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Assessment of Seismic Resistance for MSB by Introducing FVD System

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ABSTRACT

Most of the structures say buildings are actually built for gravity loads. These structures can also resist dynamic loads due to their intrinsic strength, such as earthquake and wind loads. Even when the structure is built as an under-reinforced structure, when the building is subjected to extreme dynamic loading, there is a risk of brittle failure. If the building has poor seismic strength, then the building experiences tremendous displacements that contribute to the collapse of major structural components, such as columns, beams and slabs, giving way to property and human damage that is not acceptable. Thus seismic building reinforcement in high seismic zones is much needed to prevent property and loss of human beings. To strengthen the current seismically defective structures, various retrofitting techniques are available. An innovative technique for resisting dynamic loads in buildings is available in these damping systems. In this work G+4 multistoried buildings were modeled and analyzed in

ETABS under seismic coefficient method for seismic zone-5 along with limit state of collapse and limit state of serviceability load combinations. The reaction of the structure was investigated by adding viscous dampers to the structure by altering the positioning of the building dampers (P-1, P-2, and P-3), which are regular and irregular in plan, and by altering the width of the bay, dampers are inserted at four edges of the building in the first phase, dampers are inserted at the middle of the building in the second phase (P-2), and dampers are inserted at the four corners of the building in the third phase (P-3). In terms of reduced displacement, storey drift and increased base shear, the viscous damper introduced at the edges of the building showed better results. Compared to the above-mentioned cases, which are major parameters in the event of an earthquake, the entire structure displaced in an identical way with small values of displacements and inter-story drifts. Reasonable positioning of lateral load resistant device (FVD) plays a major role in uniformly resisting seismic forces in the structure without triggering any twisting moments of a structure.

KEY WORDS: Inter-Story Drift, Base Shear, Seismic Coefficient Method, Fluid Viscous Damper, Displacements.

1. INTRODUCTION

What occurs when two blocks of the earth unexpectedly slide past each other is an earthquake.

The surface they slip to is called the plane of fault or fault. The location below the earth's surface where the earthquake begins is called the hypocenter, and the location immediately above it on the surface of the earth is called the epicenter. Earthquakes also have foreshocks. These are smaller earthquakes which occur in the same place as the corresponding bigger earthquake. Scientists cannot assume an earthquake is a foreshock until the greater earthquake occurs. The main earthquake, the strongest, is called the main shock. Main shocks often have follow-up aftershocks.

There are smaller earthquakes that occur in the same location as the main shock afterward. Aftershocks will continue for weeks, months, and even years after the main shock depending on the size of the main shock. There are four primary layers on the earth: the inner core, the outer core, the mantle and the crust. On the surface of our earth the crust and the top of the mantle made up with a thin skin.But the skin isn't all in one layer – it's made up of several parts which covers the earth's surface. Not only that, but these layers keep going around slowly, slipping past each other and hitting to each other.

Many faults are made up of the plate boundaries, and most of the world's earthquakes occur on these faults. Since the plates' edges are rough, they get trapped while the rest of the surface keeps going. Finally, the edges unstick on one of the faults when the plate has shifted far enough, and an earthquake occurs.While the edges of faults are locked together, and the rest of the block is moving, the energy that would usually allow the blocks to slip past one another is being stored up. When the force of the moving blocks inevitably overcomes the friction of the fault's jagged edges and it unsticks, all of the energy extracted is released.The seismic waves shake theearth as they pass through it.

Instruments called seismographs record earthquakes. The seismograph has a strongly grounded base and a heavy weight that hangs loose. The seismograph’s foundation shakes too when an earthquake causes the ground to shake, but the hanging weight does not.

There are three major forms of fault: natural, reverse (thrust), and strike-slip, all of which can cause an inter-plate earthquake. Examples of dip-slip are natural and reverse faulting, where the displacement along the fault is in the direction of dip and where movement requires a vertical part on them. Standard faults occur mostly in places where the crust, such as a divergent boundary, is being extended. In places where the crust is being shortened, such as at a convergent boundary, reverse faults arise. Strike-slip faults are steep structures where the two sides of the fault slip horizontally past each other; a specific type of strike-slip fault is the transforming boundaries. Many earthquakes are triggered by motion on faults which have both dip-slip and strike-slip components; this is known as oblique slip.

Viscous damping force is a formulation of the damping phenomenon in which the damping force source is modeled as a function of the length, shape and velocity of an object that traverses a real viscosity fluid.

Typical examples of mechanical systems with viscous damping include:

1. Fluid sequences between surfaces
2. In a cylinder the fluid flows around a piston
3. Fluid circulates into an orifice

Viscous damping also applies to devices for damping. They most frequently dampen movement by supplying a force or torque that opposes motion proportional to the velocity. Fluid flow or displacement of magnetic structures can be used to do this. Improving the damping ratio is the expected result.

