS1893(Part 1):2O16 for 5% damping	
14.	Time History data	El-Centro

2.1 Flowchart

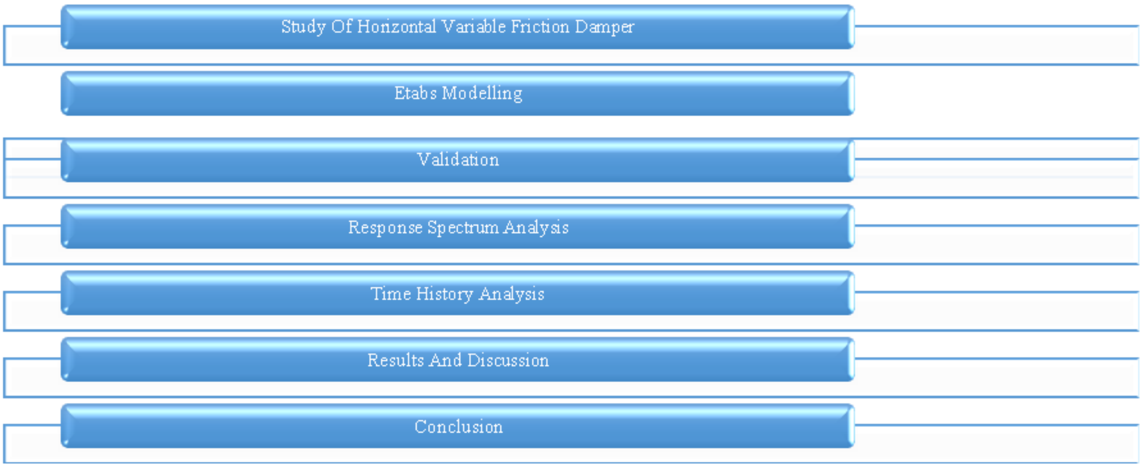


Figure no 2.1- Flowchart

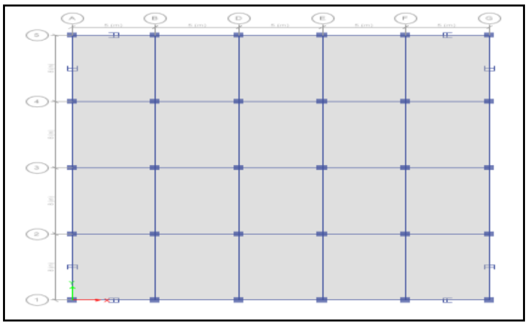


Figure no 2.2- Plan view of the building

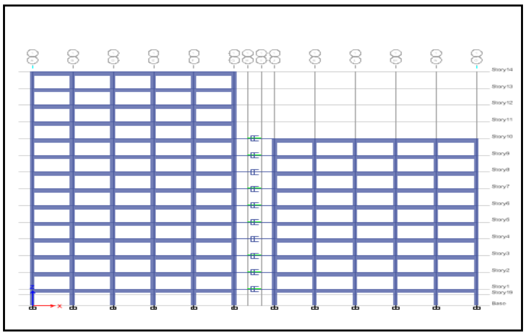


Figure no 2.3-Model 1- Coupled building with damper

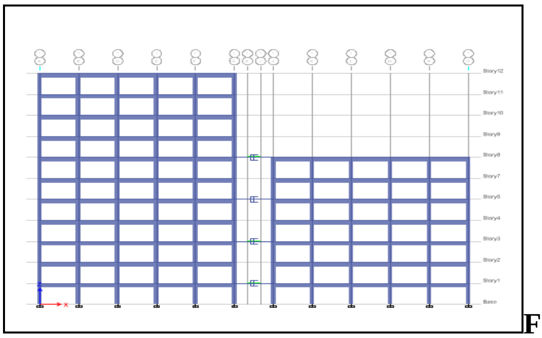


Figure no 2.4-Model 2- Coupled building with alternate damper

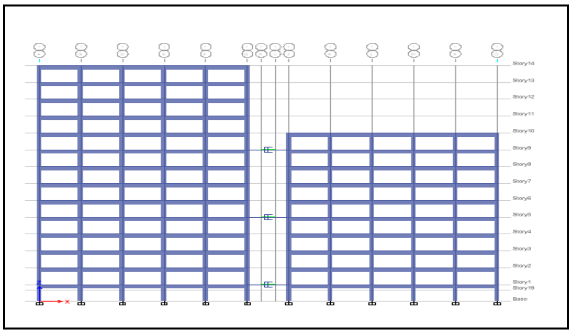


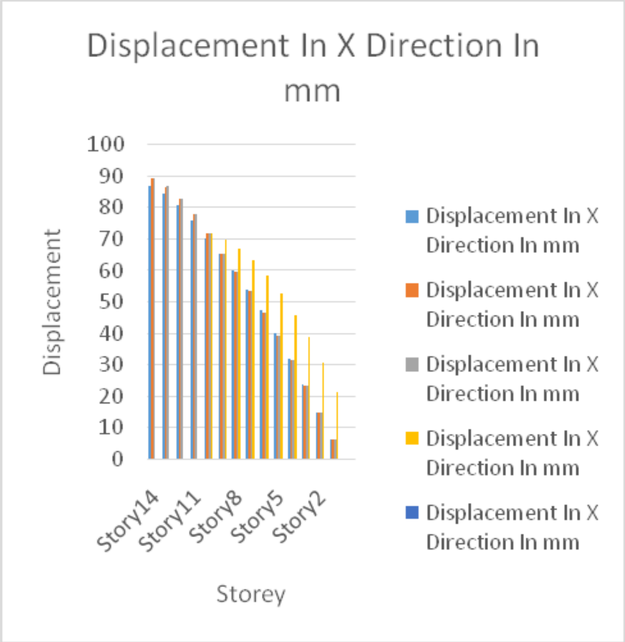
Figure no 2.5-Model 3- Coupled building with double alternate damper

3.RESULTS AND DISCUSSION

Comparison Result of Coupled Building with 10 Storey Building

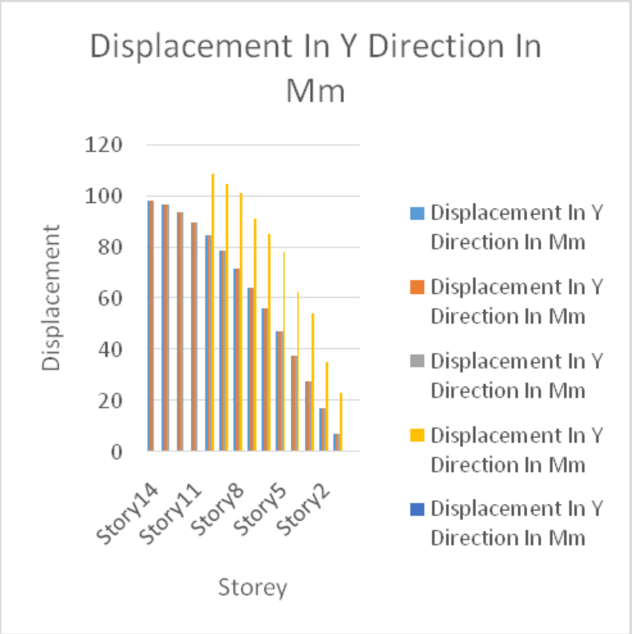
Table no 4.1- Displacement in X Direction

Displacement In X Direction In mm					
Storey	Adjacent Coupled	Alternate Damper	Double Alternate Dampers	Individual Building	Storey
Story14	87.038	89.358	89.37		
Story13	84.487	86.724	86.738		
Story12	80.707	82.837	82.852		
Story11	75.796	77.762	77.777		
Story10	70.276	71.712	71.728	71.719	Story10
Story9	65.239	65.241	65.272	69.94	Story9
Story8	59.912	59.454	59.554	67.085	Story8
Story7	53.903	53.322	53.471	63.161	Story7
Story6	47.189	46.628	46.721	58.26	Story6
Story5	39.837	39.348	39.371	52.476	Story5
Story4	31.93	31.532	31.525	45.905	Story4
Story3	23.569	23.275	23.255	38.637	Story3
Story2	14.893	14.705	14.691	30.717	Story2
Story1	6.233	6.154	6.15	21.187	Story1
Base	0	0	0	0	Base



Graph no 4.1- Displacement in X Direction

Above graph shows deformation in EQX direction for adjacent coupled, alternate damper, Double alternate dampers, individual building. as we can see that individual building has the higher deformation than the other. individual building has higher deformation than adjacent coupled by 19.75 %.



