International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 06 Issue: 11 | Nov 2019 www.irjet.net p-ISSN: 2395-0072

COMPARATIVE ANALYSIS OF EFFECTS OF BASE ISOLATOR & FLUID VISCOUS DAMPER ON RESPONSE OF A RCC STRUCTURE

Gitanjali Sahu[1], Pukhraj Sahu[2]

[1]*M.Tech (Structural Engineering) Student, Department of Civil Engineering, GEC Jagdalpur 494001, C.G, India*
[2]Assistant Professor, Department of Civil Engineering, GEC Jagdalpur 494001, C.G, India

---***---

Abstract - *Paucity of space in urban habitation, along with cost effectiveness, makes presence of high rise structures inevitable. But these high rise structures are more susceptible to significant lateral loads arising from earthquake and effects of wind. The response of structure to such loads in form of displacement, story drift, overturning moment, base shear, etc is profound in high rise structures as compared to lower ones. Many techniques have been developed to reduce these responses, out of which are base isolator and fluid viscous dampers. Base isolator & Fluid viscous damper are the techniques which help to reduce the seismic response of structure as compared to fixed base building. An example is given to illustrate the design procedure. However, a systematic comparison between the base isolated building and building with fluid viscous damper shows that the vibration control effects of the base isolated building are generally better than those of the building with fluid viscous damper under earthquake loads. Comparative study is also done by keeping the values of stiffness and damping values constant for base isolation and fluid viscous damper and is tuned to the structural frequency of the structure.*

***Key Words*: Base Isolator, Fluid Viscous Damper, Time History Analysis, Story Displacement, Overturning Moment, Base Shear, Time period, Story Shear.**

1. INTRODUCTION

Nowadays Earthquake has increased due to excavation and other sources. Earthquake is the largest source of casualties and causes damages in inhabited areas. Great efforts had been made in recent years for solving the problem of building design in seismic areas; no structure can entirely remove damage from earthquakes. The main purpose of earthquake-resistant construction is to build structures that perform better during seismic activity than conventional construction. According to building codes, earthquake-resistant structures are intended to withstand the largest earthquake of a certain probability that is likely to occur at their location. This means that structures should be able to resist minor level earthquakes without any damages, moderate level earthquakes with some non-structural damage that will be repairable and major level earthquake without collapse.

Today high rise buildings are increasing, which are flexible and have low damping value. Due to decrease in stiffness, the displacement tends to increase. Many techniques have been developed to make structures free from earthquake and structural vibrations caused by wind load. Techniques are classified as follows: (i) Active control, (ii) Passive control, (iii) Semi-active control and (iv) Hybrid control.

1.1 Base Isolation

Base Isolation is a technique in which superstructure of a building is separated from its sub-structure by providing a suspension system between them. Earthquake resistant is provided to the structure using this mechanism. In this system, the building is decoupled from the lateral ground motion induced by the earthquake, by providing a vertical component with a high stiffness which acts as a connection between the superstructure and the sub-structure. In simple word it can be said that there is no effect of ground motion on structure, if the structure is floating on its base.

It is a Passive control device which consists of a structure, isolation, foundation and soil. In this isolation system is between structure and foundation to reduce the dynamic response of the structure. In this system ground is allowed to move freely without affecting the superstructure and without transferring the motion. In ideal case the separation should be total but in practical it's not possible, there should be little contact between superstructure and substructure. It can be placed in the structure during the construction stage or can be placed while maintenance as a seismic retrofitting. The main concept of base isolation is to reduce input energy, which results in reduction of acceleration in the structure. The response time of structure against earthquake increases due to increase in fundamental period of structure.

1.2 Fluid Viscous Damper

Fluid viscous dampers were initially used in the military and aerospace industry. They were designed for use in structural engineering in the late of 1980s and early of 1990s. FVD typically consist of a piston head with orifices contained in a cylinder filled with a highly viscous fluid, usually a compound of silicone or a similar type of oil.