1. Automatic shock absorbers
2. Viscous dampers for seismic retrofitting
3. In tall buildings, Tuned Mass Dampers

Instead, the spring or string from which it hangs absorbs all the motion. What's registered is the difference in location between the shaking seismograph part and the motionless part.

The objective of seismic strengthening of building is to make structural safety and providing comfort by minimizing stresses and displacements within in permissible limits as per code. Damping is the common method for preventing structure from huge displacements by dissipating the external seismic energy which provides resistance against dynamic loads. Large amount of energy is applied on the structure during seismic event. The structure will vibrates more if the structure having low damping and stiffness. Therefore fluid viscous dampers (FVD) can control the responses of the structure which is subjected to seismic loads and reduces the seismic excitation. FVD does not require any external energy as this comes under passive seismic control system which is activated by seismic energy itself. FVD consists of hollow cylinder along with fluid inside. The fluid inside the cylinder flows at high velocities when the piston of damper and piston head get stroked which results in the development of friction. Damper will dissipates energy and resists dynamic motion for building in the event of earth quake or high winds to with stand severe seismic energy and reduces displacements, stresses and deflections in the structure. The fluid which is in the damper is silicone oil which is stable for tremendously long periods of time, inert material, non-flammable, non-toxic material.

Because of fluid moving through orifices, FVD operates on the theory of dissipation of energy. In the damper, a stainless steel piston is in place. The head of the piston breaks the steel cylinder into two chambers. There is silicon oil (compressible hydraulic fluid) in one chamber and a smooth fluid circulation accumulator in another chamber. As shown in the figure, Taylor devices fabricated a typical fluid damper (Taylor Devices, Inc. 1956). The fluid in the damper travels from one chamber to another chamber as, depending on the seismic energy transfer, the piston moves from left to right or right to left. The fluid movement from a smaller area (orifice) to a larger area (cylinder chamber) and from a larger area (cylinder chamber) to a smaller area (orifice) contributes to energy dissipation due to head loss.

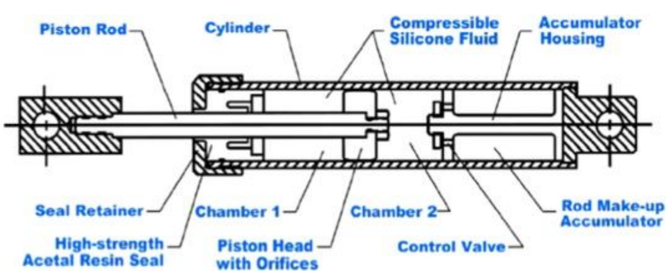

Fig 1.1 Skeleton of Fluid Viscous Damper

Various research papers which were available in the scope of this work

FarzadHejazi, NimaOstovar and Abdilahi Bashir (2019)donemodeling of shear wall at different locations have been adapted in this study. Model type one, the shear wall is located at the frame of three spans in the middle span. The shear wall is located at the corner spans of the same structure, model type two.The other goal of this research is to use commercial package ETABS to find out the optimum viscous damper position under three dimensions of earthquake excitation. Thus, in both two separate shear wall models, where the viscous damper embedded cut out of shear wall, four different position of the viscous damper was adapted.The analysis of the peak deflection and structural member forces of both models of shear wall with and without viscous damper implementation was successfully obtained and their results were contrasted accordingly. The result suggests the shear wall's best output with model type two. On the other side, when the viscous damper at the top of the shear wall frame system has achieved the maximum percentage reduction of the shear wall frame's deflection and structural component forces, and the optimal position of viscous damper under earthquake.

AnisShatnawi and Yousef(2018) This research seeks to illustrate the effects of viscoelastic damper bracings on the seismic design factors that are used to design moment frames for reinforced concrete (RC). The goal is to evaluate and provide RC ordinary moment frames (OMFs) that are braced with viscoelastic damping systems with the seismic response modification factor. Even the causes of ductility and over strength are evaluated. For identical but un-braced frames, these design considerations have also been examined. In this study the impact of number of storeys was considered by using models of four, eight, twelve, and seventeen storeys. The frame members were constructed using the technique of linear response history analysis. The study was conducted to include the variability in seismic parameters of ground motions using nine separate earthquakes.

A.K. Sinha, Sharad Singh (2017) Discussed about theeffectiveness of one of fluid viscous dampers, structural reaction control and reduction of damping demand on the structural system. In this paper a non-linear time history study was performed using 3-directional synthetic accelerogram on a 3D model of a 12 storey RCC MRF building. The results of the non-linear modal time history analysis performed with and without FVD on a 12-story RC frame structure, described using storey responses and time history plots for different parameters, show that the storey response of the structure in the form of AMSD was significantly reduced by the use of dampers. The time history plot of roof displacement over the event time scale by using dampers indicates complete reduction in the overall displacement value. The displacement values are within the required restricted range proving the efficiency of the dampers in reducing the structure's displacement response. Although the responses have been substantially reduced by the FVDs, the damping demand of the framework can be further reduced by optimal selection and installation of FVDs at different critical locations.