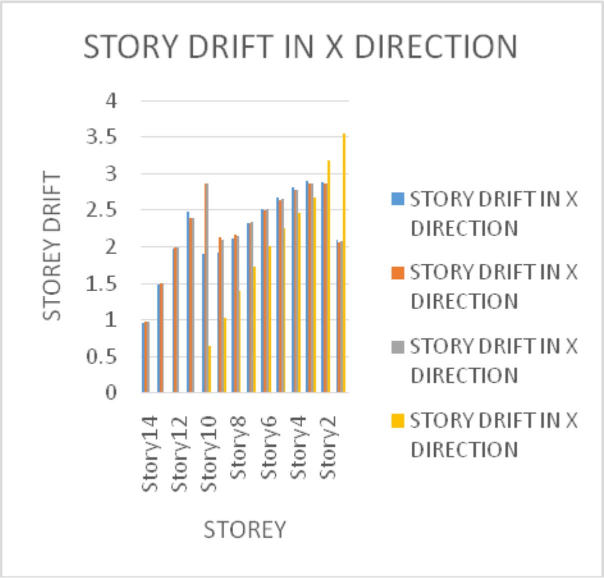
Graph no 4.2- Displacement in Y Direction

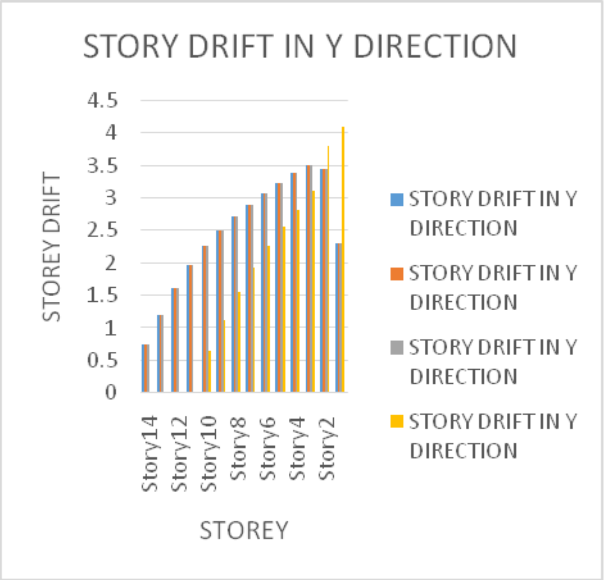
Above graph shows deformation in EQY direction for adjacent coupled, alternate damper, Double alternate dampers and individual building. As we can see that individual building has the higher deformation than the other. individual building has higher deformation than adjacent coupled building by 9.65 %

Table no 4.3- Story drift in X Direction

STORY DRIFT IN X DIRECTION					
	Adjacent Coupled	Alternate Damper	Double Alternate Dampers	Individual	
Story14	0.969	0.984	0.983		
Story13	1.492	1.506	1.505		
Story12	1.977	1.985	1.983		
Story11	2.489	2.396	2.396		
Story10	1.91	2.861	2.869	0.638	Story10
Story9	1.928	2.13	2.1	1.031	Story9
Story8	2.115	2.171	2.151	1.401	Story8
Story7	2.325	2.323	2.344	1.725	Story7
Story6	2.512	2.49	2.519	2.006	Story6
Story5	2.671	2.644	2.653	2.248	Story5
Story4	2.804	2.773	2.773	2.459	Story4
Story3	2.897	2.865	2.862	2.665	Story3

Story2	2.888	2.856	2.86	3.18	Story2
Story1	2.094	2.069	2.07	3.5445	Story1





Graph no 4.3- Story drift in X Direction

Above graph shows Story drift in EQX direction for adjacent coupled, alternate damper, Double alternate dampers, individual building. as we can see that individual building has the higher Story drift than the other. individual building has higher story drift than adjacent Damper by 70.60 %

