Seismic Response of Asymmetric Composite Structures with and without Visco-Elastic Dampers

Jaswanth M[1], Sreenivasa M B[2]

[1]Post graduation Student, Department of Structural Engineering Centre for post-graduate studies Visvesvaraya Technological University, Mysore, Karnataka, India
[2]Assistant Professor, Department of Structural Engineering, Centre for post-graduate studies Visvesvaraya Technological University, Mysore, Karnataka, India

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Abstract – *Earthquake is one of the nature's greatest hazard for the life which cause destruction of buildings and environment. Most of the problems related to earthquake design are due to the structural design concept. In modern days, structures are given primary importance for architectural appearance rather than structural importance which leads to difficult for planning with regular shapes of buildings. This leads to planning with Irregularity in structure which are responsible for collapse of the building. The damages caused during earthquake, clearly demonstrates that the shape of the building plays an important role in torsional effects of building. In this study, we have considered 4 different shapes such as Rectangular-Shape, L-Shape, T-Shape, C-Shape of asymmetric composite G+14 storey buildings for the seismic analysis which has been analyzed through Equivalent static method and Response spectrum method of analysis in ETABS 2015 Software. The methodology and specifications are adopted according to IS 1893 (Part 1):2002. For each different shape of building Visco-elastic damper has been added in two different configurations i.e., Alternate bays and Alternate floor configuration along both Longitudinal and lateral direction. The result shows that, asymmetric composite building provided with viscoelastic damper at Alternate floor configuration in Longitudinal direction effectively reduces the Lateral Displacement, Inter Storey-Drift, Fundamental Natural Period and Torsional Irregularity in all shapes of building. It has been observed that, when the dampers arranged in Alternate Floor configuration along Longitudinal direction T-shape of asymmetric composite building reduces the Torsional effects compared to Rectangular-Shape C-Shape and L-Shape of building.*

***KeyWords*: Visco-Elastic Damper, Alternate Bay, Alternate Floor, Equivalent static method, Response spectrum method, Etabs 2015**

1. INTRODUCTION

Earthquake is the sudden shaking of ground caused due to the passage of seismic waves. Earthquake ground motions (EQGMs) gives large amount of dissipating energy to structures and thus make them more susceptible to sudden damage. So, the design of structures to reduce vibrations caused due to earthquakes has been a major concern for structural engineers from many years. Earthquake Ground Motions are the most dangerous natural hazard where both economic and life losses occur. Most of the losses are due to building collapses or damages [11]. During earthquake, the behavior of building mainly depends on its Overall Shape, Size and Geometry of the structure and how the earthquake forces affects the ground. Nowadays, most of the structures are involved with architectural importance and hence it is impossible to plan with regular shapes. These irregularities are responsible for structural collapse of buildings under dynamic loads [4]. Therefore, it is very important to design the structures to resist, moderate to severe EQGMs depending on its site location and importance of the structure [11].

1.1 Need for the Present Work

It is observed that there is no torsional effect in the regular frame, but in case of irregular structures due to the torsional effect there is a failure in beam-column joints. These torsional effects can be reduced by providing different types of energy dissipating devices or by providing shear walls at re-entrant corners. In this present study, we have considered visco-elastic damper with different configuration by applying at alternate floors and alternate bays to determine the optimum configuration of damper application and to reduce the torsional effects in the irregular buildings in terms of lateral displacement, torsion and storey drift.

1.2 Objectives

1. To study the torsional effect of Visco-elastic damper on asymmetrical composite buildings and to find out the difference in structural response of asymmetric composite buildings with and without damper.
2. To determine optimum configuration of damper arrangement.
3. To study the parameters like Lateral displacement, Storey drift, Torsional irregularities, Base shear, Natural time period.
4. To study the importance of Response spectrum method of analysis in the seismic analysis of asymmetric composite structures and to compare between

structural responses obtained from dynamic analysis and equivalent static analysis.