DevangLad, AshishSanghavi (2017) opined that developments in the field of engineering and technology, high-rise building construction is accepted everywhere. Codes imply that a structure's forces and displacements are directly proportional to its height. A lot of research is underway to minimize the response during severe wind and earthquake loading conditions. Passive control devices such as different types of dampers are very useful as they are easy to install, no need ofconsecutively costs and are easy to repair. Only when loading is applied do these devices become operational. This paper examines the reduction of the response of a G+35 RCC building located in Mumbai when seismic loading and wind loading (including raft factor) are taken into account when viscoelastic dampers are used. It studies the best kind of bracing configuration, its position and comparison of three different kinds of dampers. The analyses are carried out on ETABS 2015 and special focus is on reducing displacement and storey drift.

Luca Landi, Filippo Conti, Pier Paolo (2015) investigated the effectiveness of various vertical distributions of damping coefficients of nonlinear viscous dampers for seismic retrofitting of existing multi-storey reinforced concrete frames. Time-history studies were also carried out and nonlinear behavior was studied for both the viscous dampers and the structural members. Overall, the results have shown that the response parameter profiles, as in the case of inter-storey drifts, are very similar for structures with different damper distributions, and with no especially large variations of the maximum drifts. Special attention is required when applying the SEESPD method with regard to controlling the response parameters in the storeys without dampers. Regarding the efficiency of the different distributions, the UD has shown low efficiency in terms of consistency between the distribution of the damping coefficients and the distribution of the damper powers, while the two energy methods have shown strong efficiency in combination with the SSSA method.

1.1 OBJECTIVE

The main aim of the work is to improve the seismic resistance of the structure by inserting damping system into the building and there by determining the appropriate position of the damping system that records low displacement and storage drift values by comparing with and without damping models.

1.2 SCOPE OF THE WORK

Different bay systems (change in the plinth area of the structure), distinct buildings were modeled for both regular and irregular by adding dampers at three different locations named P-1, P-2, and P-3. The model P-1 shows that the dampers are located at the edges of the buildings (fig-1), The P-2 model shows that the dampers are located at the middle of the buildings (fig-2), while the P-3 model shows that the dampers are positioned at the four corners of the buildings (fig-3). These models are evaluated by seismic coefficient method for limit state of collapse and limit state of serviceability load combinations for seismic zone-5. The following plans will display the buildings which were modeled with and without damping device.

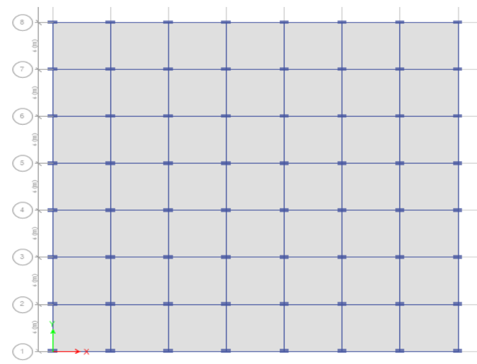

Fig 1.1 7x7 Symmetric Bay System (with out damping system)

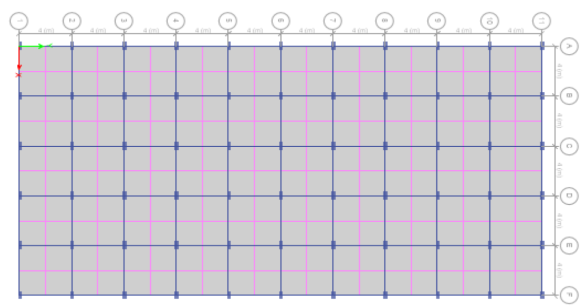

Fig 1.210x5Un-Symmetric Bay System (with out damping system)

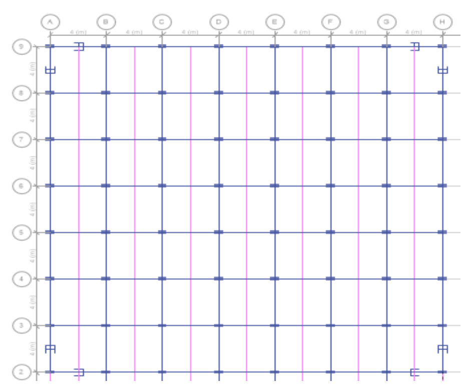

Fig 1.37x7 Bay System (P-3)