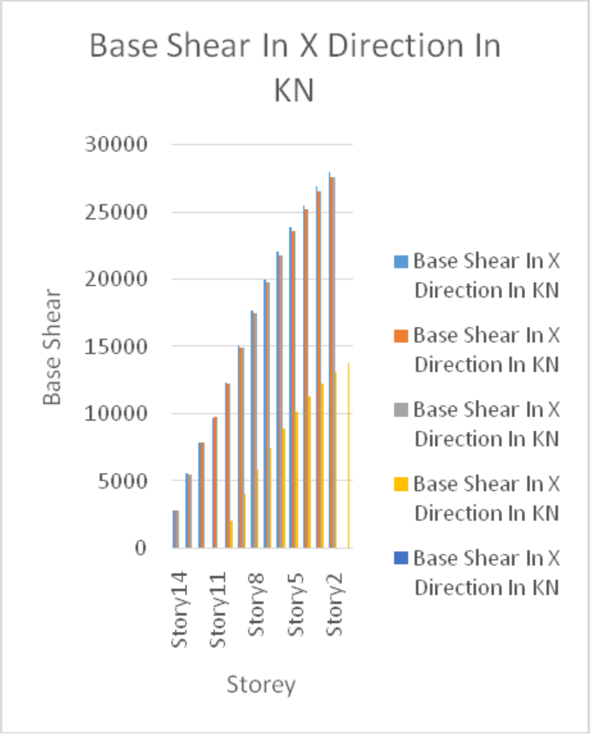
Graph no 4.4- Story drift in Y Direction

Above graph shows Story drift in EQY direction for adjacent coupled, alternate damper, Double alternate dampers, individual building. as we can see that individual building has the higher Story drift than the other. individual building has higher story drift than Adjacent Coupled by 69.48 %

Table no 4.5- Base Shear in X Direction

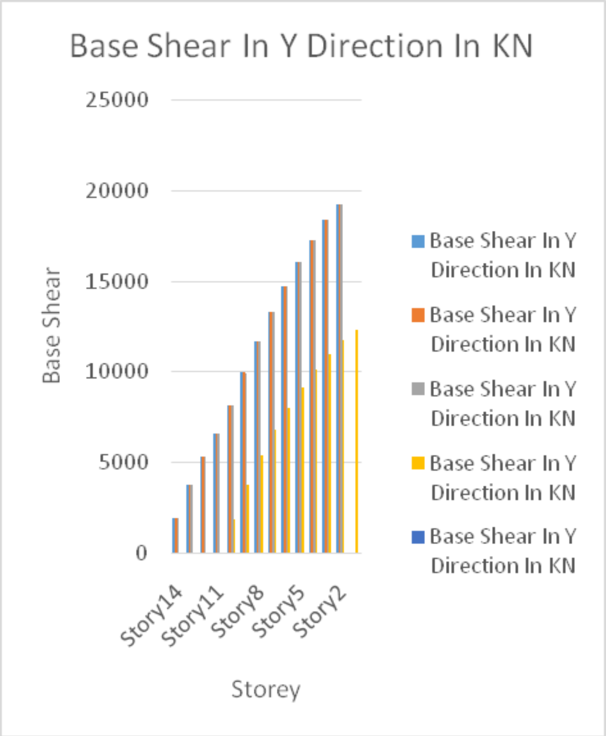
Base Shear In X Direction In KN					
Storey	Adjacent Coupled	Alternate Damper	Double Alternate Dampers	Individual Building	Storey
Story14	2868.38	2817.83	2814.62		
Story13	5608.45	5550.2	5545.09		
Story12	7900.75	7899.37	7894.45		
Story11	9700.88	9805.64	9802.69		
Story10	12390.1	12304.4	12302.1	2087.85	Story10
Story9	15112.1	14962.2	14960.4	4122.19	Story9
Story8	17688.5	17516.8	17514.8	5929.69	Story8
Story7	20011.6	19813.3	19810.9	7522.8	Story7

Story6	22063	21824.5	21821.8	8927.02	Story6
Story5	23893.9	23612.6	23610	10172.7	Story5
Story4	25542.6	25227.8	25225.1	11288.1	Story4
Story3	26952.7	26618	26614.9	12281.9	Story3
Story2	27970	27626	27622.5	13144	Story2