5. To study the effect of Visco-elastic damper in different Shapes of asymmetric composite building.

1.3 Visco-elastic damper

Viscoelastic damper is the passive damper which have been successfully installed in many of tall buildings structures to reduce the earthquake ground motion, amplitude and the acceleration occurring due to wind and earthquake forces. These dampers are capable of reducing the building motion by converting a portion of the mechanical energy of wind or earthquake to heat energy. Which results in a reduction of the amplitude of the vibratory motion [12]. The medium in which the transfer of energy takes place is a viscoelastic material. Thus, Viscoelastic damper is quite efficient method of damping where high damping at low frequency is desired.

2. METHODOLOGY

The seismic analysis is carried out for Rectangular-Shape, L-Shape, T-Shape and C-Shape asymmetric composite G+14 storey building with two different configurations. The effectiveness of Visco-elastic damper is determined by varying the installation in Alternate bays and Alternate floor along longitudinal direction and lateral direction so that whichever reduces the maximum torsional effects parameters such as Lateral Displacement, inter storey drift, Torsional Irregularity, Natural Time period, will be the best optimum Configuration.

In this present study, four different shapes of asymmetrical plans such as Rectangular, L, T and C -shapes of composite buildings are considered. Each plan is analyzed with 5 different model configurations.

Model 1 – Composite building without Visco-elastic damper.
Model 2 – Composite building with Visco-elastic damper at alternate bays in longitudinal direction.
Model 3 – Composite building with Visco-elastic damper at alternate bays in lateral direction.
Model 4 – Composite building with Visco-elastic damper at alternate floors in longitudinal direction.
Model 5 – Composite building with Visco-elastic damper at alternate floors in lateral direction.

All the five different Models of asymmetric composite G+14 Building structures are analyzed by both Equivalent static method and Response spectrum method and the results are compared from both the analysis method in lateral and longitudinal Direction

2.1 Description of Building details

Number of Storeys	15
Number of Bays along X-Direction	5
Number of Bays along Y-Direction	3
Width of the Bay along X-direction	8m
Width of the Bay along Y-direction	6m
Total dimension of building	40m X 18m
Floor to Floor height	4m

2.2 Description of Structural properties of Composite Sections.

Composite Deck Slab/Profiled Sheet	Grade of Concrete	M30
	Depth of Deck Slab	80mm with 20mmΦ Shear Connectors
Composite Beams	Grade of Structural Steel	Fe345
	All Primary beams	ISWB 600-2
	All Secondary beams	ISMB 225
Composite Columns	Grade of Structural Steel	Fe345
	All Columns	ISHB 450

2.3 Description of Material Properties

Material	Type	Young's modulus (N/mm2)	Density (kN/m3)
Concrete	M30	25000	25
Rebar	Fe415	200000	76.97

2.4 Description of Seismic Data

Zone factor	V
Soil type	Medium
Response Reduction Factor (R)	5
Importance Factor (I)	1
Percentage of Damping	2%

2.5 Description of Types of Load and Their Intensities

Live Load	3.0 kN/m^2
Floor Finish Load	1.0 kN/m^2
Roof Load	2.0 kN/m^2

2.6 Description of Link Properties

Type of Damper	Visco-elastic
Effective Stiffness (K_e)	85745.7 kN/m
Effective Damping (D_e)	2451.4 kN-s/m

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3. MODELLING

3.1 Configuration of Visco-Elastic Damper Arrangement

Configuration-1: Dampers arranged in **Alternate Bay** for longitudinal direction and Lateral direction.

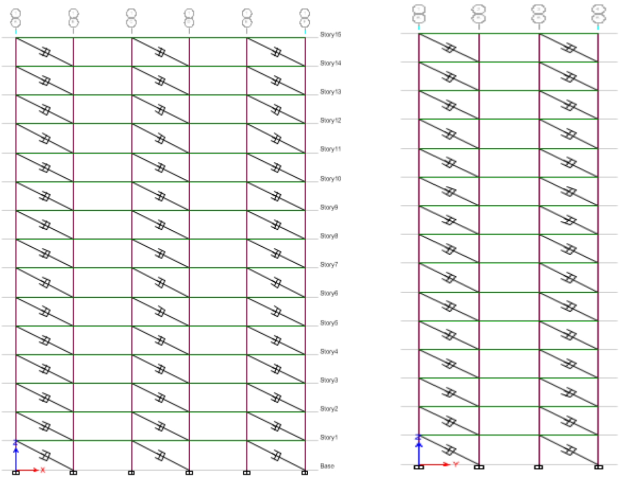

Figure 3.1 Configuration-1: Dampers arranged in Alternate Bays for Longitudinal and Lateral direction

Configuration-2: Dampers arranged in **Alternate Floor** for Longitudinal direction and lateral direction.