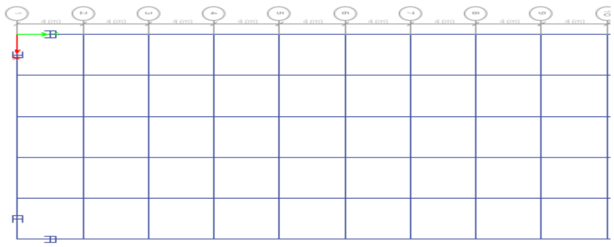

Fig1.410x5 Bay System (P-3)

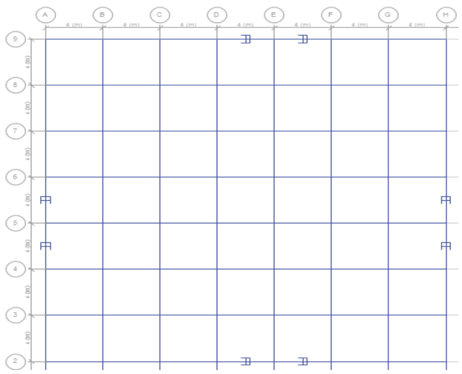

Fig 1.5 7x7 Bay System (P-1)

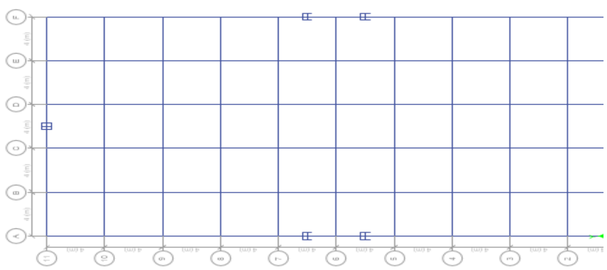

Fig 1.6 10x5 Bay System (P-1)

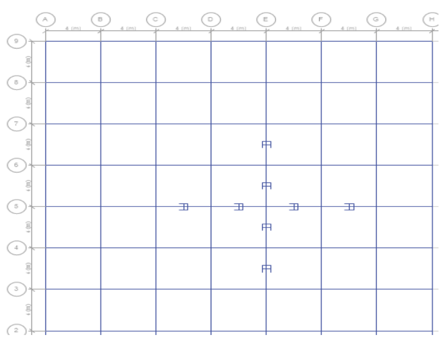

Fig 1.7 7x7 Bay System (P-2)

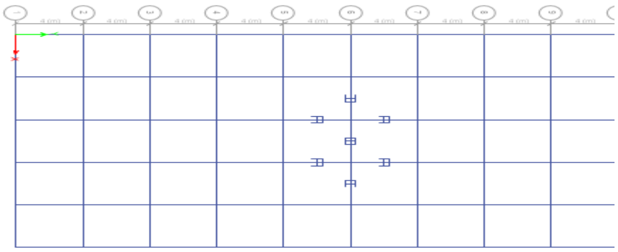

Fig 1.8 10x5 Bay System (P-2)

1.3 Scope of the work is defined in the Following Table

Table 1.1 Models with each Case under Limit State of Collapse

Limit State of Collapse (seismic zone-V)					
Phase-1		Phase -2		Phase -3	
Regular plan	Irregular plan	Regular plan	Irregular plan	Regular plan	Irregular plan
7x7	10x5	7x7	10x5	7x7	10x5

Table 1.2 Models with each Case under Limit State of serviceability

Limit State of Serviceability (seismic zone-V)					
Phase-1		Phase-2		Phase-3	
Regular Model	Irregular Model	Regular Model	Irregular Model	Regular Model	Irregular Model
7x7	10x5	7x7	10x5	7x7	10x5

2. Structure Modeling of G+10 RC Building in ETABS 2015

It is a residential-type G+4 RCC structure. The purpose of the model is to determine the effects of building responses such as storey displacements, inter-story drifts and base shear due to viscous dampers of the insertion fluid. By considering models as phases, the building was studied in several phases. The building was initially studied as a bare model, i.e. without a damping device, and dampers are then mounted in a building at three different locations. The dampers were mounted at the edges in the first phase.The model described in this case was depicted as P-1. Dampers at the edges of the building (P-2) were mounted in the second case. Dampers were mounted at the four corners of the building in case-3. For modeling of the structure along with normal and irregular bay systems, say 7x7, 10x5, both standard and irregular plans were adopted. Analysis was performed under the seismic coefficient method according to IS 1893 (Part-1):2002 for seismic zone-5 by limit state of collapse and limit state of serviceability on ETABS-2015. In the following tables, different properties of the elements and models are represented.

