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# Seismic Analysis of Irregular Builiding on Sloped Terrain with Varying Shear Wall Configuration

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**ABSTRACT—**

Structures resting on sloping ground are highly vulnerable to earthquakes due to irregularities in plan and elevation. The buildings situated on hill slopes in earthquake prone areas are generally irregular, torsion ally coupled and hence susceptible to severe damage when affected by earthquake ground motion. Also, for the analysis of this type of structure, it is necessary to carry out dynamic analysis to determine the maximum dynamic response of the building. The modal periods and frequency of the building in any mode depends on the mass and stiffness of the building at the various level of the building. In case of building constructed on sloping ground as the plan area will not remain constant the mass of building will change at every level. In addition to this the length of column is also changing at different floor levels so stiffness of the column and stiffness of building will change at every floor, so it is important to study the dynamic behavior of building constructed on the sloping ground. In this present study, an attempt has been made to study the behavior of irregular structures resting on sloping ground, considering the different positions of shear wall. The analysis has been performed by Response Spectrum Approach as per IS 1893-2016 using ETabs. Results expose the criticality associated with the sloping angle of ground on irregular structure. Importance of considering the position of shear wall system is also revealed. This study shows that for sloping and levelled ground, irregular building gives susceptible response when earthquake occurs. The results from the study are compared on their dynamic response properties like mode Period, Base Shear, Story deflection, Story drift, and mass participation ratios and also find out the frame vulnerability in irregularities of structure on the sloping ground.

Keywords: Irregular RC Building, Sloping Ground, Shear wall, Drift, Displacement, Time Period, Base Shear.

## 1. Introduction -

Building on sloping terrain has become more common in hilly regions due to the lack of plain land. The mass and rigidity of the buildings in both the horizontal and vertical planes determine how they behave during an earthquake. Step-back and set-back construction methods result in the majority of buildings built on hill slopes being asymmetrical and uneven. Shear, torsion, and uneven column heights within a storey are among the unique structural and constructional issues that these buildings are likely to encounter. These issues cause a significant variance in the stiffness of columns within the same storey. The short column is more likely to sustain damage and is subject to significantly greater lateral stresses. A parametric analysis has been carried out on several buildings using Etabs to highlight the behavioral differences, which may also be influenced by the properties of the locally accessible foundation material. Current building codes, such as IS:1893 (Part 1):2002 and IS:1893 (Part 1):2016, recommend a thorough dynamic analysis of these kinds of structures on various types of soil, including soft, medium, and hard soil. It is crucial to use static or dynamic analysis to forecast the force and deformation demands that severe earth motions will place on structures and their components in order to evaluate the design's acceptability.

Real estate development has intensified in the hilly region due to economic prosperity and growing urbanization. As a result, the hilly region's population density has significantly expanded. Therefore, the development of multi-story structures on hill slopes in and around the cities is in high demand. In hilly areas, buildings with adobe burnt brick, stone masonry, and dressed stone masonry are typically constructed on level ground. There is an urgent need to build on hill slopes because there is relatively little level ground in hilly areas. The only practical option to meet the growing demand for residential and commercial activity is to construct multi-story R.C. Frame structures on a hillside. It has been noted from previous earthquakes that, despite being built to protect residents from natural dangers, buildings in hilly areas have collapsed due to high demand. Therefore, the greatest care should be made to make these buildings earthquake resistant while implementing the practice of multi-story buildings in these mountainous and seismically active places.

The purpose of this study is to compare the positioning of shear walls in multi-story reinforced concrete buildings on sloping terrain. Because seismic stresses are distributed more uniformly in buildings on level ground, design optimizations are comparatively easier. On the other hand, because of the differing heights, constructions on sloping ground experience torsional irregularities, uneven settling, and asymmetrical load distribution. Because of these special circumstances, the location and design of the shear walls must be carefully considered in order to improve the building's seismic performance.

Engineers and designers will be guided toward techniques that improve earthquake resistance by the study's findings, which will offer a substantial grasp of the optimal way to build shear walls in structures with sloping terrain [8]. In order to make buildings stronger and safer and reduce the chance of catastrophic collapses, this research attempts to enhance building standards and design methods in seismically active areas. Critical performance metrics, including as base shear, narrative drift, torsional anomalies, and overall structural response, were analyzed. Finding shear wall sites that reduce torsional impacts and improve earthquake resilience is the aim. The results will help structural engineers create safer structures and help strengthen design standards and guidelines for areas that are vulnerable to earthquakes [9].