Energy is dissipated in the damper by fluid orifice when the piston head moves through the fluid. The fluid in the cylinder is nearly incompressible, and when the damper is subjected to a compressive force, the fluid volume inside the cylinder is decreased as a result of the piston rod area movement. A decrease in volume results in a restoring force. This undesirable force is prevented by using an accumulator. An accumulator works by collecting the volume of fluid that is displaced by the piston rod and storing it in the makeup area. As the rod retreats, a vacuum that has been created will draw the fluid out.

Procedures have been developed through years for the seismic design of buildings equipped with fluid viscous dampers. The NEHRP (National Earthquake Hazards Reduction Program) and other codes give a trial-and-error approach for identifying the mechanical characteristics of additional damping devices

2. OBJECTIVES OF STUDY

The work has been undertaken with the following objectives:

- To study the comparison of performance of Fixed Base Building, Base Isolated and Viscous Damper using published work as a reference and understands the behavioral aspects.
- To review the literature, covering various types of base isolation and the behavior of structures constructed with base isolation.
- To review the literature, covering various types of viscous dampers and the behavior of structures constructed with viscous damper.
- To develop a simplified model of a multi story building with identical parameters and simultaneously providing it with base isolation and viscous damper.
- To carry out dynamic seismic analysis on the modeled buildings using scaled records of acceleration time histories and comparing their results.
- To study the comparative response of identical conventional and (G+8) storied with base isolation and viscous damper buildings for high intensity earthquakes and comment on feasibility of using particle damper and tuned mass damper for highly seismic areas.

3. METHOD OF ANALYSIS

Many methods has been developed for the analysis, each method has different level of accuracy. The analysis procedures are classified on the basis of three factors: the behavior of structure or structural materials, the type of the externally applied loads, and type of structural model selected. Depending on the type of external action and behavior of structure, the analysis procedures are further classified as given below:

1. Linear static analysis
    - 1.1. Equivalent static method
2. Linear dynamic analysis
    - 2.1. Response spectrum method
    - 2.2. Elastic time history method
3. Nonlinear static analysis
    - 3.1. Push over analysis
4. Nonlinear dynamic analysis
    - 4.1. Inelastic time history method

For structures having limited height and simple plan, Linear Static Analysis can be performed. Linear Dynamic Analysis can be performed using two ways either Response Spectrum Method or Elastic Time History Method. By being in the elastic range, this analysis produces the higher modes of vibration and actual distribution of forces in a better way. Nonlinear Static Analysis is an improvement over the linear static and dynamic analysis, such that it also deals with the inelastic behavior of the structure. Best and accurate result and behavior of the structure during an earthquake can be analyzed only by using inelastic time history analysis. Among all the defined methods we have considered Time history method for analysis.

4. MATERIAL PROPERTIES & SPECIFICATIONS

Table -4.1: Specification

S. No.	Specifications		Size
1	Plan Dimensions (X× Y)		30 m × 24 m
2	Floor to Floor Height (Z)		3 m
3	Total Height of Building (G+ 8)		27 m
4	Type of Structure		SMRF
5	Soil Type (as per IS: 1893 (Part-1) – 2002)		Medium
6	Response Reduction Factor		5
7	Importance Factor		1
8	Seismic Zone Factor		0.36 (Zone V)
9	Grade of Concrete & Steel		M 25 & Fe 415
10	Beam Size		0.30 m × 0.50 m
11	Column Size		0.30 m × 0.60 m
12	Slab Thickness		0.150 m
13	Wall Thickness		0.200 m
14	Staircase	Rise	0.140 m
		Thread	0.300 m
		Width	1.5 m

		Stringer	0.150 m
15	Load Combination		According to IS : 1893 (Part 1) :2002
16	Loads Applied	Dead Load	Calculated as per Self Weight
		Floor Finish	1 KN/m²
		Live Load	3 KN/m²
		Seismic Load	Calculated as per IS: 1893 (Part-1) – 2002