2.1 Material Property

Table 2.1 Material Properties of Model

Density of RCC	25 kN/ m^3
Density of steel	7850 kg/m^3
Yield strength of main reinforcement	415 N/mm^2
Yield strength of secondary reinforcement	415 N/mm^2
Compressive strength of concrete	30 N/mm^2
Grade of concrete	M30
Steel grade	Fe 415

2.2 Section Property

Table 2.2 Section Properties of Structural Elements

Beam size	230x450
Column size	300x600
Slab thickness	125mm

2.3 Description of Model

Table 2.3 Detailed Models Description

Number of stories	G+4
Story height	3m
Building height	18
Bay width in x-direction	4m
Bay width in y-direction	4m
Regular bay system	7x7
Irregular bay system	10x5
Type of building	SMRF and OMRF (residential)
Fluid viscous damper	FVD 250
Placement of dampers	Phase-1 (edges) Phase-2 (center) Phase-3 (corners)

2.4 Loading on Structure

Table 2.4 Load Intensity on Structure

Live load	3kN/m^2
Self-weight of slab	5.75 kN/m^2
Load on external wall (9")	12.42 kN/m
Load on internal wall (4.5")	6.21 kN/m
Live load on terrace	1.5 kN/m^2
Parapet wall load	3kN/m

2.5 Load Combinations

The Loads are calculated according to IS 875 (part 1, and part 2 for dead and live loads respectively. Loads are calculated in two ways

1. Limit state of collapse
2. Limit state of serviceability

Limit state of collapse	Limit state of serviceability
1.5(DL+LL)	1.0(DL+LL)
1.2(DL+LL+EQX)	1.0 DL+1.0 EQX
1.2(DL+LL-EQX)	1.0 DL-1.0 EQX
1.2(DL+LL+EQZ)	1.0DL+1.0EQZ
1.2(DL+LL-EQZ)	1.0DL-1.0EQZ
1.5(DL+EQX)	1.0DL+0.8LL+0.8EQX
1.5(DL-EQX)	1.0DL+0.8LL-0.8EQX
1.5(DL+EQZ)	1.0DL+0.8LL+0.8EQZ
1.5(DL-EQZ)	1.0DL+0.8LL-0.8EQZ
0.9DL+1.5EQX	
0.9DL-1.5EQX	
0.9DL+1.5EQZ	
0.9DL-1.5EQZ	

3. RESULTS AND DISCUSSIONS

Limit State of Serviceability

3.1 Maximum StoryDisplacement for Symmetric Frame (7x7) Located in Zone-5 with and without Damping System (UX)

Table 3.1 Story Displacement of all Cases for Symmetric Frames in X-Direction

Frame type	**Bay system**
	7x7
Bare frame	93.53
P-1	67.46
P-2	59.76
P-3	73.59

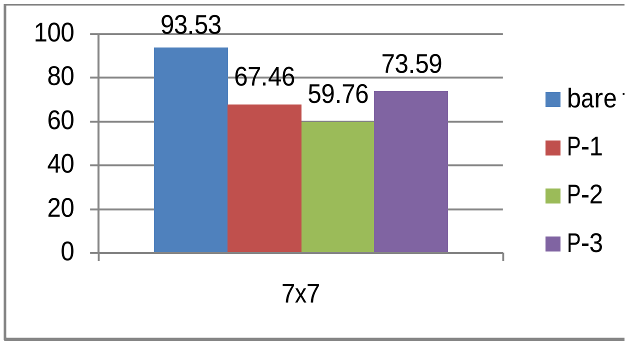

Fig 3.1 Maximum Story Displacement of all cases for Symmetric Frames in X-direction

- There is a decrease in maximum floor displacement of 27.87%, 36.10%, and 21.31% due to the insertion of the damping system at the edges (P-1), middle (P-2) and corner (P-3) for a building that has 7x7 bay systems compared to the bare frame.

3.2 Maximum Story Displacement for Symmetric Frame (7x7) Located in Zone-5 with And without Damping System (UY)

Table 3.2 Story Displacement of all Cases for Symmetric Frames in Y-Direction

Frame type	Bay system
	7x7
Bare frame	94.65
P-1	77.53
P-2	65.12
P-3	87.24

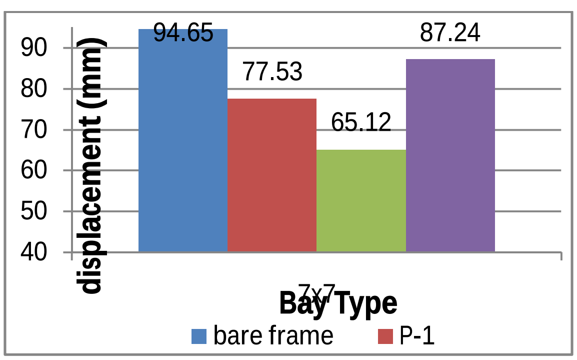

Fig3.2 Maximum Story Displacement of all Cases for Symmetric Frames in Y-direction

- There is a decrease in maximum storey displacement of 18.08 %, 31.19%, 7.82% due to the insertion of damping system at edges (P-1), center (P-2) and corner (P-3) for a building that has 7x7 bay systems as compared to bare frame.

