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The Behavior of Flat Slab and Conventional RC Slab for Multi-Storey Buildings with Passive Energy Dissipating Devices Situated in High Seismic Zone.

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Abstract: ***The disaster safe construction practice for an engineer is a most difficult job. Today we have witnessed these natural disasters at its peak. Even after all highly skilled techniques used for constructions these natural disasters-like floods, earthquake, landslides etc.… are not negotiable. However, we are learning lessons from these disasters and upgrading ourselves so that a resistant structure is constructed.***

Among these disasters, the less predictable the less comprehended and highly disastrous is an earthquake. Even after the development of technology this disaster is highly unpredictable. Conventional attempts to make a building earthquake resistance which do not collapse under strong seismic forces has proved to be satisfactory but these techniques will cause a damage to non-structural components such as glass, window, door etc.… (OR) even some times the failure of structural components which leads to non-functionality of a building, but it should be noted that building like corporate offices, call centers, hospitals etc.… must remain functional even after the earthquake. Hence special techniques are required to design the buildings to overcome above problem. Passive energy dissipating devices is the technique used to dissipate the energy incorporated in the building due to an earthquake.

Keywords: ETABS, Flat Slab, Conventional RC Slab, Passive energy Dissipating Devices.

I. INTRODUCTION

The slabs are the chief component of any structural system used to provide horizontal (flat) surfaces in building as roof, floor or in bridge as carriage way and different function in different type of structural system. The slabs usually relaxed (supported) by walls, but advancement in structural system has let them too relaxed on beam reinforced with concrete cast monolithically so they behave as single unit. the depth of a slab is usually very small compared to its span.

A Slab is the most Protean Structural Element of any building,

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It Defines the durability of that project in the sense of leakage proof by rain water, Sun Shade, Snow fall, Other Climatic Conditions etc... Also, it defines the stability of the structure as a whole. Since the Conventional Method of casting Slab (resting the slab on beams OR load bearing walls) has proven to possess less seismic stability in all aspects due to the advances in Design Technologies of the RCC Structures.

Flat slab is the advancements in the slab system over the conventional slab system in almost all aspects of strength, durability, cost, stability, serviceability. Conventional earthquake resistant technique has proven to be less effective. Hence in order to increase the seismic performance of the slab, the energy incorporated in the system due to an earthquake is removed by various techniques know as energy dissipating techniques.

This project concern mainly on the behavior of flat slab and conventional RC slab in terms of seismic performance with passive energy dissipating techniques.

A study has done to identify the best seismic performance slab system with passive energy dissipating techniques using a Software aid ETABS 2016.

A.Flat Slab System

Flat Slabs are highly advance elements in slab systems, multi-spanned widely used in construction, providing minimum Depth, fast track construction. Flat slab are those slabs which directly lounge on the columns without the provision of any beams.

In case of higher loads, a drop panel with column head or a column head or a drop panel is provided to reduce the punching shear at the periphery of column.

Flat slabs are prime source of construction practice where buildings are constructed as cast in place because it gives supremacy in terms of architectural views.

In flat slab the thickening in the slab is done at the periphery of every Column-slab junction called “drop panels”.

Drop panels act as T-shape stand support to the slab. They enhance the punching shear capacity around the periphery of the column-slab junction and hence intensify the stiffness of the floor system under the action vertically distributed loads, which helps in expanding the span range, which leads to an economy.

The plan dimensions are selected as per IS456-2000. Fig 1 Shows the various types of Flat Slab that can be constructed. Here in this project Flat slab with Drop panel has been used.

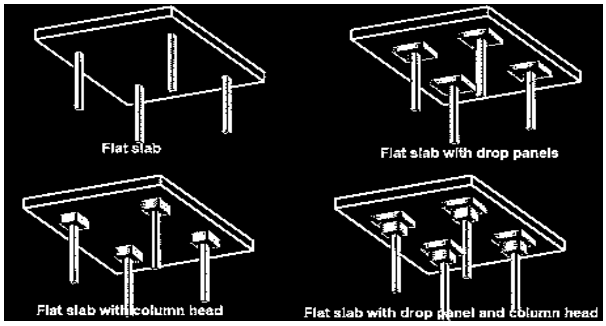

Fig 1. Types of Flat Slab.

B. Conventional RC Slab

Perhaps the most basic & a traditional R.C Structure which have been used by the man in one or the other way unknowingly is the conventional R.C slab. The Transmission of load in these structures is simple. The loads are transmitted by the slabs to the Supporting beams, then beams to the columns, then columns to the footings. Usually the beams are rest over the columns only and in the rare cases the secondary beams are provided over the span in the direction exceeding the limit as per code provision.

C. Energy Dissipating Techniques

These are the special techniques used for the dissipation of energy from the building due to an earthquake. They are broadly classified as:

i. Active Energy Dissipating Techniques

This system comprises of knowledge of structural engineering like earthquake engineering, wind engineering, structural dynamic and structural analysis, whose data is required to feed in the form of algorithm in computer control unit, sensing techniques and actuators. The technical process of this system is explained through a flow diagram in which the sensors are installed on structural components of a structural system like building, bridge, dam etc... to detect and measure both external forces and response of structural system due to external force. When earthquake is triggered i.e. during seismic excitation, the ground motion transferred to structural base, this motion is detected by sensor. Now the sensor sends the information instantaneously to computer control unit, this computer control unit processes the information using algorithm. The analysis is carried out and finally the required control forces are sent as signal to actuator. Actuator helps to minimize the effect of external excitation in structural system. Also, at the same time response of a structure system is measured by sensor which is processed by computer control unit to generate control forces. This technique is useful in multi-hazard cases when earthquake load and wind load acts simultaneously. The active system is most efficient for continuous power source, failure of power source will shut down the active energy dissipating system which is most likely to happen during a disaster. Figure 2 shows the flow diagram for the above said processes.

Figure 3 shows a pictorial representation of such system in which when a lateral force (excitation) act on the building which causes the displacement X1 (response) in order to nullify or minimize the effect of displacement, the computer-controlled pendulum (actuator) moves in opposite direction and the displacement is minimized.

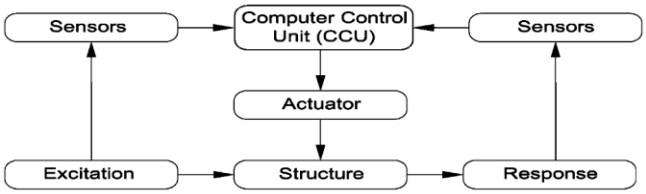

Fig 2 Flow Diagram for Active Energy Dissipating Devices.

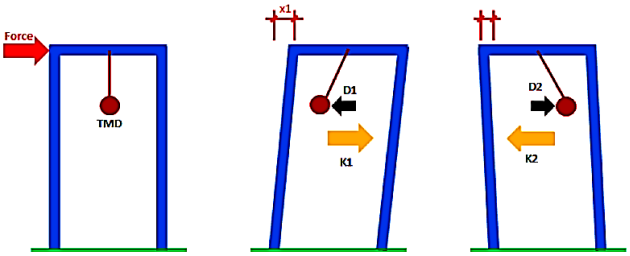

Fig 3. Pictorial Representation of Active Energy Dissipating Devices.

ii. Passive Energy Dissipating Techniques

This system is a self-activating energy dissipation system without any external power source which increases the strength, stiffness and damping of a structural system as soon as external excitation occurs. They are installed on the structural system both during new construction and rehabilitation. They are classified on the basis of their energy dissipating technique in the structural system. They have fixed capacity which does not vary due to external force as in case of active energy dissipating techniques.