Graph no 4.5- Base Shear in X Direction

Above graph shows Base Shear in EQX direction for adjacent coupled, alternate damper, double alternate dampers, individual building. as we can see that individual building has the less Base Shear than the other. individual building has less base shear than Adjacent Coupled by 1.76 %



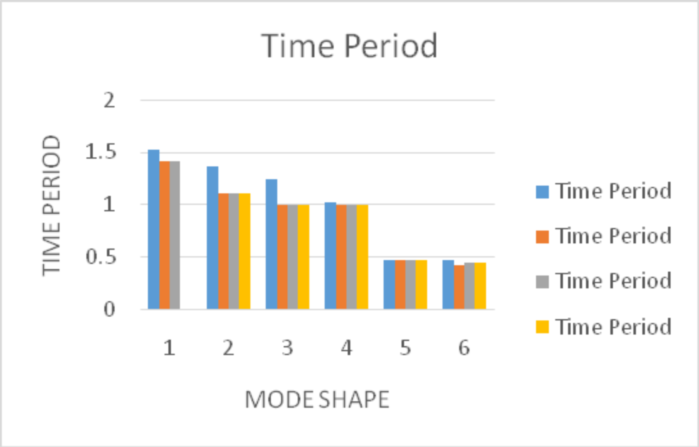
Graph no 4.6- Base Shear in Y Direction

Above graph shows Base Shear in EQY direction for adjacent coupled, alternate damper, double alternate dampers, individual building. as we can see that individual building has the less Base Shear than the other. Coupled building has less base shear than individual building by 0.48 %.

Table no 4.7- Time Period

Time Period				
Mode Shape	Individual Building	Adjacent Coupled	Alternate Damper	Double Alternate Dampers
1	1.5184	1.407	1.407	1.407
2	1.3624	1.099	1.106	1.106
3	1.2428	0.994	0.995	0.995

4	1.01888	0.989	0.994	0.994
5	0.47155	0.463	0.463	0.463
6	0.46974	0.417	0.441	0.442



Graph no 4.7 - Time Period

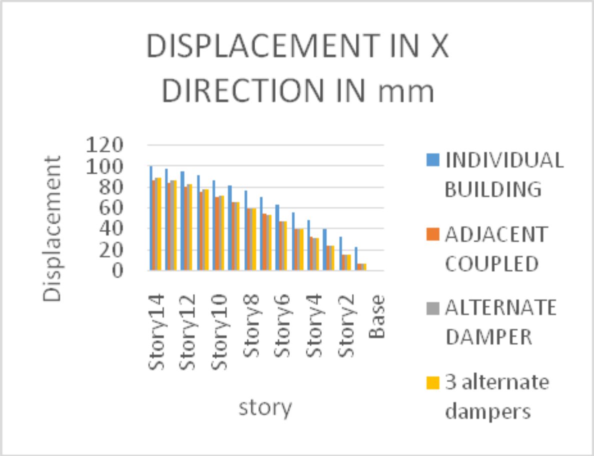
Above graph shows time period in direction for adjacent coupled, alternate damper, double alternate dampers, individual building. as we can see that individual building has the higher time period than the other. individual building has higher time period than Adjacent Coupled by 7.03 %

Comparison Result of Coupled Building with 14 Storey Building

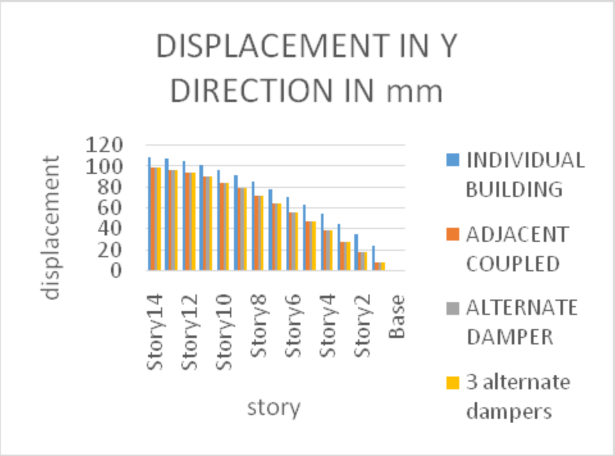
Table no 4.8- Displacement in X Direction