3.3 Inter Story Drift of all cases for 7x7 Bay System Located in Zone-5

Table 3.3 Inter-Story Drifts of 7x7 Bay Systems for Each Case

Storey level	Bare Frame	P-1	P-2	P-3
Storey-13	2.35	5.45	4.72	2.01
Storey-12	3.31	5.74	4.91	3.04
Storey-11	4.72	5.84	5.03	4.07
Storey-10	5.47	6.36	5.33	5.03
Storey-9	6.46	6.59	5.51	5.85
Storey-8	7.34	6.68	5.59	6.48
Storey-7	7.83	6.62	5.57	6.95
Storey-6	8.26	6.35	5.40	7.27
Storey-5	8.32	5.81	4.89	7.48
Storey-4	8.54	4.98	4.59	7.43
Storey-3	8.32	3.81	3.87	6.98
Storey-2	7.24	2.09	2.90	6.58
Storey-1	3.72	0.00	1.63	3.27
Base	0.00	0.00	0.00	0.00

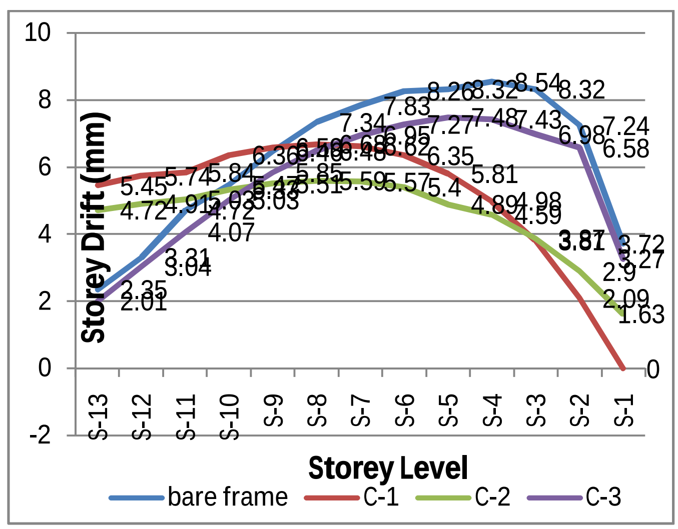

Fig 3.3 Inter-Story Drifts of 7x7 bay systems for Each Case

- Total inter-storey drift is decreased by 21.77%, 34.54%, 12.41%, due to the insertion of the damping system at the edges (P-1), middle (P-2) and corner (P-3) for a building that has 7x7 bay systems when compared to the bare frame.

3.4.0Limit state of Collapse

3.4.1 Maximum Base Shear for symmetric frame (7x7) located in zone-5 with and without damping system (kN)

Table 3.4.1 Maximum Base Shear of Each Case for Symmetric Frames

` Frame type	Bay system
	7x7
Bare frame	1388
C-1	2680
C-2	3526
C-3	2930

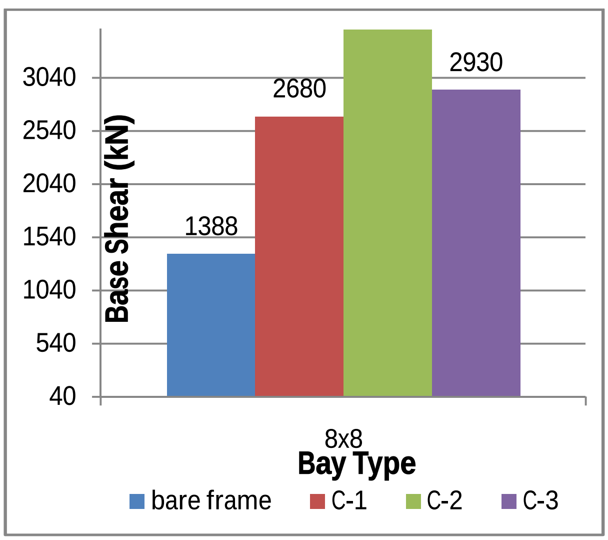

Fig 3.4.1 Base Shear of Symmetric Models for Each Case

- There is a 93.08% 154.03%, 111.09% increase in base shear, due to the insertion of the damping system at the edges (P-1), middle (P-2) and corner (P-3) for a building that has 7x7 bay systems in comparison with the bare frame.