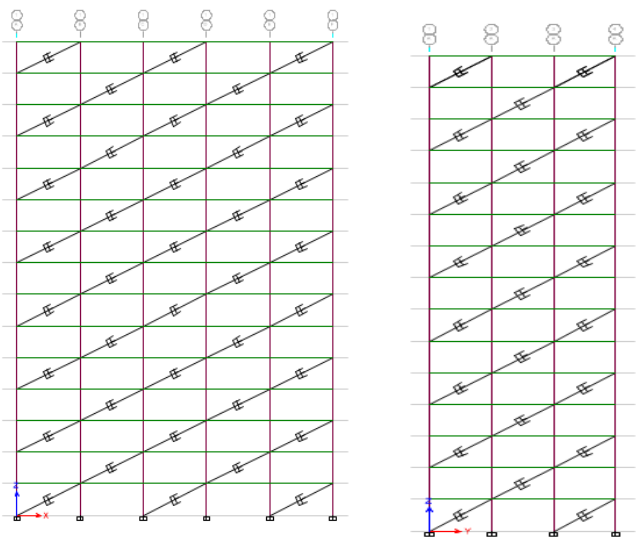

Figure 3.2 Configuration-2: Dampers arranged in Alternate Floors for longitudinal direction and Lateral direction

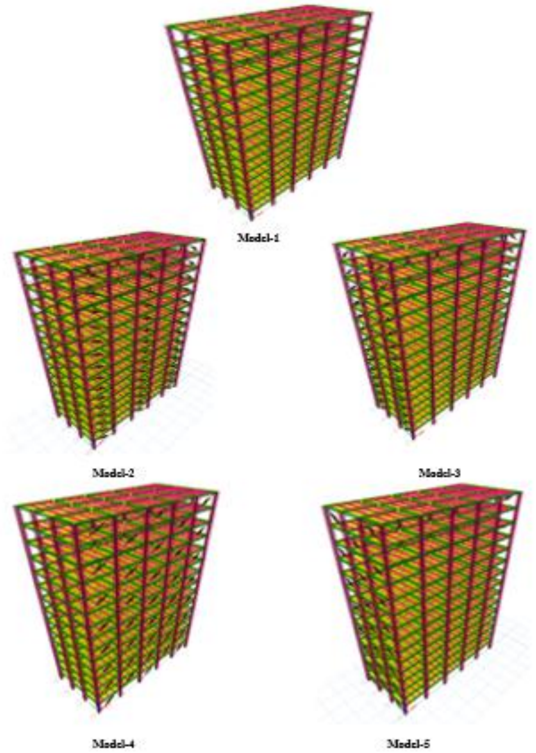

Figure 3.3 - 3D Rendered View of G+14 storey Building of Rectangular-Shape Composite structure