Displacement In X Direction In mm				
Storey	Individual Building	Adjacent Coupled	Alternate Damper	Double Alternate Dampers
Story14	99.733	87.038	89.358	89.37
Story13	97.762	84.487	86.724	86.738
Story12	94.967	80.707	82.837	82.852
Story11	91.341	75.796	77.762	77.777
Story10	86.956	70.276	71.712	71.728
Story9	81.884	65.239	65.241	65.272
Story8	76.191	59.912	59.454	59.554
Story7	69.932	53.903	53.322	53.471
Story6	63.158	47.189	46.628	46.721
Story5	55.909	39.837	39.348	39.371
Story4	48.225	31.93	31.532	31.525
Story3	40.142	23.569	23.275	23.255

Story2	31.653	14.893	14.705	14.691
Story1	21.724	6.233	6.154	6.15
Base	0	0	0	0



Graph no 4.8- Displacement in X Direction



Graph no 4.9- Displacement in Y Direction

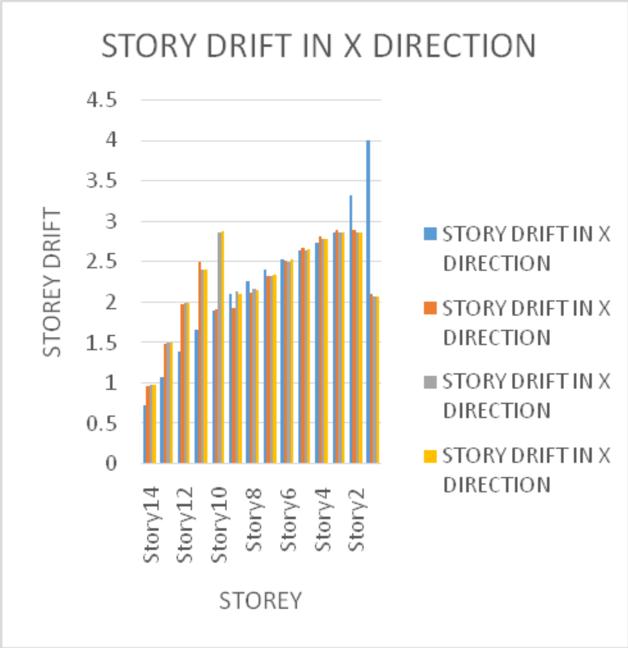
Above graph shows deformation in EQX direction for adjacent coupled, alternate damper, double alternate dampers, individual building. as we can see that individual building has the higher deformation than the other. individual building has higher deformation than adjacent coupled by 10.39 %

Above graph shows deformation in EQY direction for adjacent coupled, alternate damper, double alternate dampers and individual building. As we can see that individual building has the higher deformation than the other. individual building has higher deformation than adjacent coupled building by 9.65 %

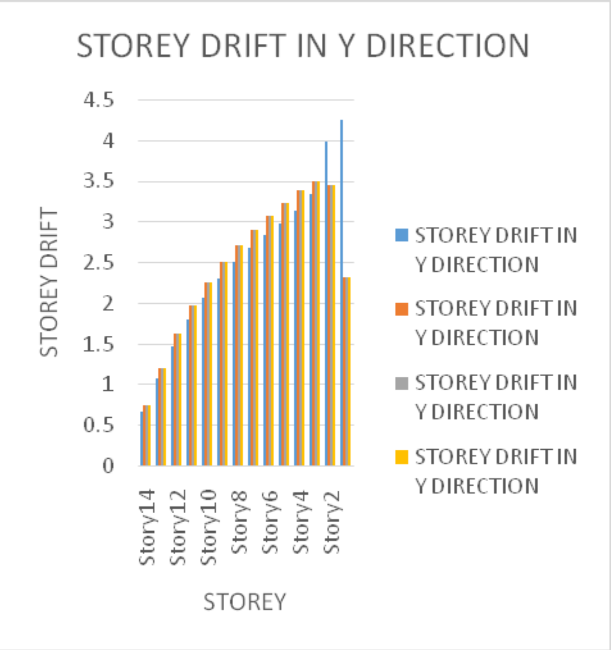
Table no 4.10- Story drift in X Direction