Limit state of serviceability

3.5 Maximum Storey displacement for un-symmetric frame (10x5) located in zone-5 with and without damping system (UX)

Table 3.5.1 Maximum Story Displacement of Each Case in X-Direction

Frame type	Bay system
	10x5
Bare frame	94.68
C-1	69.72
C-2	61.41
C-3	72.76

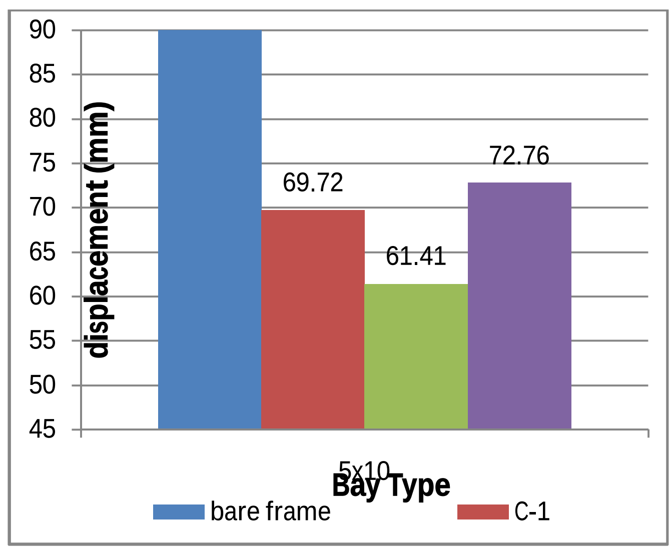

Fig 3.5.1 Maximum Story Displacement of Each Case in X-Direction

- Total storey displacement is decreased by 26.36 percent, 35.13 percent, 23.15 percent, due to the insertion of the damping system at the edges (P-1), middle (P-2) and corner (P-3) for a building that has 10x5 bay systems as opposed to the bare frame.

3.6 Maximum Storey displacement for un-symmetric frame (10x5) located in zone-5 with and without damping system (UY)

Table 3.6.1 Maximum Story Displacement of Each Case in Y-Direction

Frame type	
	10x5
Bare frame	87.73
C-1	67.82
C-2	62.84
C-3	68.08

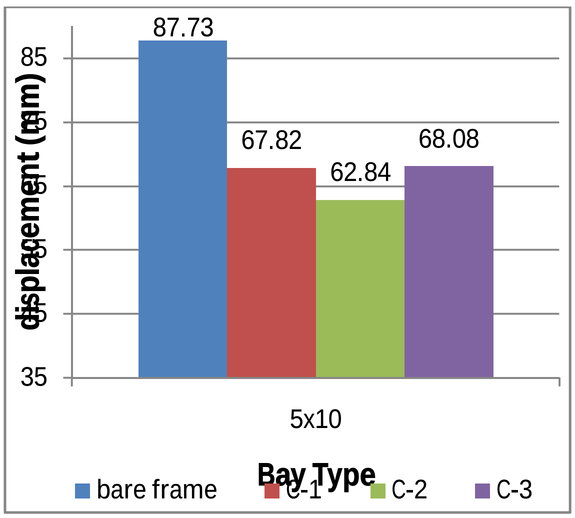

Fig 3.6.1 Maximum Story Displacement of Each Case in Y-Direction

- Total floor displacement is decreased by 22.69%, 28.37%, 22.39%, due to the insertion of the damping system at the edges (P-1), middle (P-2) and corner (P-3) for a building that has 10x5 bay systems when compared to the bare frame.

3.7 Inter Story Drift of 10x5 Bay Systems for Each Case Located in Zone-5

Table 3.7.1 Inter Story Drift of 10x5 Bay Systems for Each Case

Storey level	Bare Frame	P-1	P-2	P-3
Storey-13	2.68	5.93	4.32	9.86
Storey-12	3.93	6.05	4.68	9.85
Storey-11	5.09	6.26	5.13	6.36
Storey-10	6.32	6.65	5.69	6.79
Storey-9	7.26	6.78	6.12	6.86
Storey-8	6.46	6.82	6.45	7.23
Storey-7	7.78	6.75	6.67	7.36
Storey-6	8.94	6.41	6.74	7.12
Storey-5	9.06	5.25	6.32	6.84
Storey-4	10.45	4.86	5.84	6.23
Storey-3	8.87	3.68	4.92	5.41
Storey-2	7.64	1.86	3.46	4.32
Storey-1	3.92	0.00	1.32	1.91
Base	0.00	0.00	0.00	0.00