## 2. OBJECTIVES OF THE STUDY

Seismic analysis of a R.C. irregular building with varying shear wall locations on sloping land is part of this work. The goals are as follows, taking into account the following factors:

- To examine how multi-story irregular buildings built on sloping terrain behave seismically. Recognize how building performance is impacted by slope-induced anomalies during seismic occurrences.
- To assess how various shear wall locations affect a building's structural reaction on sloping terrain. Examine the best locations for shear walls to increase seismic resistance.
- To assess how well structures with and without shear walls perform seismically on sloping terrain. Examine differences in lateral displacement, base shear, and structural stability.
- To investigate how sloping topography affects plan abnormalities and vertical irregularities brought on by stepped columns or different column heights. Examine its load redistribution patterns and torsional consequences.
- In accordance with applicable seismic codes (such as IS 1893 Part 1), conduct dynamic analysis (Response Spectrum or Time History Analysis). Verify adherence to Indian earthquake-resistant design standards.

To identify the best shear wall design that reduces base shear, displacement, and inter-story drift. Make suggestions regarding design procedures for sloping plots in seismic zones.

## 3. Methodology –

Previous earthquakes have shown that structures with irregular shapes on level ground sustain more damage and collapse. On sloping terrain, however, irregular structures continue to behave as they do. The purpose of this work is to analyze the dynamic properties of these kinds of buildings with varying shear wall locations.

**Model Details –**

Model 1 – G+6 storied building on levelled ground

Model 2 - G+6 storied irregular RC building on sloping ground of an angle 15º

Model 3 - G+6 storied irregular RC building on levelled ground with shear wall at corner at the outer perimeter of the building.

Model 4 - G+6 storied irregular RC building on levelled ground with shear wall at center of the outer perimeter of the building.

Model 5 - G+6 storied irregular RC building on levelled ground with shear wall at the core of the building.

Model 6 - G+6 storied irregular RC building on sloping ground of an angle 15º

Model 7 - G+6 storied irregular RC building on sloping ground of an angle 15º with shear wall at corner at the outer perimeter of the building.

Model 8 - G+6 storied irregular RC building on sloping ground of an angle 15º with shear wall at center of the outer perimeter of the building.

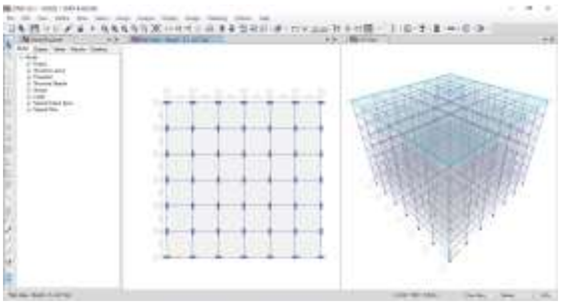
Model 9 - G+6 storied irregular RC building on sloping ground of an angle 15º with shear wall at the core of the building.

For analytical purposes, the dimensions of the slab, columns, and beams are maintained constant. Additional information utilized for analysis came from IS 1893:2016.

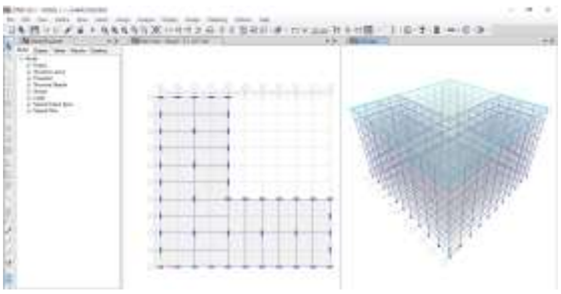
| General Properties | |
|---|---|
| No. of storeys | G+6 |
| Typical Storey Height | 3.1 m. |
| Size of Column | 300 mm x 900 mm |
| Size of Beam | 300 mm x 600 mm |

| | |
|---|---|
| Thickness of Slab | 150 mm. |
| Thickness of Shear Wall | 200 mm. |
| Material Properties | |
| Grade of Concrete | M 30 |
| Grade of Steel Rebar | Fe 550 |
| Type of Loading | |
| Wall Load | 10 KN/m |
| Live Load | 3 KN/$m^2$ |
| Floor Finishing | 1.5 KN/$m^2$ |
| Seismic Details (IS 1893:2016) | |
| Seismic Zone | V |
| Zone Factor | 0.36 |
| Importance Factor | 1 |
| Type of Soil | II - Medium |
| Building Type (R) | 5 (SMRF) |