5. CALCULATION

Time History Method has been used for following calculation:

5.1 Base Isolation

STEP 1: Estimation of Effective Stiffness of base isolators

$$T_D = 2\pi\sqrt{\frac{W}{K_D \times g}} \qquad K_D = 108632.16 \text{ KN/m}$$

STEP 2: Calculation of Design Displacement

$$D_D = \frac{g \times S_{D1} \times T_D}{4\pi^2 \times B_D} = 0.133 \text{ m}$$

STEP 3: Determination of Thickness of LRB

$$t_r = \frac{D_D}{\gamma_{max}} = 0.089 \text{ m}$$

Assuming the end plates as 25 mm thick and steel shim as 2 mm each

Total Height, h = 2 $\times$ 25 + 5 $\times$ 20 + 4 $\times$ 2 = 158 mm

The steel shim will have a diameter of 650 mm giving 5 mm cover.

$$F_Y = Q_d + K_2 \times D_Y = 3777.91 \text{ KN}$$

Where, F_Y = Yield Strength

$$V_b = K_{Dmax} \times D_D = 15892.89 \text{ KN}$$

$$V_s = \frac{K_{Dmax} \times D_D}{R_1} = 7946.44 \text{ KN}$$

Where, V_b = Minimum base shear strength below isolation interface

V_s = Minimum base shear strength above isolation interface

R_1 = Response modification coefficient

R_1 = 2 (For SMRF) (ASCE 7-05 Table 12.2-1)

5.2 Fluid Viscous Damper

STEP 1: Determination of Linear Damping Coefficient

$$C_L = \varepsilon\omega \frac{W_{Total}}{g}\left(\frac{N+1}{n}\right)\frac{1}{\cos^2\theta} = 15867.37 \text{ KN-sec/m}$$

STEP 2: Estimation of Peak damper velocity, stroke, and force for linear damper

$$V_{max} = \frac{S_a}{\omega} \times \frac{2}{N+1} \times \cos\theta = 0.30 \text{ m/s}$$

$$F_{dmax} = 2\,\varepsilon \frac{W_{total} \times S_a}{g \times n \times \cos\theta} = 4895.60 \text{ KN}$$

$$S_{max} = \frac{S_a \times 2\cos\theta}{\omega^2 \times (N+1)} = 0.90 \text{ cm}$$

STEP 3: Maximum Axial Force

$$P_{base} = P_{1max} = N \times 0.8^{1-\alpha} \times 2\varepsilon \times \frac{W_{total}}{g} \times \frac{S_a \times \tan\theta}{n}$$