The Following are some important/mainly used Passive energy Dissipating Devices:

a) **Base Isolator**
b) **Fluid Viscous Damper**
c) Metallic Yield Damper
d) Tuned Mass Damper

A brief discussion of base isolator and fluid viscous damper has been made. Since they have been used in this project

a) Base Isolator

The theory of base isolation is demonstrated through a hypothetical building resting on frictionless rollers (figure 4 a). When ground moves to and fro during an earthquake. The rollers are free to move to and fro but the motion is not transferred to the above building i.e. building does not experiences any earthquake.

Now consider a same building which rests on a flexible rubber pad which provide hindrance to the lateral motion of ground (figure 4 b). The smaller amount of lateral motion of ground is experienced to the above building. If the flexible rubber pads are properly designed for the earthquake then a much smaller earthquake is experienced as compare to fixed base building (figure 4 c).

The above said technique is known as base isolation, whereas the flexible rubber pads are called base isolators and the building in which these pads are installed at the base is called base isolated building.

The main aim of this technique is to impart flexibility which enhances the damping property of a structural system. They are recommended to use in low rise buildings or building resting on hard rock but not for high rise building or building resting on soft rock situated in earthquake prone zone.

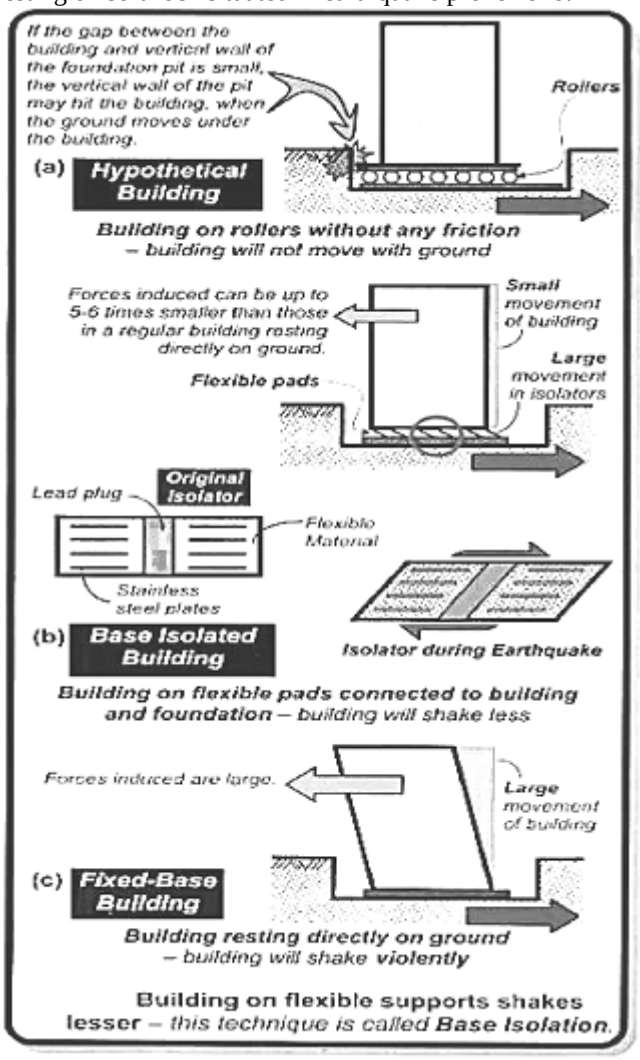

Fig 4. Concept of Base Isolator.

b) Fluid Viscous Damper

In structural dynamic, vibrations are controlled by the addition damping in a system. Fluid viscous damper is one of the best dampers among all the dampers which has shown high performance results in damping a system. They just act as a shock absorber in a vehicle system. They are capable of decreasing the lateral deflection and stresses in a structural system simultaneously. Figure 5 shows a longitudinal section of fluid viscous damper.

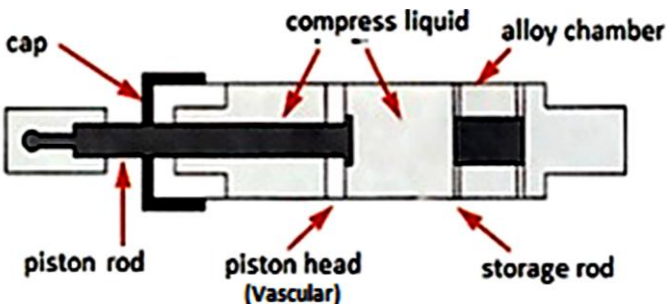

Fig 5. Longitudinal Section of Fluid Viscous Damper.

Fluid viscous damper generally comprises a piston head (vascular) inserted in a cylinder which is filled with highly incompressible viscous fluid required to give sufficient stiffness to the inward movement of the piston. When piston moves inward, the volume inside the cylinder decreases which tries to compress the fluid. As a result, the energy is absorbed by the fluid. When the fluid discharges slowly through vascular pores from a piston this energy gets released.

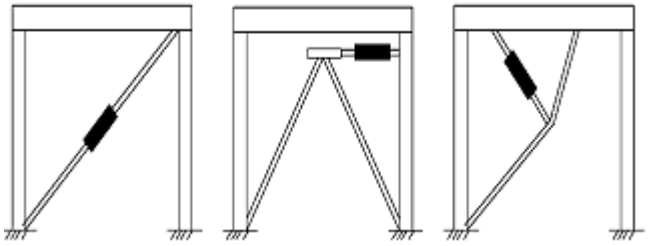

Fig 6. Method of Installation of Fluid viscous damper in a building.

Figure 6 shows, how a fluid viscous damper is attached to a bare frame. The best location of the bare frame in a building is the corner frame in a diagonal fashion. In order to have optimum utilization of these dampers they are attached in both the directions at corner. The limitations of this fluid viscous damper are, if the fluid inside the damper is compressed beyond its incompressibility limit it may lead to loss of its viscosity and hence the damper losses its stiffness.

II. OBJECTIVE OF THE PROJECT

A. To model and perform seismic analysis of the flat slab and conventional RC slab using passive energy dissipating devices as per IS1893-2016 (Part I) using software aid such as ETABS 2016.

B. To Study the behavior of flat Slab and conventional RC Slab for a typical floor plan due to the applications of passive energy dissipating devices.

C. To Study the seismic stability of flat slab and conventional RC Slab due to the application of passive energy dissipating devices.

III. METHODOLOGY

An RCC structure system is typically composed of foundations, columns, beams and slabs and this structural system behave as a structural unit and the load transfer mechanism is basically from slab to beam then, beam to column and ultimately from column to footing. In this project, different types of Typical Floor (Asymmetric) plan such as **I, T, U, L** shaped for flat and conventional RC Slab with and without dampers are taken and for the analysis purpose ETABS 2016 software will be used. These types of slabs will have same elevation. The dampers used will be Fluid Viscous damper and Base Isolators.