MODEL 1 -



MODEL 2 -



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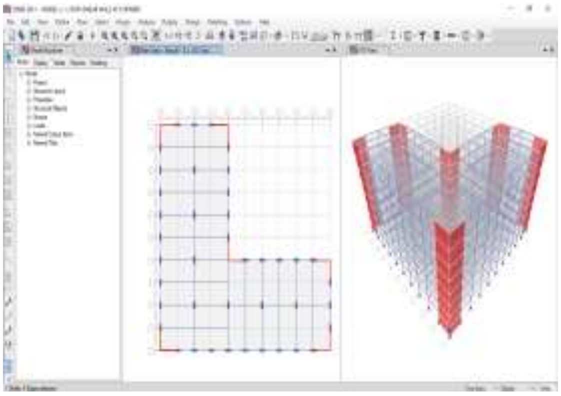

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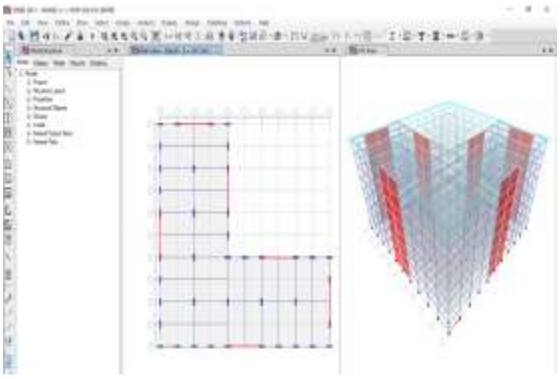

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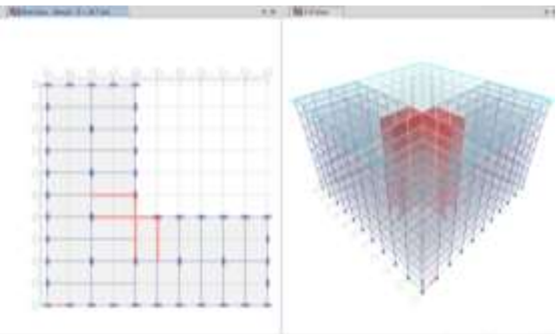

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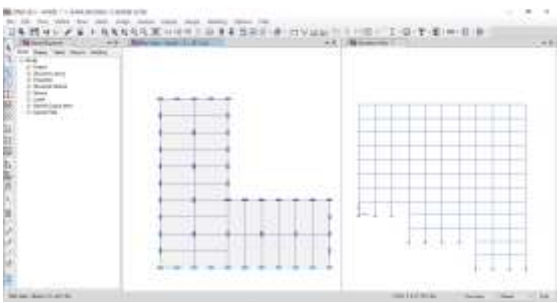

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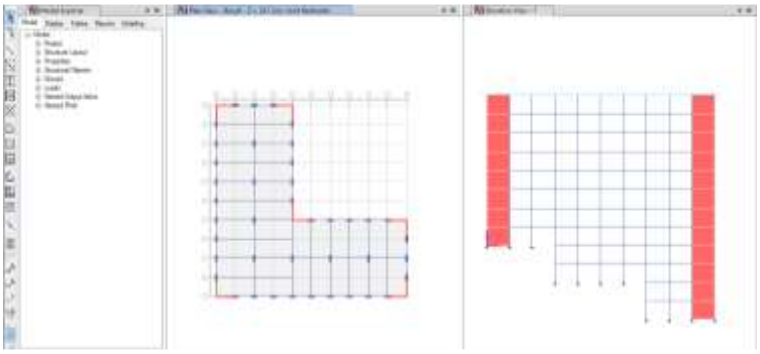