P_{base} = 18750.36 KN

K_{axial} = 10 $\times$ C_L $\times$ ω_l = 553771.21 KN/m

K_{axial} =Linear Stiffness

6. MODELING AND ANALYSIS

6.1 Plan of Building

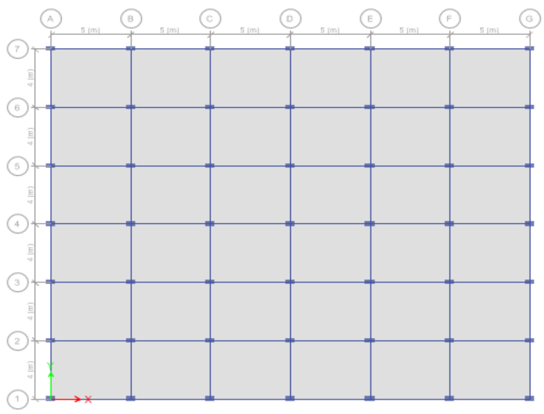

Fig -6.1: Plan of Building

6.2 Isometric View of Building

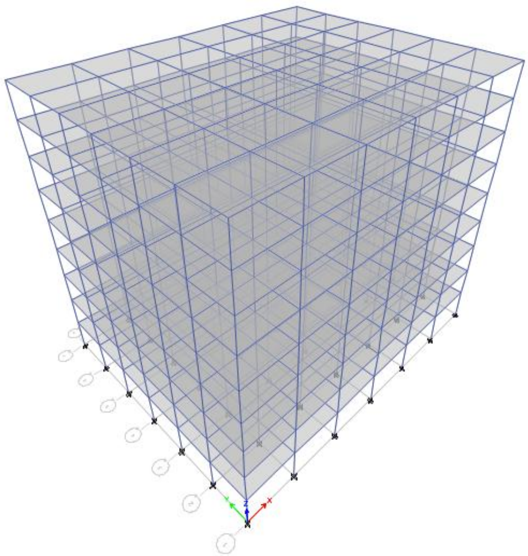

Fig -6.2: Isometric View of Building

6.3 Setup View of Base Isolation

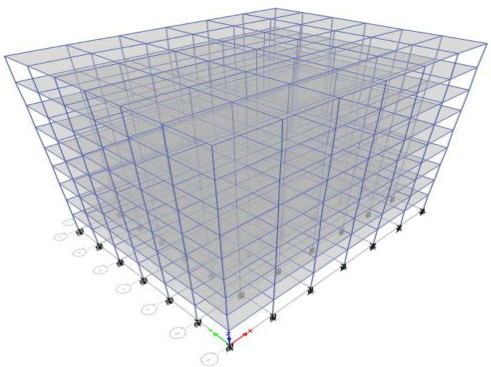

Fig -6.3: Setup view of Base Isolation

6.4 Setup View of Fluid Viscous Damper

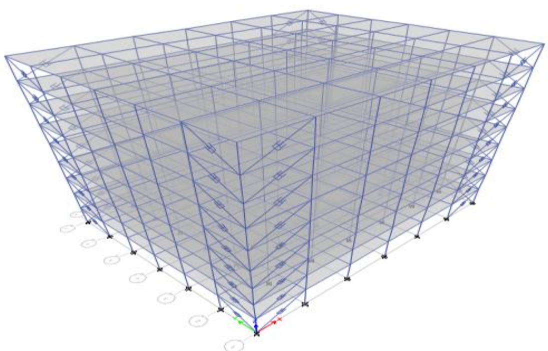

Fig -6.4: Setup view of Fluid Viscous Damper

7. RESULTS

7.1 Story Displacement

Displacements of different stories were determined using Time History Analysis in x and y direction for fixed base building, base isolated building and building with fluid viscous damper. Tables and graphs are shown to determine the efficiency of isolator, damper and reduction in response.

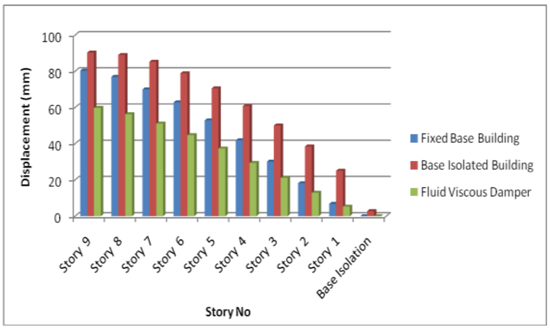

Fig 7.1 Story displacement in x direction due to EX

Table 7.1: Displacement from time history analysis in x direction due to EX

Story	Elevation	Fixed Base Building	Base Isolated	Viscous Damper
	m	mm	mm	mm
Story 9	27	80.40	90.34	59.82
Story 8	24	76.96	89.05	56.29
Story 7	21	70.01	85.26	51.15
Story 6	18	62.83	78.93	44.74
Story 5	15	52.94	70.59	37.36
Story 4	12	41.89	60.82	29.39
Story 3	9	30.11	50.08	21.15
Story 2	6	18.18	38.52	12.97
Story 1	3	6.79	25.06	5.28
Base Isolation	0.158	0	2.81	0