The Fluid Viscous Damper will be Installed at the corners of the building throughout its height. The position of the dampers in these irregular plans is calibrated with respect to the rectangular plan such that the rectangular piece in an irregular plan is considered as a whole and the dampers are installed at a single corner bay directing towards outer edge of the corner.

Fig 5 give the pictorial representation of installation and Base Isolators are installed at each column foundation junction.

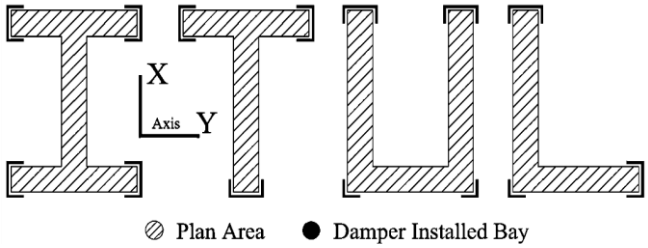

Fig. 5. Pictorial representation of damper installed corner bay.

The process of Analysis of structure is performed on ETABS 2016 in accordance with IS 456-2000 and IS **1893-2016 (part I). Figure 6 shows Flow of work in ETABS.**

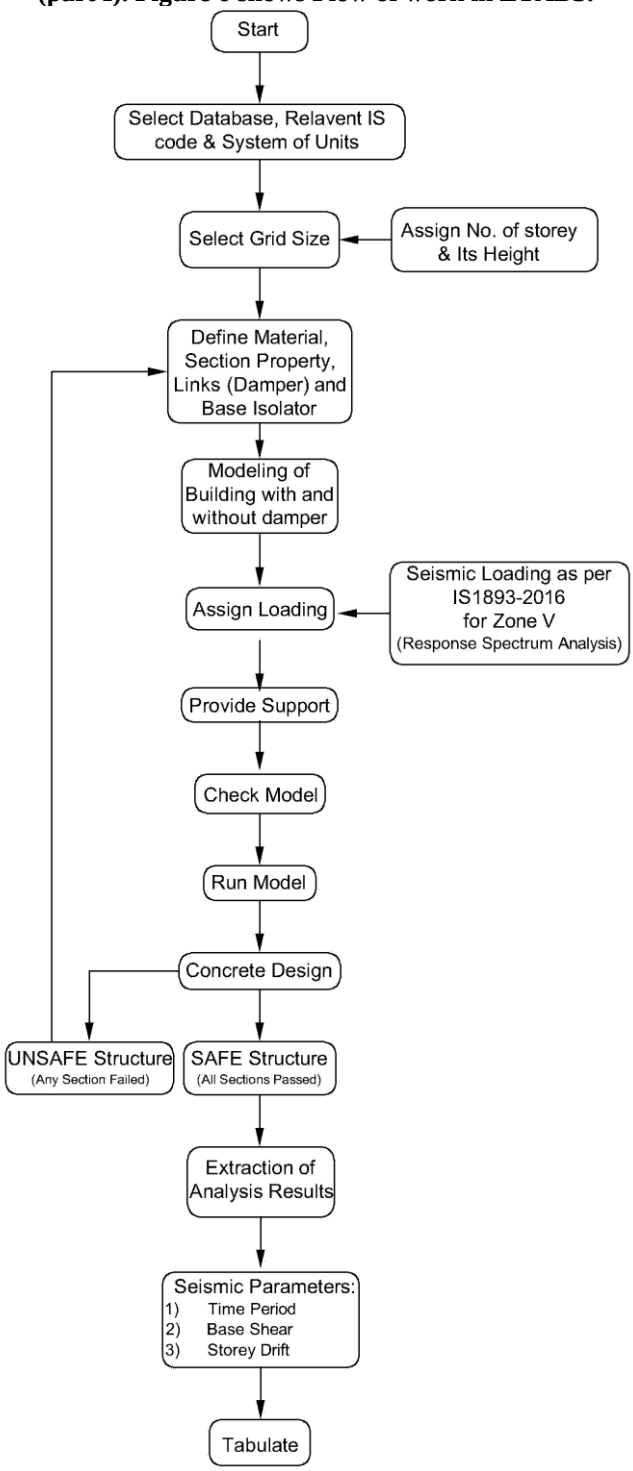

Fig. 6. Flow Diagram of Methodology

IV. MODELING AND PROBLEM FORMULATION

To model a building in ETABS 2016, we require some preliminary data to input such as codes for design, material specifications, passive energy dissipating devices specification, building specification with the dimensions of each structural component, load case, load patterns & load combination. However, the building modelling may differ from case to case.

A. Codes for Design

- **i.** IS456-2000 code of practice for plain and reinforce concrete design
- **ii.** IS1893-2016 (part I) code for earthquake loading
- **iii.** IS875-1987 (part I) code for dead load
- **iv.** IS875-1987 (part II) code for live load

B. Material Specification

Table I. Material Specification.

Sl No.	Material specification	
1	Grade of Concrete – M_{30}	f_{ck}= 30 N/mm^2
2	Grade of Steel – Fe-500	f_y= 500 N/mm^2
3	Density of Concrete	D_c = 25 KN/m^3
4	Density of Steel	D_s = 77 KN/m^3
5	Partial safety factor for Concrete	γ_m = 1.5
6	Partial safety factor for Steel	γ_m = 1.15

C. Passive Energy Dissipating Devices Specifications

The two passive energy dissipating devices will be opted namely fluid viscous damper and base Isolation with following necessary specification required for input in ETABS 2016.

i. Fluid Viscous Damper (FVD)

The Fluid viscous damper (FVD) opted for the project is a manufacture product of ITT infrastructure product. The FVD opted was a H Series with the following specification.

Table II. Fluid Viscous Damper Specification.

Sl No.	FVD specification	
1	Model No.	FVD-H-2000-150
2	Max Damping Forces	2000 KN
3	Stroke Length	75 mm
4	Stiffness	$\frac{2000}{0.075}$ = 26666.666 KN/m
5	Damping	8000 KN-Sec/m
6	Mass	385 Kg

ii. Base Isolator (HDRB)

The base isolator opted for the project was a manufactured product of DOSHIN rubber Engineering Company. The base isolators opted are high damping rubber bearing (HDRB) made up of normal compound with following specification.

Table III. High-Density Rubber Bearing Specification.

Sl No.	HDRB specification	
1	Model No.	DSH-N 450/126
2	Diameter of Rubber Bearing	650 mm
3	Maximum Horizontal Displacement	250 mm
4	Height of the Rubber Bearing	500 mm
5	Vertical Stiffness	1122000 KN/m
6	Yield Stiffness	1140 KN/m
7	Damping	11346.11 KN-Sec/m
8	Strength	5327 KN
9	Post Yield Ratio	0.1
10	Shear Modulus G	0.6 MPa
11	Mass	200 Kg

D. Building Specification

The following table 4 shows the building specifications for all the different typical plan cases such as **I, T, U, L**. It should be noted that the plan area for all the cases remains same but the working plan area OR the area for construction for the typical plan shape changes as per the plan i.e. these typical plans will be bounded within a same rectangular plan so that the comparison remains authenticated.