STORY DRIFT IN X DIRECTION				
	INDIVIDUAL BUILDING	ADJACENT COUPLED	ALTERNATE DAMPER	Double alternate dampers
Story14	0.729	0.969	0.984	0.983
Story13	1.068	1.492	1.506	1.505
Story12	1.388	1.977	1.985	1.983
Story11	1.664	2.489	2.396	2.396
Story10	1.898	1.91	2.861	2.869
Story9	2.094	1.928	2.13	2.1
Story8	2.258	2.115	2.171	2.151
Story7	2.399	2.325	2.323	2.344
Story6	2.522	2.512	2.49	2.519

Story5	2.633	2.671	2.644	2.653
Story4	2.736	2.804	2.773	2.773
Story3	2.856	2.897	2.865	2.862
Story2	3.313	2.888	2.856	2.86
Story1	3.9974	2.094	2.069	2.07



Graph no 4.10- Story drift in X Direction



Graph no 4.11- Story drift in Y Direction

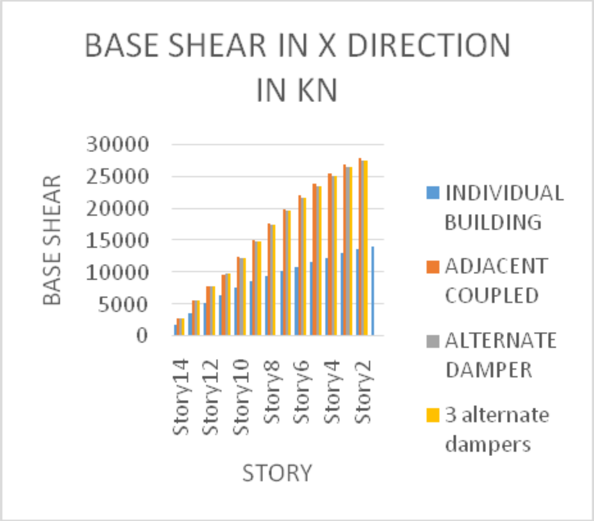
Above graph shows Story drift in EQX direction for adjacent coupled, alternate damper, double alternate dampers, individual building. as we can see that individual building has the higher Story drift than the other. individual building has higher storey drift than Alternate Damper by 71.21 %

Above graph shows Story drift in EQY direction for adjacent coupled, alternate damper, double alternate dampers, individual building. as we can see that individual building has the higher Story drift than the other. individual building has higher storey drift than Adjacent Coupled by 70.42 %

Table no 4.12- Base Shear in X Direction

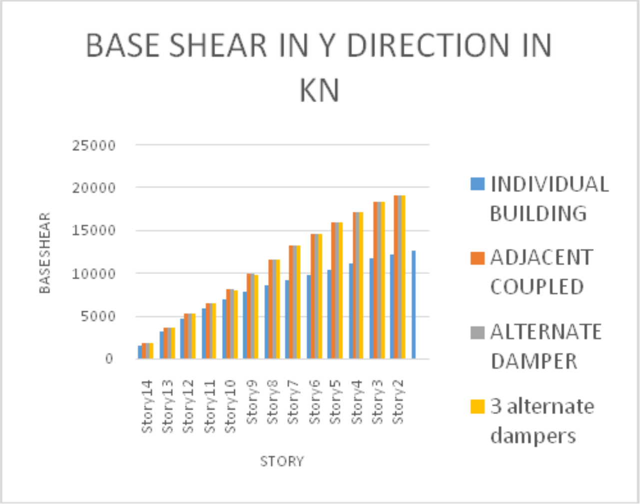
Base Shear In X Direction In KN				
Storey	Individual Building	Adjacent Coupled	Alternate Damper	Double Alternate Dampers
Story14	1823.182	2868.384	2817.834	2814.617
Story13	3597.46	5608.449	5550.195	5545.094
Story12	5154.702	7900.745	7899.368	7894.452
Story11	6489.302	9700.879	9805.637	9802.685