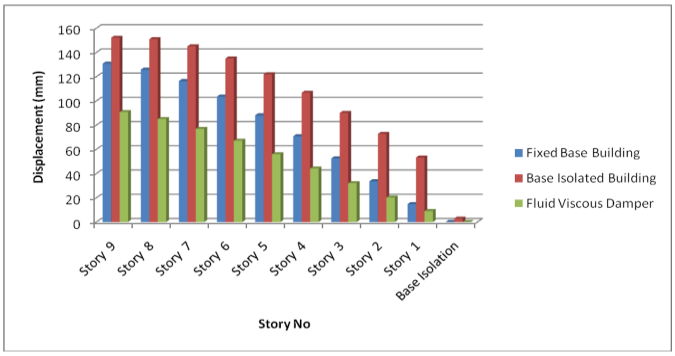

Fig 7.2 Story displacement in y direction due to EY

Table 7.2: Displacement from time history analysis in y direction due to EY

Story	Elevation	Fixed Base Building	Base Isolated	Viscous Damper
	m	mm	mm	mm
Story 9	27	130.77	152.12	90.77
Story 8	24	125.79	150.94	85.01
Story 7	21	116.45	145.06	76.93
Story 6	18	103.57	135.03	67.11
Story 5	15	88.10	121.93	56.02
Story 4	12	70.87	106.70	44.17
Story 3	9	52.54	90.12	32.08
Story 2	6	33.66	72.75	20.23
Story 1	3	14.81	53.30	9.07
Base Isolation	0.158	0	2.78	0

7.2 Story Drift

Drifts of different stories were determined using Time History Analysis in x and y direction for fixed base building, base isolated building and building with fluid viscous damper. Tables and graphs are shown to determine the efficiency of isolator, damper and reduction in response.

Table 7.3: Story Drift from time history analysis in x direction

Story	Elevation	Fixed Base Building	Base Isolated	Viscous Damper
	m	mm	mm	mm
Story 9	27	0.001151	0.000438	0.001216
Story 8	24	0.001983	0.001262	0.001741
Story 7	21	0.002728	0.002113	0.00218
Story 6	18	0.003294	0.00278	0.002492
Story 5	15	0.003686	0.003255	0.002685
Story 4	12	0.003925	0.00358	0.00277
Story 3	9	0.004005	0.003858	0.002745
Story 2	6	0.003773	0.004518	0.002573
Story 1	3	0.002266	0.007607	0.001761
Base Isolation	0.158	0	0	0

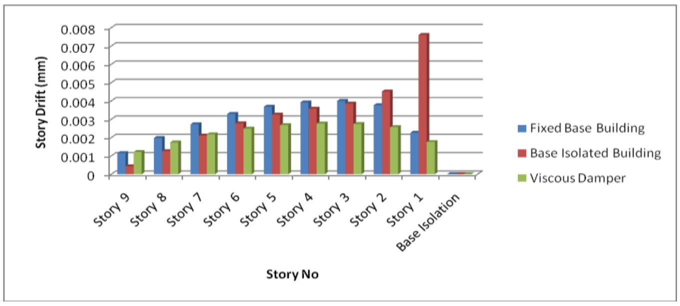

Fig 7.3 Story Drift in x direction

Table 7.4: Story Drift from time history analysis in y direction

Story	Elevation	Fixed Base Building	Base Isolated	Viscous Damper
	m	mm	mm	mm
Story 9	27	0.001661	0.000409	0.001955
Story 8	24	0.003115	0.001959	0.002717
Story 7	21	0.004293	0.003343	0.003312
Story 6	18	0.005155	0.004368	0.003729
Story 5	15	0.005745	0.005077	0.003974
Story 4	12	0.00611	0.005525	0.004051
Story 3	9	0.006293	0.005792	0.003971
Story 2	6	0.006286	0.006491	0.00373
Story 1	3	0.004938	0.017002	0.003025
Base Isolation	0.158	0	0	0