Table IV. Building Specifications.

Sl No.	Specification	Types of Slab System	
		Conventional Slab	Flat Slab
1	Plan Area	50m X 70m	50m X 70m
2	Spacing of Column in X-Direction	5m	5m
3	Spacing of Column in Y-Direction	5m	5m
4	Floor Height	3.65m	3.65m
5	Plinth Height	2m	2m
6	No. of Stories	G+10=11	G+10=11
7	Slab Thickness	150 mm	150 mm
8	Effective Cover for Slab	15 mm	15 mm
9	Column Size	600mm X 600mm	600mm X 600mm
10	Clear Cover for Column	40 mm (from all four sides)	40 mm (from all four sides)
11	Beam Size	300mm X 450mm	-
12	Effective Cover for Beam	30 mm (Both top and bottom)	-
13	Drop Size	-	3m X 3m
14	Drop Thickness	-	120 mm
15	Edge Distances (From all 4 sides)	-	300 mm

E. Load Patterns

In ETABS 2016 Load Patterns are the types of load considered. Here for this project, Dead Load, Live Load & Earthquake Load for Zone-V is considered.

i. Dead Loads

a) Self-weight of slab =

= (Thickness of slab) X (Density of Concrete)

= 0.15 X 25 = 3.75 KN/m^2

However, the self-weight of each structural component is calculated automatically on the basis of input data by ETABS 2016 & hence the above value is only for illustration purpose

b) Floor finish load= 1.2 KN/m^2

(To be imposed in addition to the dead load)

ii. Live Load

Live load on floor = 3 KN/m^2

The above value of live load is for commercial buildings used with appropriate live load reduction factor as per IS875-1987 (part II)

iii. Earthquake Loads

Seismic Definition: Response Spectrum Analysis (Linear Dynamic Analysis)

Earthquake Zone- V, Z = 0.36

Response Reduction Factor (R) = 5 (S.M.R.F.)

Importance Factor (I) = 1.5 (Very Important Building)

Soil Type = II (Medium Soil)

Type of Structure = I, Diaphragm Damping = 5%

Natural Time Period = Program Calculated

PSA Variation = Linear X - Linear Y

RSA Evaluation = Complete Quadratic Combination (CQC)

Scale Factor = $\frac{I}{R}g$ = 1.5 X 9801/5 = 2943

Seismic Weight on Floor=D.L + 0.25L.L

(Since live load on floor is less than 3 KN/m^2)

F. Load Cases

Load cases here in ETABS 2016 is referred as the type of analysis carried out for a particular load pattern. The Dead Load (D.L), Live Load (L.L) and the equivalent earthquake loads (earthquake load in X-direction (EQ-X) & earthquake load in Y-direction (EQ-Y)) are consider as linear static load. Whereas, the earthquake loads due response spectrum (earthquake load in X-Direction (RSA-X) and earthquake load in Y-direction (RSA-Y)) are consider as linear dynamic load.

G. Load Combinations

As per IS 456-2000, the following are the various possible load combinations for the given loading cases. Also, due to plan Irregularity the ground motion due earthquake load is considered in both the direction:

1) 1.5(D.L)
2) 1.5(D.L + L.L)
3) 1.2(D.L + L.L + EQX)
4) 1.2(D.L + L.L - EQX)
5) 1.2(D.L + L.L + EQY)
6) 1.2(D.L + L.L - EQY)
7) 1.5(D.L + EQX)
8) 1.5(D.L - EQX)
9) 1.5(D.L + EQY)
10) 1.5(D.L - EQY)
11) 0.9D.L + 1.5EQX*

12) 0.9D.L - 1.5EQX*
13) 0.9D.L + 1.5EQY*
14) 0.9D.L - 1.5EQY*
15) 1.2(D.L + L.L+RSA-X)
16) 1.2(D.L + L.L + RSA-Y)
17) 1.5(D.L + RSA-X)
18) 1.5(D.L + RSA-Y)
19) 0.9D.L +1.5RSA-X*
20) 0.9D.L + 1.5RSA-Y*

***** Combination to be consider when dead load and earthquake load are of opposite nature.

H. Plan and 3D Views of Different Cases

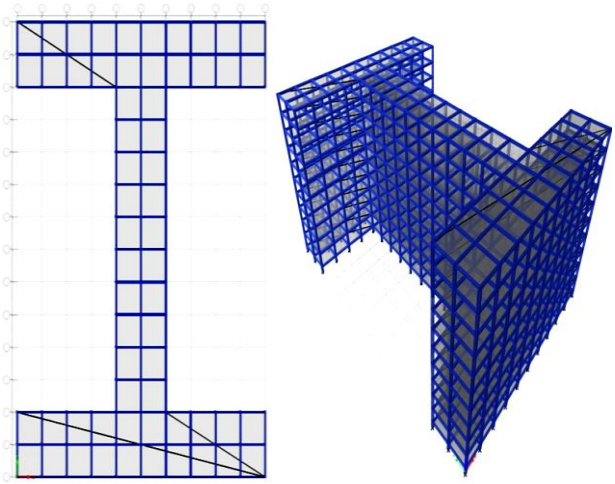

Fig. 7. I Shape Conventional RC Slab.

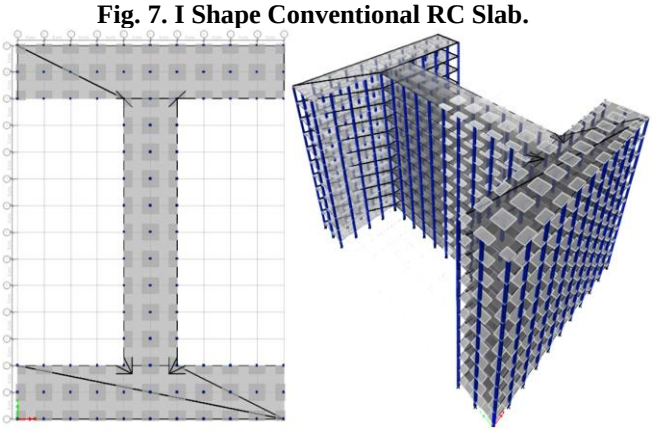

Fig. 8. I Shape Flat Slab.

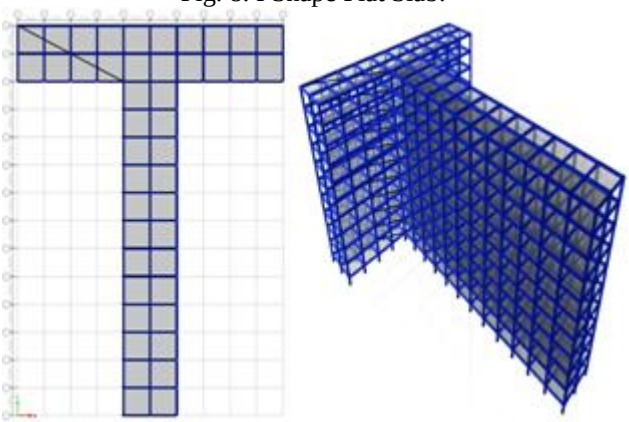

Fig. 9. T Shape Conventional RC Slab.