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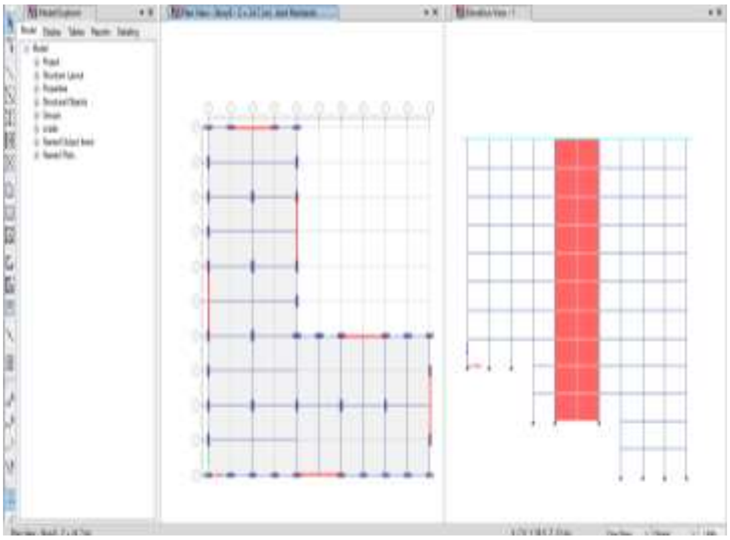

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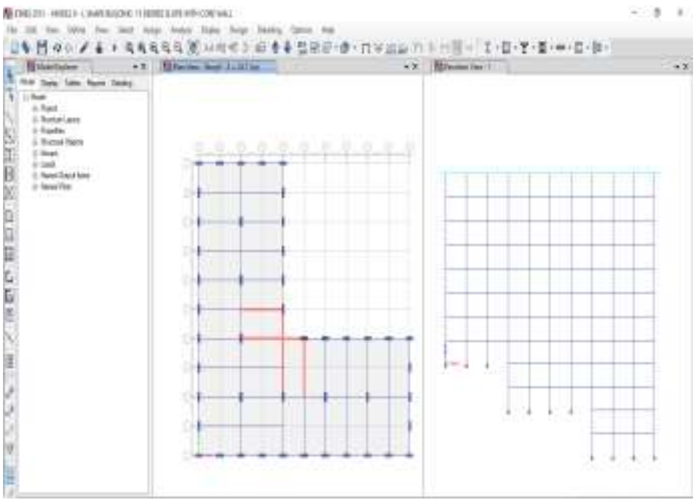
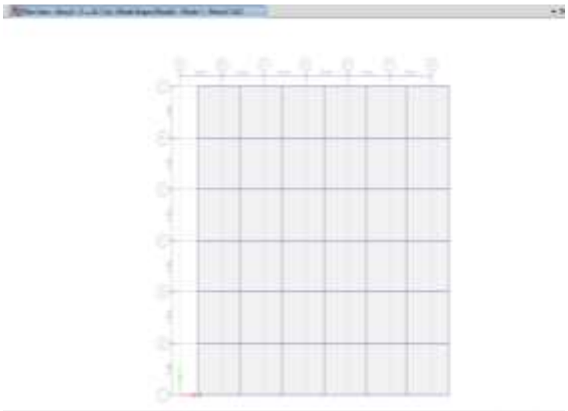