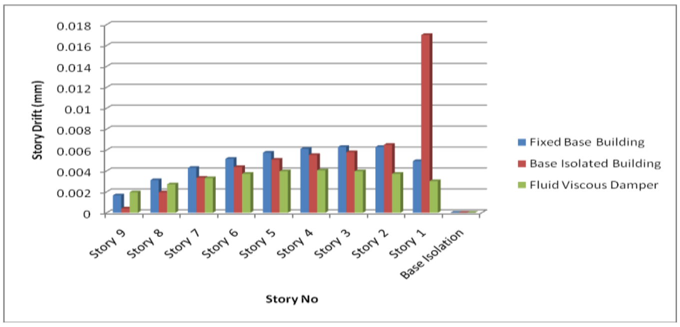

Fig 7.4 Story Drift in y direction

7.3 Story Overturning Moments

Overturning Moments of different stories were determined using Time History Analysis for fixed base building, base isolated building and building with fluid viscous damper. Tables and graphs are shown to determine the efficiency of isolator, damper and reduction in response.

Table 7.5: Overturning Moments of building from time history analysis

Story	Elevation	Fixed Base Building	Base Isolated	Viscous Damper
	m	KN-m	KN-m	KN-m
Story 9	27	0.0054	0.0022	0.005
Story 8	24	0.4063	0.233	0.0124
Story 7	21	1.347	0.7795	0.0197
Story 6	18	2.7969	1.6301	0.0268
Story 5	15	4.71	2.7674	0.0334
Story 4	12	7.0267	4.1685	0.0393
Story 3	9	9.6756	5.8054	0.0444
Story 2	6	12.5755	7.646	0.0484
Story 1	3	15.638	9.6538	0.0512
Base Isolation	0.158	18.7718	0	0.0526

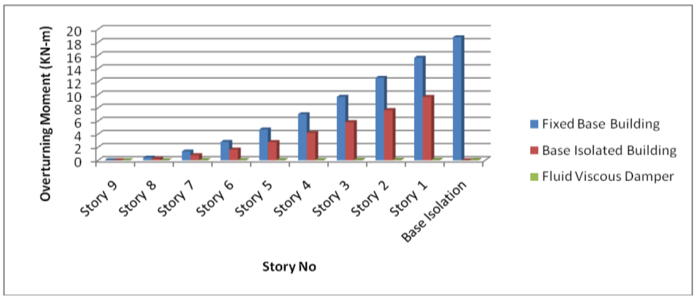

Fig 7.5 Story Overturning Moments

7.4 Story Shear

Shear of different stories were determined using Time History Analysis for fixed base building, base isolated building and building with fluid viscous damper. Tables and graphs are shown to determine the efficiency of isolator, damper and reduction in response.

Table 7.6: Story Shear of building from time history analysis

Story	Elevation	Fixed Base Building	Base Isolated	Viscous Damper
	m	KN	KN	KN
Story 9	27	0.1311	0.0759	0.2174
Story 8	24	0.311	0.1811	0.508
Story 7	21	0.4808	0.2825	0.7748
Story 6	18	0.6354	0.3781	1.0114
Story 5	15	0.7702	0.4662	1.2124
Story 4	12	0.8813	0.5449	1.3736
Story 3	9	0.9653	0.613	1.4924
Story 2	6	1.0202	0.669	1.568
Story 1	3	1.0446	0.7105	1.6015
Base Isolation	0.158	0	0	0

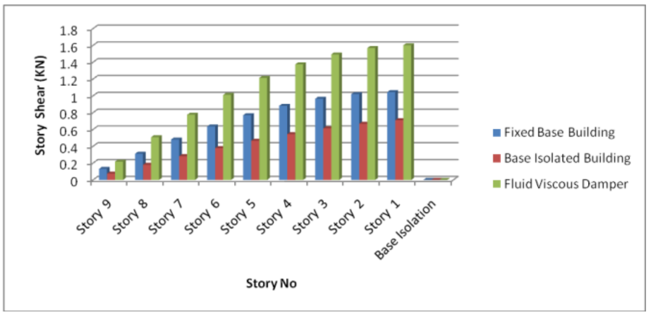

Fig 7.6 Story Shear

7.5 Base Shear

Base Shear of buildings was determined using Time History Analysis for fixed base building, base isolated building and building with fluid viscous damper. Tables and graphs are shown to determine the efficiency of isolator, damper and reduction in response.