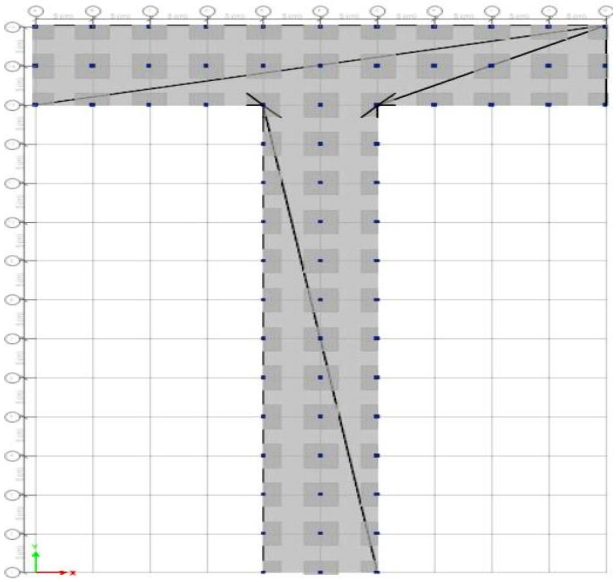

Fig. 10. T Shape Flat Slab.

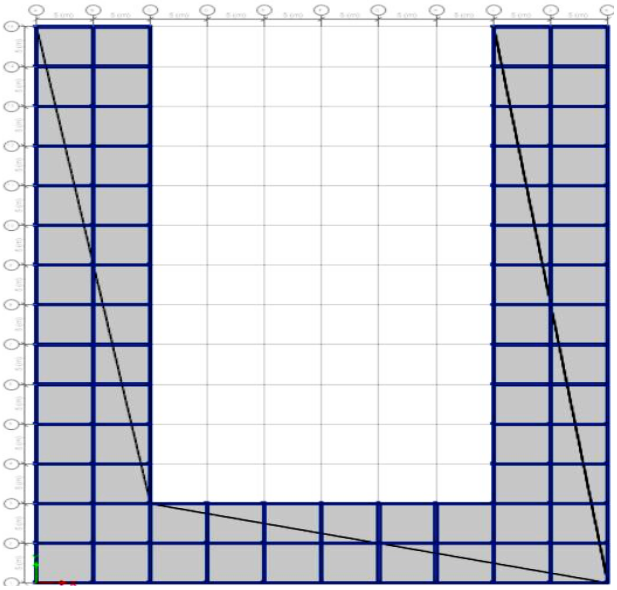

Fig. 11. U Shape Conventional RC Slab.

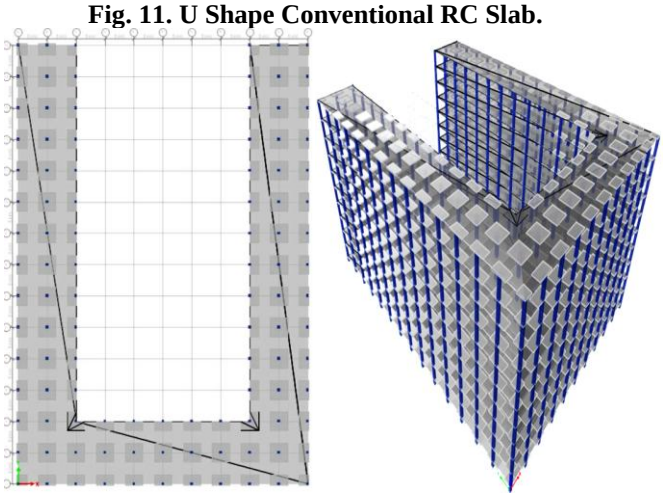

Fig. 12. U Shape Flat Slab.

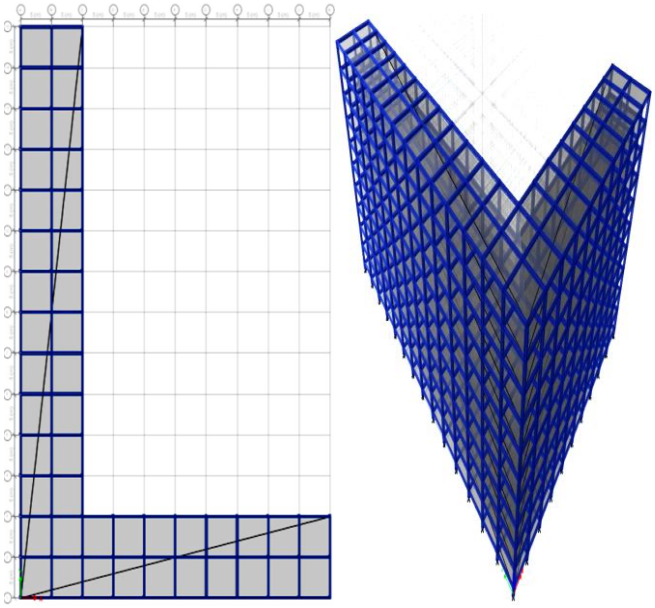

Fig. 13. L Shape Conventional RC Slab.

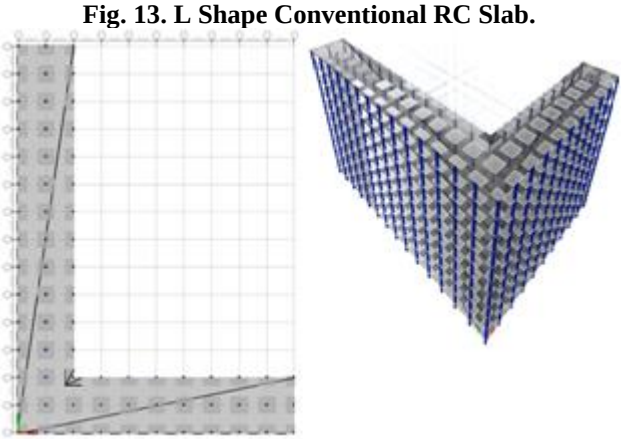

Fig. 14. L Shape Flat Slab.

V. RESULTS, OBSERVATIONS AND DISCUSSIONS

After the completion of analysis of the building the results are extracted as stated above, now these results are tabulated accordingly and the effect of various parameters are observed and discussed. This project mainly focuses on the seismic behavior of the building hence the seismic parameters are tabulated and are discussed. Then latter the column behavior is discussed with the help of column forces.

A. Generalize Coordinates in ETABS 2016

ETABS 2016 uses Finite Element Method (FEM) to analyze the various unknowns in a structural system. It is necessary to understand the generalize coordinate system, with respect to which the results are generated so that the behavior of structural system can be studied. Figure 15 shows the reference axis in ETABS 2016. The X and Y Coordinates are referred as horizontal direction of the parameter, whereas the Z Coordinates is referred as vertical direction of the parameter. These are the generalize coordinates in an ETABS 2016.