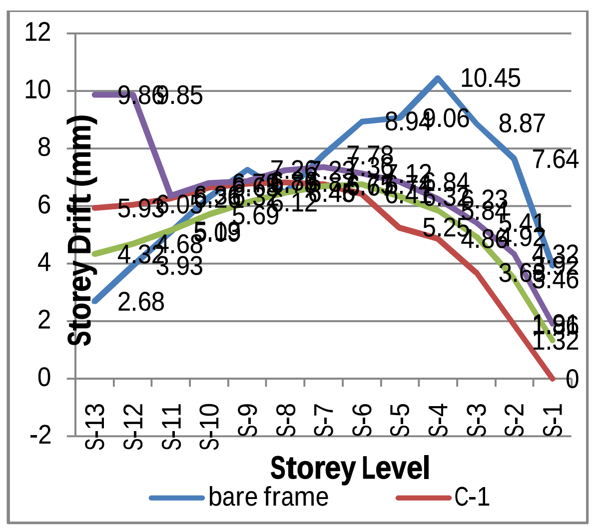

Fig 3.7.1 Inter Story Drift of 5x10 Bay Systems for Each Case

- The overall inter-storey drift is decreased by 35.11%, 36.17 %, 5.64 %, due to the insertion of the damping system at the edges

(P-1), middle (P-2) and corner (P-3) for a building that has 5x10 bay systems in comparison to the bare frame.

Limit state of Collapse

3.8Maximum Base Shear for un-symmetric frame (10x5) located in zone-5 with and without damping system (kN)

Table 3.8.1 Maximum Base Shear of each case for un-symmetric frame

Frame type	Bay system
	10x5
Bare frame	691
C-1	1732
C-2	4841
C-3	896

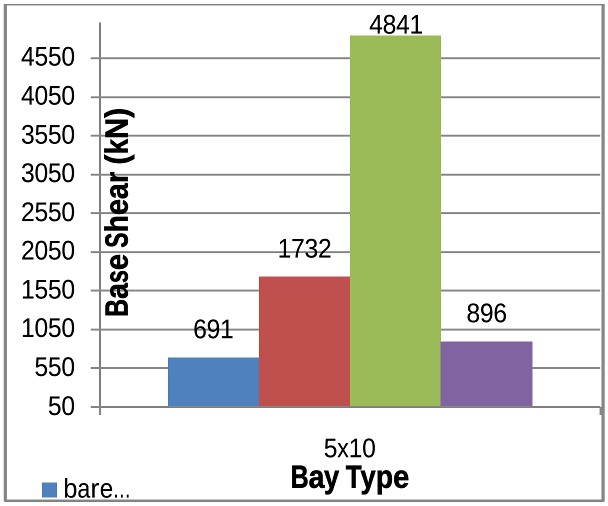

Fig 3.8.1 Maximum Base Shear of each case for un-symmetric frame

- There is a 150.65 percent improvement in base shear, 600.57 percent, 29.66 percent due to the insertion of the damping system at the edges (P-1), middle (P-2) and corner (P-3) for a building that has 10x5 bay systems when compared with the bare frame.

4. CONCLUSIONS

- There is a decrease in maximum floor displacement of 27.87%, 36.10%, and 21.31% due to the insertion of the damping system at the edges (P-1), middle (P-2) and corner (P-3) for a building that has 7x7 bay systems compared to the bare frame.
- There is a decrease in maximum storey displacement of 18.08 %, 31.19%, 7.82% due to the insertion of damping system at edges (P-1), center (P-2) and corner (P-3) for a building that has 7x7 bay systems as compared to bare frame.
- Total inter-storey drift is decreased by 21.77%, 34.54%, 12.41%, due to the insertion of the damping system at the edges (P-1), middle (P-2) and corner (P-3) for a building that has 7x7 bay systems when compared to the bare frame.
- There is a 93.08% 154.03%, 111.09% increase in base shear, due to the insertion of the damping system at the edges (P-1), middle (P-2) and corner (P-3) for a building that has 7x7 bay systems in comparison with the bare frame.
- Total storey displacement is decreased by 26.36 percent, 35.13 percent, 23.15 percent, due to the insertion of the damping system at the edges (P-1), middle (P-2) and corner (P-3) for a building that has 10x5 bay systems as opposed to the bare frame.
- Total floor displacement is decreased by 22.69%, 28.37%, 22.39%, due to the insertion of the damping system at the edges (P-1), middle (P-2) and corner (P-3) for a building that has 10x5 bay systems when compared to the bare frame.
- The overall inter-storey drift is decreased by 35.11%, 36.17 %, 5.64 %, due to the insertion of the damping system at the edges (P-1), middle (P-2) and corner (P-3) for a building that has 5x10 bay systems in comparison to the bare frame.
- There is a 150.65 percent improvement in base shear, 600.57 percent, 29.66 percent due to the insertion of the damping system at the edges (P-1), middle (P-2) and corner (P-3) for a building that has 10x5 bay systems when compared with the bare frame.

5.SUMMARY ON CONCLUSIONS

Lateral load resisting device positioning plays a major role in uniformly resisting seismic forces in the structure without triggering twisting moments. Compared to the above phases and various parametsrs, when dampers are inserted at the edges of the building (P-1), the entire structure is displaced in a uniform way with lower values of displacement and inter-story drifts, which are important parameters in the event of an earthquake.

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