## 4. Results –

MODE SHAPES –

- Deflected Shapes for first three fundamental natural Period for model 1

Mode 1



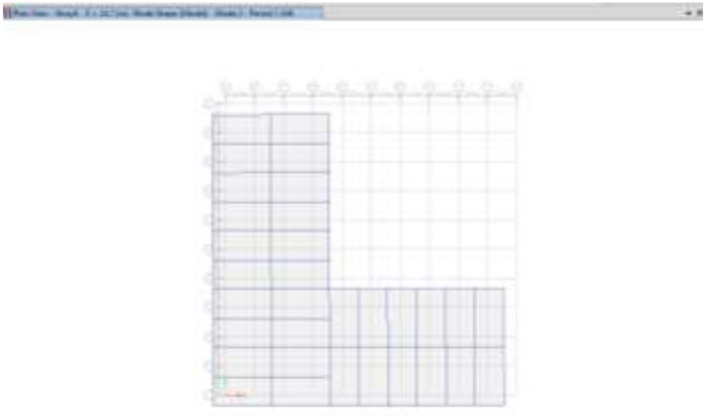
Mode 2

Mode 3

- Deflected Shapes for first three fundamental natural Period for model 2 -

Mode 1

Mode 2



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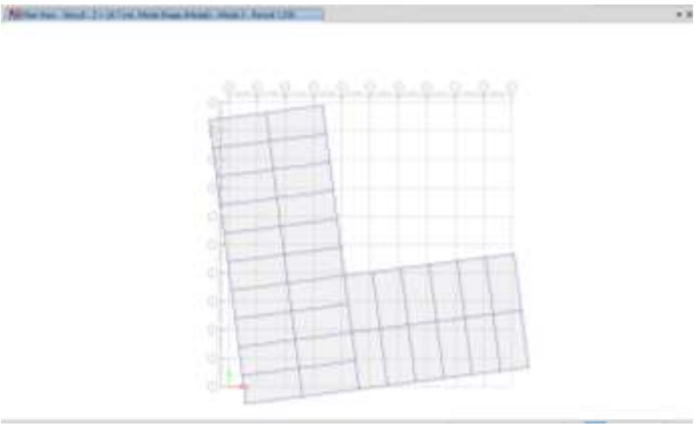
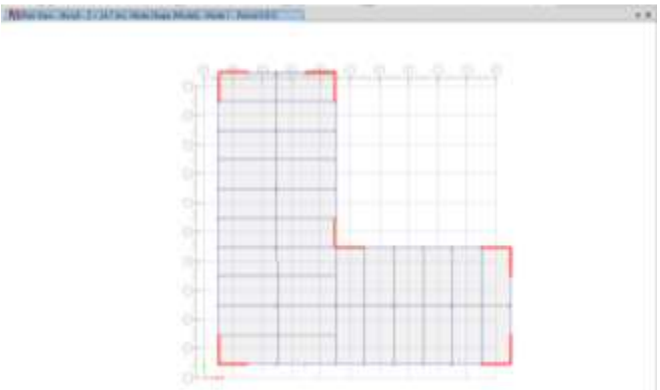


- Deflected Shapes for first three fundamental natural Period for model 3 -

Mode 1



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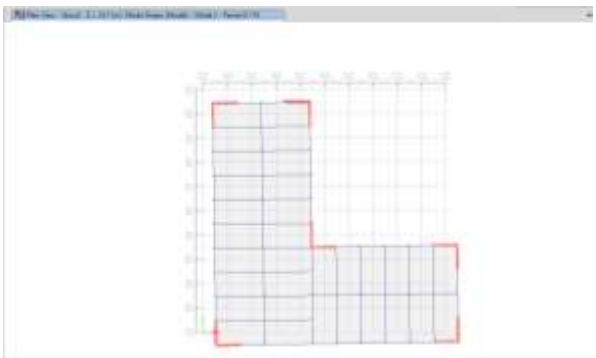
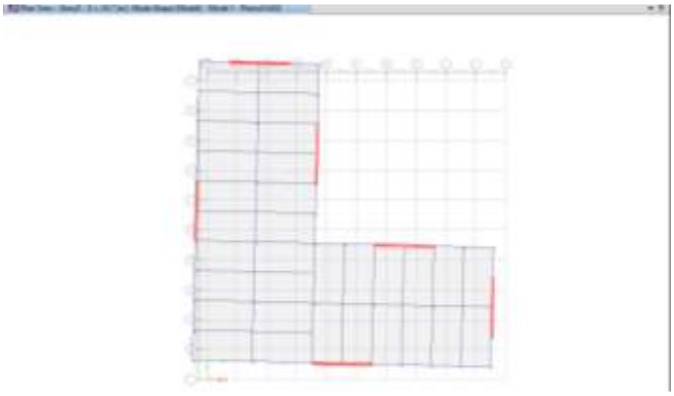


Mode 3

- Deflected Shapes for first three fundamental natural Period for model 4 -

Mode 1



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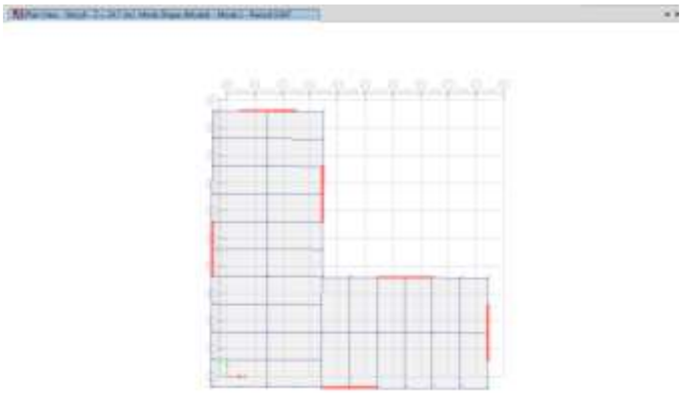