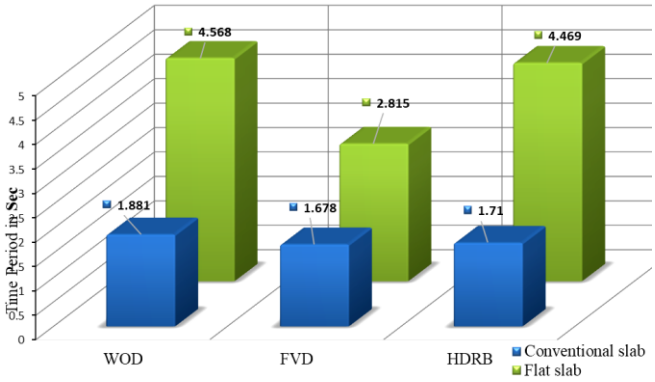

Fig. 15 Generalized Coordinates in ETABS 2016.

B. Seismic Results

The seismic results for the different type of buildings discussed are time period, base shear, storey drift. These parameters are of core importance for a building to be an earthquake resistance.

We shall discuss the variation of these seismic parameters of a structure for a particular plan shape with a different type of slab, with and without dampers.

i. Time Period

Table V. Time period (sec) of I Shape Plan.

Types of Damper Types of Slab	Without Damper (WOD)	Fluid Viscous Damper (FVD)	High Density Rubber Bearing (HDRB)
Conventional Slab	1.824	1.688	1.804
Flat Slab	4.598	2.693	4.388

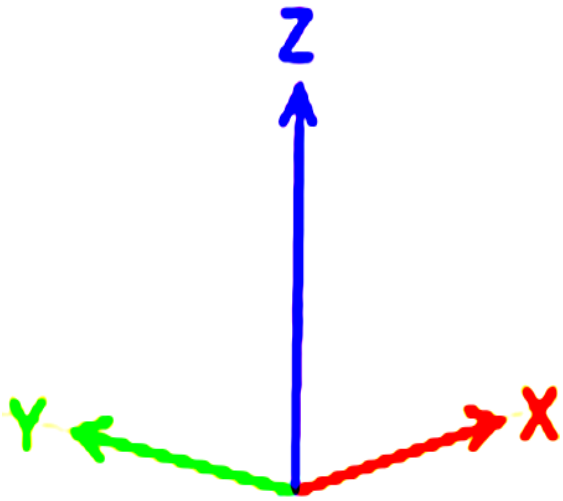

Fig. 16. Time period of I Shape Plan.

Table VI. Time Period (sec) of T Shape Plan.

Types of Damper / Types of Slab	Without Damper (WOD)	Fluid Viscous Damper (FVD)	High Density Rubber Bearing (HDRB)
Conventional Slab	1.878	1.697	1.818
Flat Slab	4.477	2.578	4.429

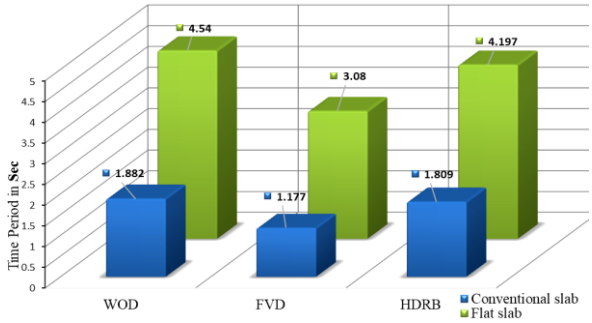

Fig. 17. Time Period of T Shape Plan.

Table VII. Time Period (sec) of U Shape Plan.

Types of Damper / Types of Slab	Without Damper (WOD)	Fluid Viscous Damper (FVD)	High Density Rubber Bearing (HDRB)
Conventional Slab	1.882	1.177	1.809
Flat Slab	4.54	3.08	4.197

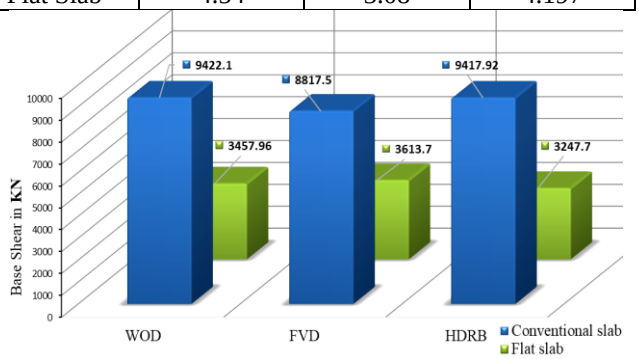

Fig. 18. Time Period of U Shape Plan.

Table VIII. Time Period (sec) of L Shape Plan.

Types of Damper / Types of Slab	Without Damper (WOD)	Fluid Viscous Damper (FVD)	High Density Rubber Bearing (HDRB)
Conventional Slab	1.881	1.678	1.710
Flat Slab	4.568	2.815	4.469

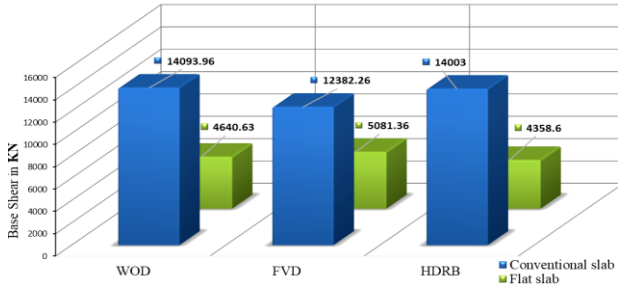

Fig. 19. Time Period of L Shape Plan.

ii. Base Shear

Table IX. Base Shear (KN) of I Shape Plan in X Direction.

Types of Damper / Types of Slab	Without Damper (WOD)	Fluid Viscous Damper (FVD)	High Density Rubber Bearing (HDRB)
Conventional Slab	14093.96	12382.26	14003
Flat Slab	4640.63	5081.36	4358.6

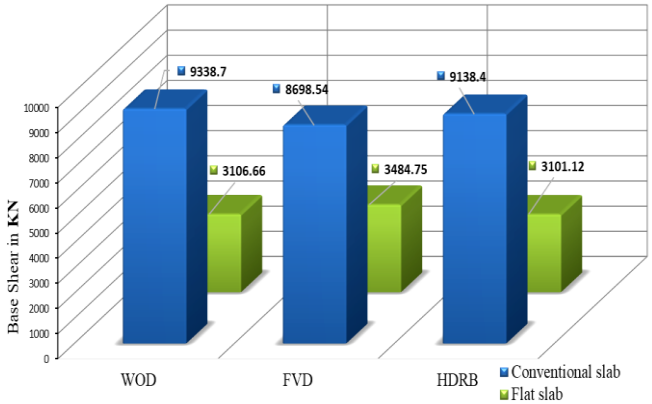

Fig. 20. Base Shear of I Shape Plan in X Direction.

Table X. Base Shear (KN) of T Shape Plan in X Direction.