Table 7.7: Base Shear from time history analysis in x and y direction.

Direction	Fixed Base Building	Base Isolated	Viscous Damper
	KN	KN	KN
X	7820.3406	7214.1208	7820.3400
Y	7820.3406	7214.1208	7820.3400

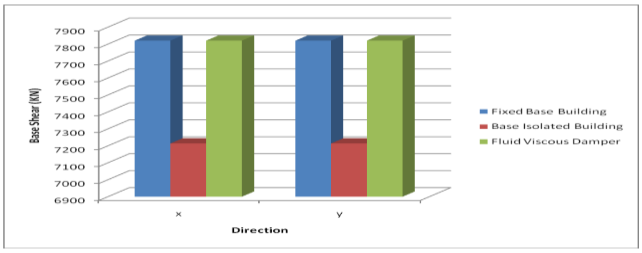

Fig 7.7 Base Shear in x and y direction

7.6 Time Period

Time Period of buildings was determined using Time History Analysis for fixed base building, base isolated building and building with fluid viscous damper. Tables and graphs are shown to determine the efficiency of isolator, damper and reduction in response.

Table 7.8: Time Period of buildings from time history analysis

Fixed Base Building	Base Isolated	Viscous Damper
sec	sec	sec
1.802	2.248	1.443

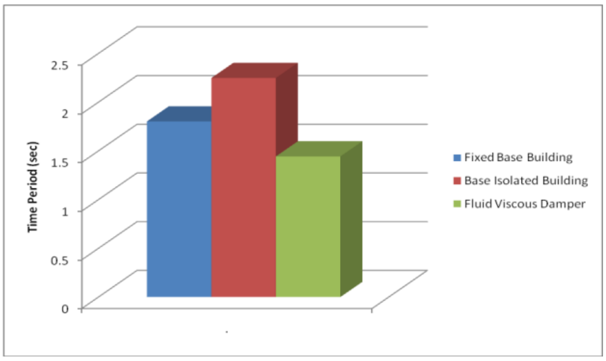

Fig 7.8 Time Period of building

8. CONCLUSIONS

1. Analytical study has been done on a building by applying Base Isolation and Fluid Viscous Damper separately; it has been found that displacement in base isolation increases while in fluid viscous damper displacement decreases.

2. Time period of base isolated building is greater than fixed base building and fluid viscous building, which gives more time for the structure to react during earthquake.
3. There is reduction in base shear of base isolated building while in fixed base building and building with fluid viscous damper, base shear remains same, due to which, the maximum lateral forces in base isolated building due to ground motion decreases at base of the building, which makes the structure more stable.
4. From this study, it is clear that both fluid viscous damper and base isolation reduces the overturning moment of the structure as compared to fixed base building, due to which more moment will be required to turn the building, which makes building more stable and resistant towards earthquake. Fluid viscous damper is twice as effective in decreasing the overturning moment as compared to base isolation.
5. From this study, it has seen that story shear in base isolation decreases while in fluid viscous damper story shear increases as compared to fixed base building. Due to which there is reduction of seismic effect on base isolated building.
6. From this study, it is clear that both fluid viscous damper and base isolation reduces the story drift of the structure in higher stories as compared to fixed base building, which makes structure safe against earthquake. Fluid viscous damper is twice as effective in decreasing the overturning moment as compared to base isolation.