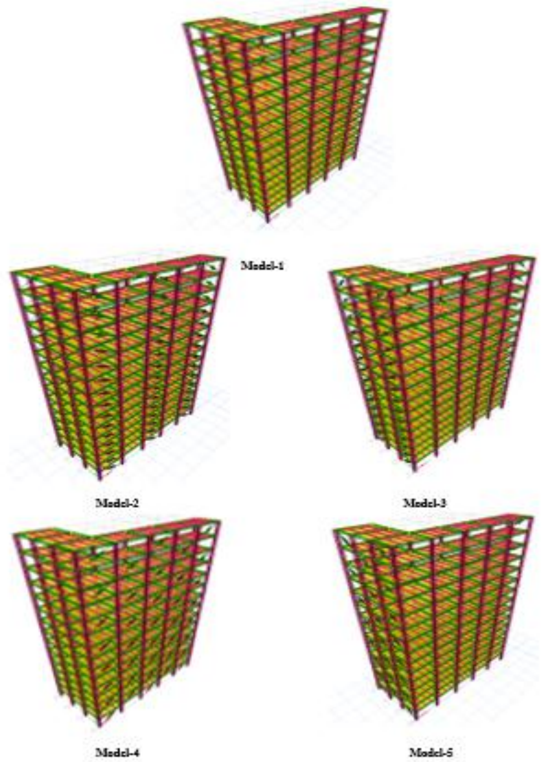

Figure 3.4 - 3D Rendered View of G+14 storey Building of L-Shape Composite structure

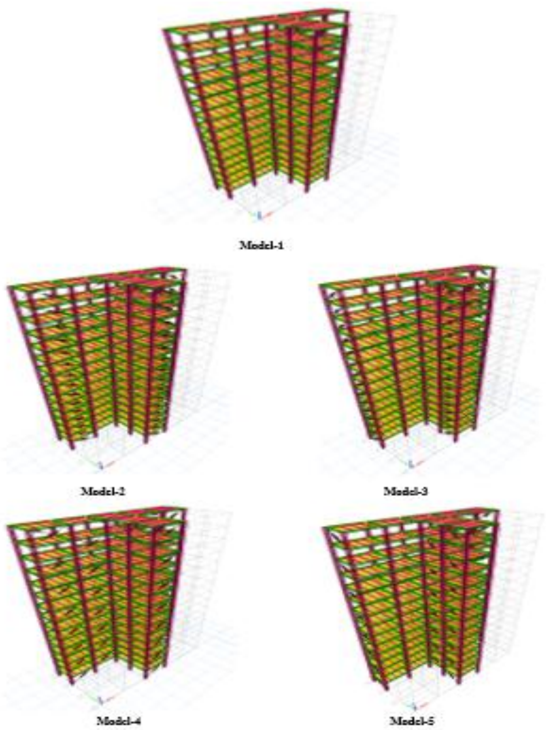

Figure 3.5 - 3D Rendered View of G+14 storey Building of T-Shape Composite structure

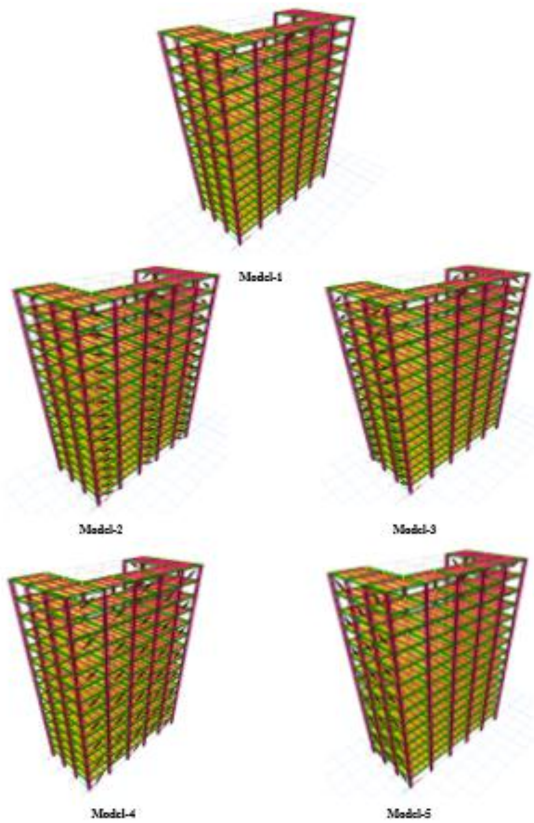

Figure 3.6 - 3D Rendered View of G+14 storey Building of C-Shape Composite structure

4. RESULTS AND DISCUSSION

4.1 LATERAL DISPLACEMENTS

Lateral displacement is defined as the absolute displacement of the storey under the action of lateral forces