Types of Damper Types of Slab	Without Damper (WOD)	Fluid Viscous Damper (FVD)	High Density Rubber Bearing (HDRB)
Conventional Slab	9338.7	8698.54	9138.4
Flat Slab	3106.66	3484.75	3101.12

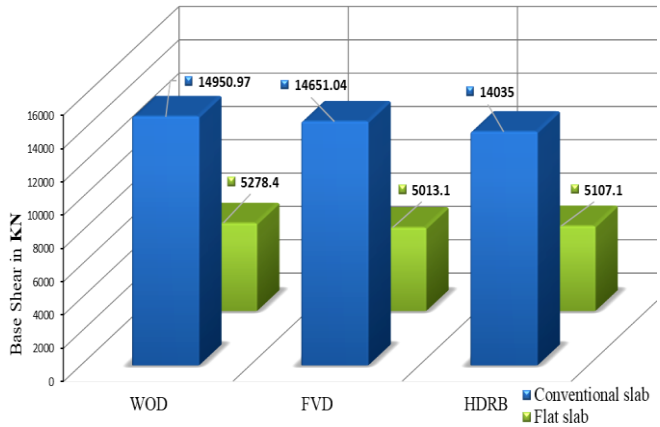

Fig. 21. Base Shear of T Shape Plan in X Direction

Table XI. Base Shear (KN) of U Shape Plan in X Direction.

Types of Damper / Types of Slab	Without Damper (WOD)	Fluid Viscous Damper (FVD)	High Density Rubber Bearing (HDRB)
Conventional Slab	14950.97	14651.04	14035
Flat Slab	5278.4	5013.1	5107.1

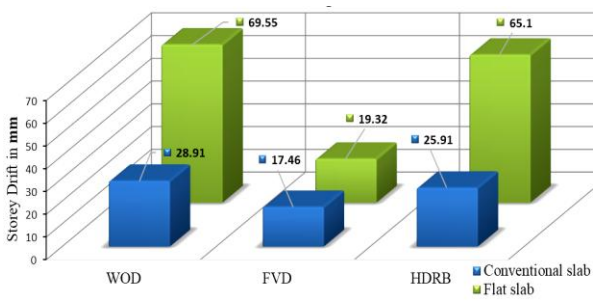

Fig. 22. Base Shear of U Shape Plan in X Direction.

Table XII. Base Shear (KN) of L Shape Plan in X Direction.

Types of Damper / Types of Slab	Without Damper (WOD)	Fluid Viscous Damper (FVD)	High Density Rubber Bearing (HDRB)
Conventional Slab	9422.1	8817.5	9417.92
Flat Slab	3457.96	3613.7	3247.7

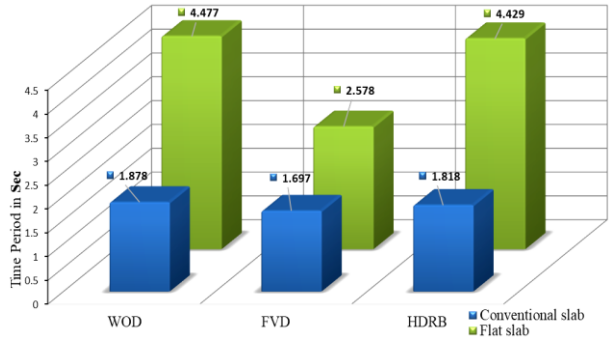

Fig. 23. Base Shear of L Shape Plan in X Direction.

Note: The Same Trend was observed for Base Shear in Y Direction.

iii. Storey Drift

Table XIII. Max Storey Drift (mm) of I Shape Plan in X Direction

Types of Damper / Types of Slab	Without Damper (WOD)	Fluid Viscous Damper (FVD)	High Density Rubber Bearing (HDRB)
Conventional Slab	21.134 (S03)	15.23 (S03)	19.31 (S03)
Flat Slab	60.308 (S05)	19.88 (S05)	58.31 (S05)

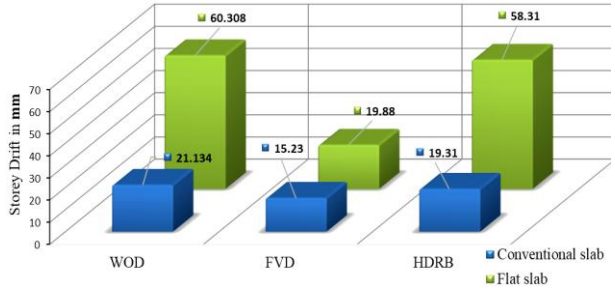

Fig. 24. Max Storey Drift of I Shape Plan in X Direction.

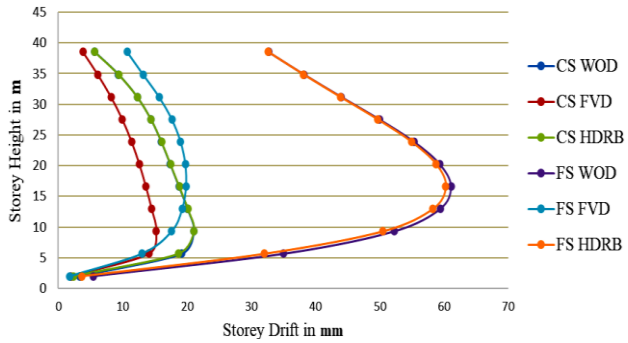

Fig. 25. Storey Drifts of I Shape Plan in X Direction.

Table XIV. Max Storey Drift (mm) of T Shape Plan in X Direction.

Types of Damper / Types of Slab	Without Damper (WOD)	Fluid Viscous Damper (FVD)	High Density Rubber Bearing (HDRB)
Conventional Slab	28.91 (S03)	17.46 (S03)	25.91 (S03)
Flat Slab	69.55 (S05)	19.32 (S05)	65.1 (S05)

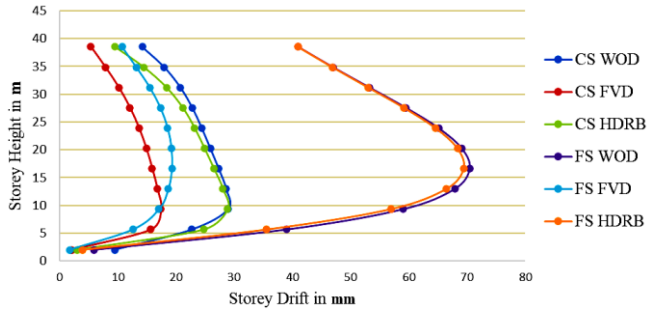

Fig. 26. Max Storey Drift of T Shape Plan in X Direction.

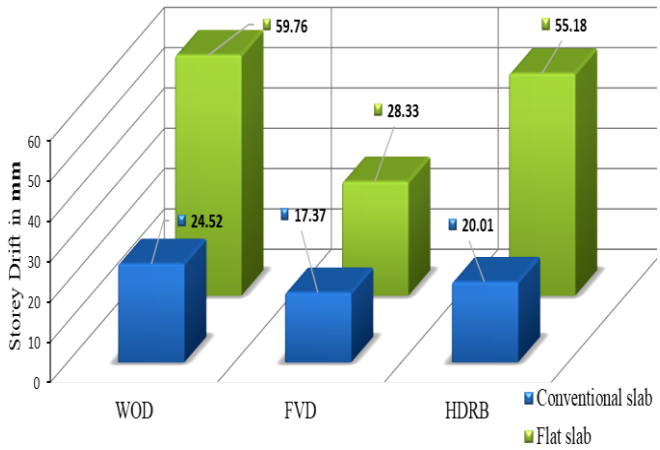

Fig. 27. Storey Drifts of T Shape Plan in X Direction.