9. FUTURE SCOPE

1. The study can also be done by using Fluid Viscous Damper with different arrangement, which may result in reduction of response at every story.
2. A study can be done by applying both base isolation and Fluid Viscous Damper simultaneously at a structure.
3. In current study, base isolation of same material is placed at every column; it can also be analyzed by installing base isolation at external and inner column with different material.
4. The study can also be done by placing a single viscous damper from base to top instead of placing damper at each story.

REFERENCES

1. Anil K. Chopra. "Dynamics of Structures" Theory and Application to Earthquake Engineering, Third Edition.

2. ASCE/SEI 7-05 Minimum Design Loads for Buildings and Other Structures.

3. D. De Domenico, G Ricciardia, I. Takewakib. Design strategies of viscous dampers for seismic protection of building structures.

4. Dia Eddin Nassani, Mustafa Wassef Abdulmajeed. Seismic Base Isolation in Reinforced Concrete Structures.

5. Etabs 2016 documentation.

6. E. Tubaldi1, A. Dall'Asta2, M. Broggi3, E. Patelli3, M. De Angelis. Reliability-Based Design of Fluid Viscous Damper for Seismic Protection of Building Frames.

7. FEMA 273 / October 1997, NEHRP GUIDELINES FOR THE SEISMIC REHABILITATION OF BUILDINGS.

8. H.H. Lee, M.W. Hur, H.Jiang, Y.C. You and K.H Kim. EVALUATION OF DYNAMIC CHARACTERISTICS OF BASE ISOLATED RESIDENTIAL BUILDING.

9. H. Kit Miyamoto, Amir SJ Gilani. Response of structures with viscous dampers subjected to large earthquakes.

10. HOSSEIN SHAKERI SOLEIMANLOO. A Survey study on design procedure of Seismic Base Isolation Systems.

11. IS 456: (2000) Indian Standard Code of Practice for Plain and Reinforced Concrete, Bureau of Indian Standards, New Delhi.

12. IS 1893 (Part I): 2002 Criteria for Earthquake Resistant Design of Structures. Part I General provisions and

buildings (*Fifth revision*). Bureau of Indian Standards, New Delhi.

13. Microsoft Word 2010.

14. P. Lakshmaiah Chowdary and G.karthic. ANALYSIS OF A HIGH RISE RESIDENTIAL BUILDING WITH VISCOUS DAMPERS USING ETABS.

15. Pankaj Agrawal and Manish Shrikhande "Earthquake resistant design of structures" Eastern economy edition, online resources www.phindia.com, *chapter 12 pp. 196-197&296.*

16. Samir Khizar Hashmi & Syed Mohsin Basha. Dynamic Behaviour of RC Framed Structure using Lead Rubber Bearing.

17. S.K. Duggal "Earthquake resistant design of structures" Second edition, Oxford University Press, online resource www.oupinheonline.com, *chapter 5 pp. 202-203*.

18. STEFANO SILVESTRI, MICHELE PALERMO & TOMASO TROMBETTI University of Bologna, Italy. A DIRECT PROCEDURE FOR THE SEISMIC DESIGN OF FRAME STRUCTURES WITH ADDED VISCOUS DAMPERS.

19. T.Nagajyothi, Dr. Vaishali G.Ghorpade. DESIGN OF LEAD RUBBER BEARING SYSTEM AND HIGH DAMPIN G RUBBER BEARING SYSTEM FOR ISOLATED STRUCTURE FOR LONG TIME PERIODS FOR A FIVE STOREY R.C. BUILDING.

20. Tong Guo, M.ASCE; Jia Xu; Weijie Xu; and Zhiqiang Di. Seismic Upgrade of Existing Buildings with Fluid Viscous Dampers: Design Methodologies and Case Study.

21. Yagneshkumar Patel, Pradeep Kumar Pandey, Comparision of Fixed Base and Base Isolation Reinforced Concrete Structure for Seismic Response.