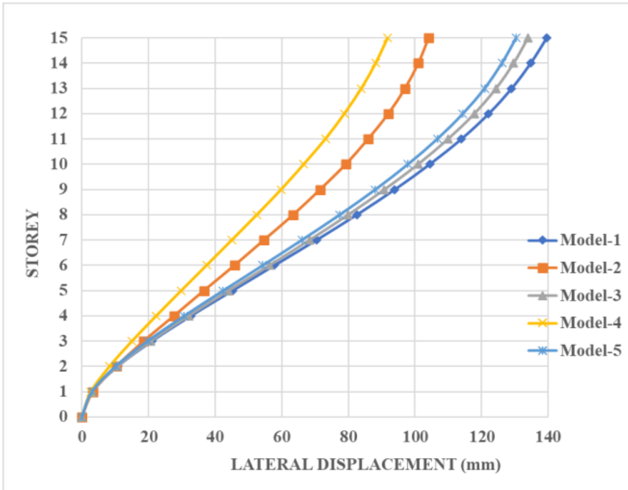

Figure 4.1 -Lateral displacement profile of T-shape asymmetric composite G+14 storey building along longitudinal direction with respect to Equivalent Static Method of Analysis

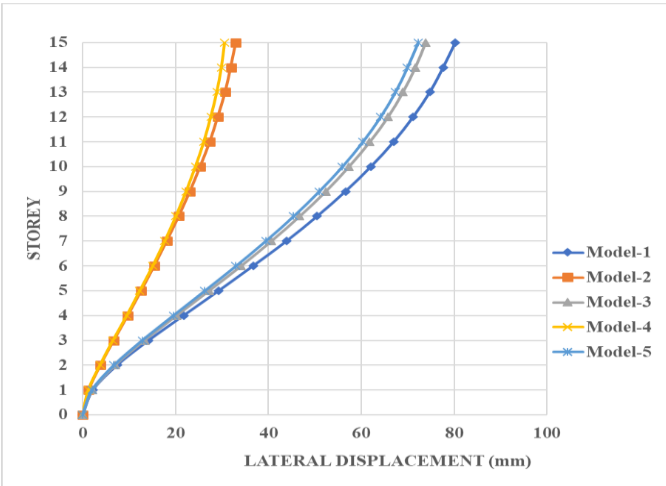

Figure 4.2 – Lateral Displacement profile of T-shape asymmetric composite G+14 storey building along longitudinal direction with respect to Response spectrum Method of Analysis.

By installing the visco-elastic dampers at alternate floors along longer face the overall reduction of lateral displacement in Model-4 is upto **60.35%** with respect to Model-1. Here, the Equivalent static method of analysis shows **34.97%** of reduction in lateral displacement and response spectrum method of seismic analysis shows **60.35%** of reduction in lateral displacement value along longitudinal direction. Therefore, we can conclude that the Response spectrum method of analysis is more efficient than equivalent static method of analysis.

Table 4.1 Comparision table on overall % reduction of lateral displacement of asymmetric composite G+14 storey building along longitudinal and lateral direction

Overall % Reduction of Lateral Displacement Value	
Shape of Building	**% of reduction**
Rectangular-Shape	30.65
L- Shape	38.57
T-Shape	**43.11**
C-Shape	40.82

We observe that, T- Shape Composite G+14 storey building model shows efficiency in reducing lateral displacement value as compared with L and C Shape building. Hence, we can say that out of these three types, T-Shape Composite G+14 storey building model perform very well during earthquake and hence this shape shall be adopted.

4.2 INTER STOREY DRIFT

It is defined as the displacement of one level relative to the other level above or below. The storey drift in any storey due to the minimum specified design lateral force, with partial load factor of 1.0 shall not exceed 0.004 times the storey height.