Table XV. Max Storey Drift (mm) of U Shape Plan in X Direction.

Types of Damper / Types of Slab	Without Damper (WOD)	Fluid Viscous Damper (FVD)	High Density Rubber Bearing (HDRB)
Conventional Slab	24.52 (S03)	17.37 (S03)	20.01 (S03)
Flat Slab	59.76 (S05)	28.33 (S04)	55.18 (S05)

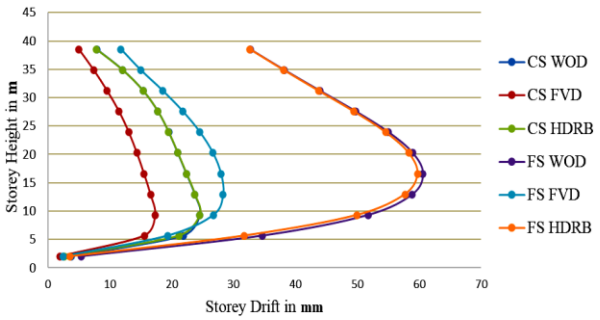

Fig. 28. Max Storey Drift of U Shape Plan in X Direction.

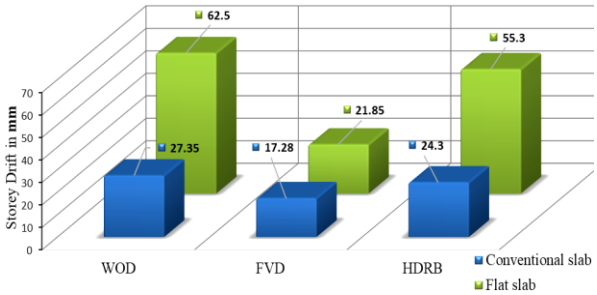

Fig. 29. Storey Drifts of U Shape Plan in X Direction.

Table XV. Max Storey Drift (mm) of L Shape Plan in X Direction.

Types of Damper / Types of Slab	Without Damper (WOD)	Fluid Viscous Damper (FVD)	High Density Rubber Bearing (HDRB)
Conventional Slab	27.35 (S03)	17.28 (S03)	24.3 (S03)
Flat Slab	62.5 (S05)	21.85 (S04)	55.3 (S05)

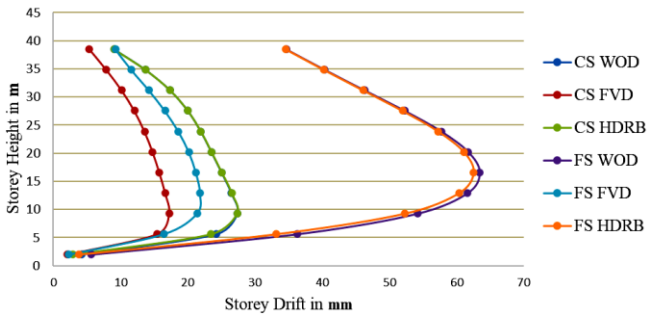

Fig. 30. Max Storey Drifts of L Shape Plan in X Direction.

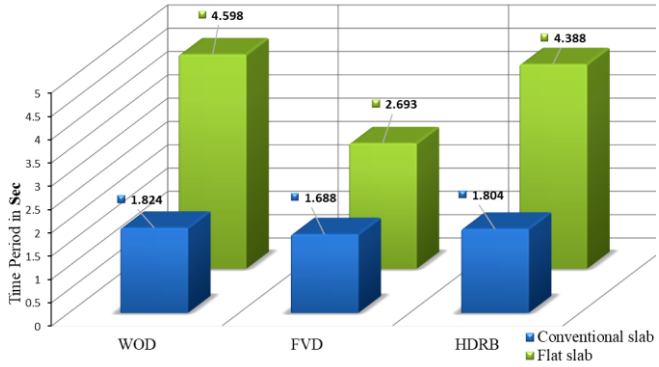

Fig. 31. Storey Drifts of L Shape Plan in X Direction

Note: The same trend was observed for storey drift in Y direction.

C. Observations and Discussions

The following are observations and discussions that came to light by evaluating the above results:

1) The time period of flat slab system for all the plan shapes (considered above) have been reduced by 40-50% due to the application of fluid viscous damper, whereas about 5-8% reduction in time period due to the application of high-density rubber bearing.
2) The time period of conventional RC slab system for all the plan shapes (considered above) have been reduced by 20-30% due to the application of fluid viscous damper, whereas about 5-8% reduction in time period due to the application of high-density rubber bearing.
3) The base shears for flat slab system for all the plan (considered above) have been increased by 6-12% due to the application of fluid viscous damper, whereas about 5-8% decrease in base shear due to the application of high-density rubber bearing.
4) The base shears for conventional RC system for all the plan (considered above) have been decreased by 10-14% due to the application of fluid viscous damper, whereas about 5-8% decrease in base shear due to the application of high-density rubber bearing.
5) The maximum storey drifts usually occurs at storey No. 5 in flat slab system with the reduction on the same for all plan shapes (considered above) by 60-70% due to the application of fluid viscous damper, whereas about 5-7% reduction in storey drifts due to the application of high-density rubber bearing.
6) The maximum storey drifts usually occurs at storey No. 3 in conventional RC slab system with the reduction on the same for all plan shapes (considered above) by 20-40% due to the application of fluid viscous damper, whereas about 5-7% reduction in storey drifts due to the application of high-density rubber bearing.
7) It was also observed that the storey drifts was lesser for U shape plan followed by I shape plan for a flat slab system without dampers.
8) It was also observed that the storey drifts was lesser for I shape plan followed by U shape plan for a conventional RC slab system without damper.

VI. CONCLUSIONS

The main conclusion of this project is the application of fluid viscous damper have shown versatile improvement in every aspects of earthquake resistant design of a building with an I shape as an ideal for conventional RC Slab and Flat slab (U shape is preferable for flat slab). Whereas the application high density rubber bearing has moderate improvement because of larger forces and moments on columns. The following are some key conclusions of this project with regards to specific terms:

1) The application of fluid viscous damper has shown a significant decrease in time period, whereas high-density rubber bearing has shown negligible decrease in time period for both flat slab and conventional RC slab system.
2) The application of fluid viscous damper has shown increase in base shear for flat slab and decrease in base shear for conventional RC slab. This is because the provision of beam has increased the lateral stiffness in conventional slab to resist the horizontal forces, whereas due to absence of beam in flat slab the lateral forces are resist by columns only which is lateral stiffness effect. There is no much improvement due to high-density rubber bearing.
3) The application of fluid viscous damper has shown a significant decrease in storey drift, whereas high-density rubber bearing has shown negligible decrease in storey drift for both flat slab and conventional RC slab.

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I am very much thankful to my beloved PARENTS especially to my mom *SYEDA ATHERUNISSA*, it is power of their blessing that gave me strength, courage and confidence to materialize my dreams in this COVID-19 pandemic and I dedicate these efforts to my beloved parents.

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