Story10	7629.816	12390.07	12304.36	12302.13
Story9	8611.064	15112.08	14962.16	14960.38
Story8	9467.883	17688.51	17516.8	17514.81
Story7	10239.81	20011.57	19813.29	19810.86
Story6	10964.47	22062.95	21824.51	21821.84
Story5	11664.27	23893.91	23612.63	23609.95
Story4	12345.3	25542.63	25227.84	25225.12
Story3	13003.11	26952.74	26617.95	26614.93
Story2	13613.69	27969.95	27625.96	27622.49



Graph no4.12- Base Shear in X Direction

Above graph shows Base Shear in EQX direction for adjacent coupled, alternate damper, double alternate dampers, individual building. as we can see that individual building has the lessBase Shear than the other. individual building has less base shear than Adjacent Coupled by 36.43 %



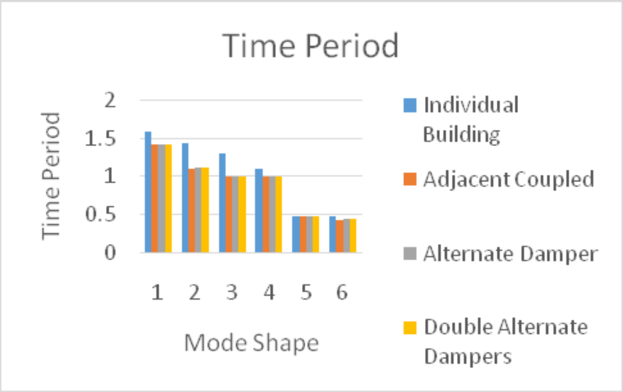
Graph no 4.13- Base Shear in Y Direction

Above graph shows Base Shear in EQX direction for adjacent coupled, alternate damper, double alternate dampers, individual building. as we can see that individual building has the lessBase Shear than the other. individual building has less base shear than Adjacent Coupled by 12.30 %.

Table no 4.14- Time Period

Time Period				
Mode Shape	Individual Building	Adjacent Coupled	Alternate Damper	Double Alternate Dampers
1	1.581	1.407	1.407	1.407
2	1.426	1.099	1.106	1.106

3	1.286	0.994	0.995	0.995
4	1.0878	0.989	0.994	0.994
5	0.47	0.463	0.463	0.463
6	0.4642	0.417	0.441	0.442



Graph no 4.14 - Time Period

Above graph shows time period in direction for adjacent coupled, alternate damper, double alternate dampers, individual building. as we can see that individual building has the higher time period than the other. individual building has higher time period than Adjacent Coupled by 11.00 %

4. CONCLUSION

In the present study G+8, G+12 coupled with horizontal friction damper at 3 different locations such as dampers at throughout storey,damper at alternate storey and damper at double alternate storey. Based on this storey following conclusions can be drawn

- The fundamental natural period of the structure (coupled building) decreases due to presence of friction damper in the buildingfrom above mentioned table comparing with G+8 and G+12 building there is considerable decrease. There is no considerable difference among 3 model so we can go for dampers atdouble alternate storey.
- Base shear increases with the increase of mass and stiffness of friction dampers in buildings and it decreases for the buildings without friction damper. There is no considerable difference of base shear among 3 models.
- Compared to the building connected with friction dampers the lateral displacement decreases for 3 model. Among 3 different model there is no considerable difference.
- The storey lateral displacement of model 1 get reduced about 19.75% in EQX direction and 9.65% in EQY direction compared with G+8 individual building.For G+12 get reduced about 10.39% and 9% in EQX and EQY direction.
- The storey drift decreases as flexibility decreases in building due to dampers connected in building.

- The friction devices limit the amount of energy that is input into the structure.
- The amplitude of displacements, natural time periods, storey drift is considerably reduced
- The result shows that the buildings with friction dampers are more vulnerable compared to buildings without friction dampers.
- When dampers provided to each floor and dampers provided at double alternate floor, there is marginal reduction in response, hence it has been stated that seismic response reduction will be marginal gain with the expense of heavy damper cost. From the benefit cost ratio, there is marginal reduction in building response.

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