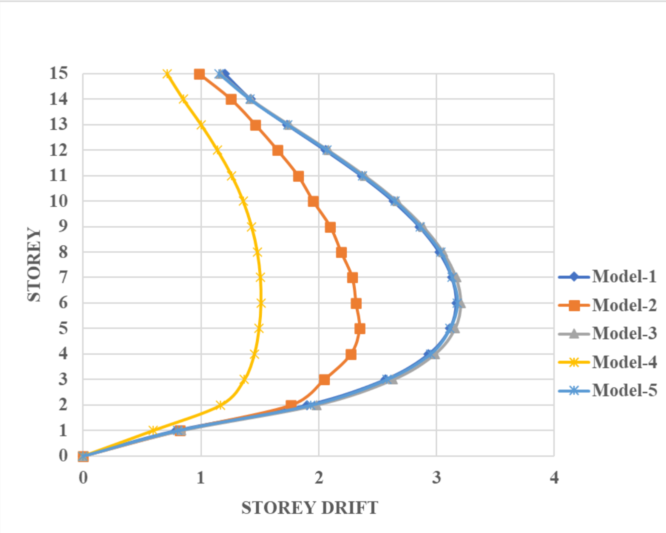

Figure 4.3 Inter storey drift profile of T-Shape asymmetric composite G+14 storey building along longitudinal direction with respect to Equivalent Static Method of Analysis

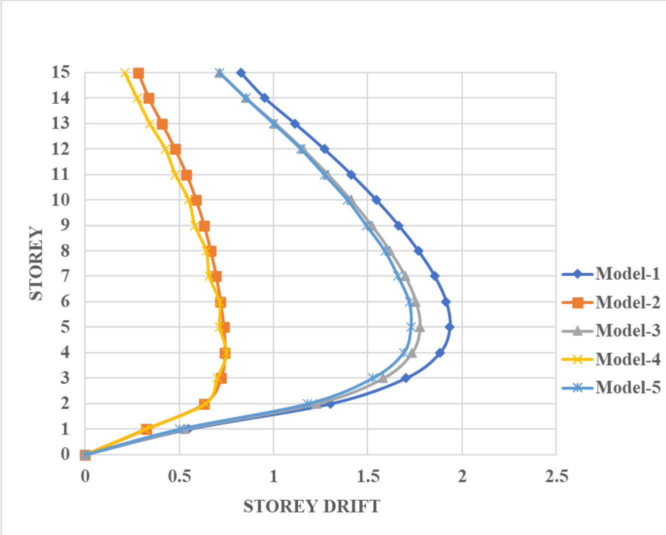

Figure 4.4 – Inter storey drift profile of T-Shape asymmetric composite G+14 storey building along longitudinal direction with respect to Response spectrum Method of Analysis

By installing the damper at alternate floors along longitudinal direction in asymmetric composite G+15storey building, the overall reduction of storey drift value in Model-4 is upto **63.10%** with respect to Model-1. Thus, we can observe that, Equivalent static method of analysis shows **47.50%** of reduction and response spectrum method of analysis shows **63.10%** of reduction along longitudinal direction.

Table 4.2 Comparision table on overall % reduction of Inter storey drift of asymmetric composite G+14 storey building along longitudinal and lateral direction.

Overall % Reduction of Inter Storey drift Value	
Shape of Building	**% of reduction**
Rectangular- Shape	34.17
L- Shape	38.80
T-Shape	**43.95**
C-Shape	42.65

We observe that, L- Shape Composite G+14 storey building model shows efficiency in reducing Inter Storey drift value as compared with Rectangular, T & C Shape building. Hence, we can say that out of these three types, T-Shape Composite G+14 storey building model perform very well during earthquake and hence this shape shall be adopted.

4.3 TORSIONAL IRREGULARITIES

In case of G+14 storey asymmetrical Rectangular-Shape composite building torsional irregularity, ratio was obtained as unity for both the Building without damper and with visco-elastic damper. The maximum storey drift and minimum storey drift values across two ends of the floor was found to be 1.119 and 1.040 respectively. The ratio of these maximum and minimum storey drift values was obtained as 1.075. But, according to IS 1893:2002 the torsional irregularity ratio should be greater than 1.2. So, the torsional irregularity ratio at the remaining floors for all the models were found to be lesser than 1.2. Hence, it can be said that asymmetrical rectangular building possesses no torsional irregularity.

4.4 TIME PERIOD

The rate at which building vibrates due to the seismic loads is called as natural time period. Modal Analysis is carried for the study of time period in each model with and without damper for both alternate bays and alternate floor cases

Table 4.3 Comparision table on overall % reduction of Time period of asymmetric composite G+14 storey building models

Overall % Reduction of Natural Period Value	
Shape of Building	**% of reduction**
Rectangular- Shape	29.18
L- Shape	30.68
T-Shape	**40.36**
C-Shape	19.38

We observe that, T- Shape Composite G+14 storey building model shows efficiency in reducing natural period value as compared with Rectangular, T & C Shape building. Hence, we can say that out of these four types, T-Shape Composite G+14 storey building model perform very well during earthquake and hence this shape shall be adopted.

4.4 BASE SHEAR

Base Shear is an estimate of the maximum expected lateral force which will occur due to the ground motion at the base of the structure. This Base shear values are tabulated for all the four different shapes of asymmetric composite G+14 storey buildings along both longitudinal and lateral direction and the scale factor is calculated. The base shear values has been increased in all the 4-shapes of building due to increase in the stiffness of the structure compared to the building without damper.

5. CONCLUSIONS

Based on the seismic response parameters results obtained from equivalent static method and response spectrum method the following conclusions were drawn.

1. When the visco-elastic damper is arranged in **Alternate bay** configuration along longitudial direction (Model-2), the reduction of lateral displacement is about 33.06% in Rectangular-Shape, 58.70% in L-Shape, 58.48% in T-Shape and 55.33 % in C-Shape of building. Similarly, when the viscoelastic damper is arranged in **Alternate floor** configuration along longitudial direction (Model-4), the reduction of lateral displacement is about 43.97% in Rectangular-shape, 58.72% in L-Shape, 60.35% in T-Shape and 55.33 % in C-Shape Building.
2. The overall reduction of lateral displacement when the visco-elastic damper is installed in alternate floor configuration along longitudinal diretion is 5.86% more compared to alternate bay configuration is observed in all the four shapes of buildings. The maximum reduction of lateral displacement with 60.35% is observed in T-shape of asymmetric composite building along longitudinal direction.
3. When the visco-elastic damper arranged in **Alternate bay** configuration along longitudinal direction (Model-2), the overall reduction in Inter storey drift is about 35.83% in Rectangular-Shape, 44.97% in L-Shape, 60.84% in T-Shape and 40.40% in C-Shape buildng. Similarly, when the viscoelastic damper is arranged in **Alternate floor** configuration along longitudial direction (Model-4), the overall reduction of inter-storey drift is about 48.53% in Rectangular-shape, 57.48% in L-Shape, 63.10% in T-Shape and 52.39 % in C-Shape Building.
4. The overall reduction of inter storey drift when the visco-elastic damper is installed in alternate floor configuration along longitudinal diretion is 17.80% more compared to alternate bay configuration is observed in all the four shapes of buildings. The maximum reduction of inter storey drift with 63.10% is observed in T-shape of asymmetric composite building along longitudinal direction.
5. Visco-elastic Damper arranged in alternate floor configuration along longitudinal direction, the overall reduction of Lateral Displacement is 60.35% and Inter storey drift is about 63.10%. Similarly, when the dampers arranged along lateral diection, the reduction of lateral displacemnt is about 48.31% and reduction of inter storey drift is about 30.75%. This shows the dampers arranged along longitudinal direction gives better results than the dampers arranged in lateral direction.
6. In a G+14 storey asymmetric composite building with viscoelastic damper reduces the torsional irregularity compared with the building without damper. 22% of reduction L-shape building, 21% of reduction is observed in C-Shape building and 19% of reduction is observed in T-Shape building as it is more irregular in plan.

7. Response Spectrum Method of Analysis is found to be more efficient as the percentage of reduction in lateral displacement, inter storey drift and natural time period is more compared to Equivalent Static Method of Analysis, for all the four shapes of G+14 Storey asymmetric composite buildings.

5.1 Scope of the Future Work

1. The seismic responses and torsional effects can be determined by Inelastic seismic analysis procedures such as Static pushover analysis and Inelastic Time history analysis.
2. Seismic performance shall be determined for asymmetric composite building for different shapes by providing base isolators
3. This can be analyzed further by providing shear walls, steel bracing system and steel structures.

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