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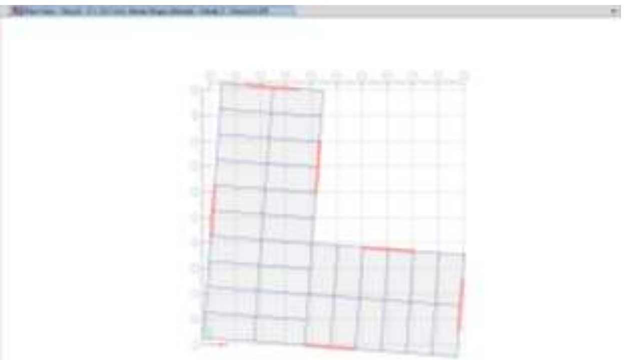
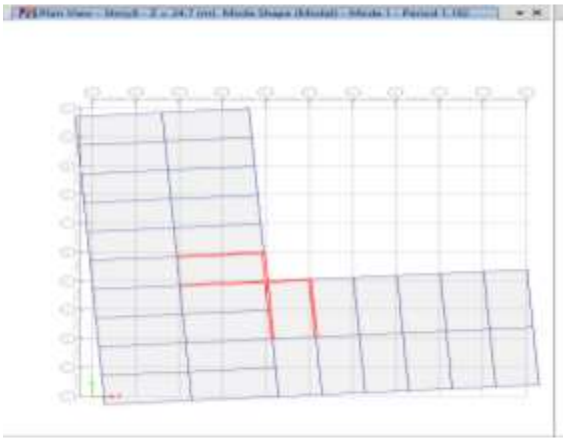


- Deflected Shapes for first three fundamental natural Period for Model 5 -

Mode 1



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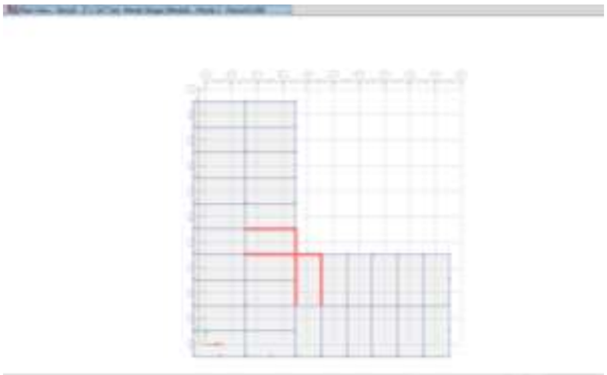

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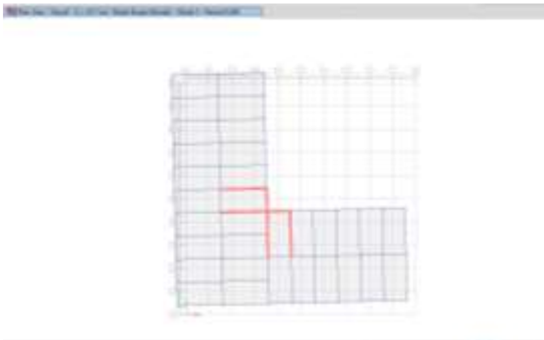
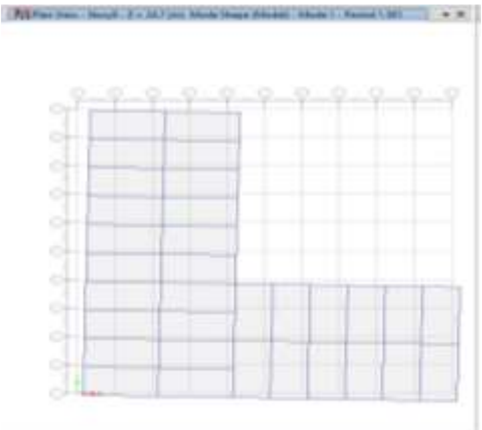


- Deflected Shapes for first three fundamental natural Period for Model 6 -

Mode 1



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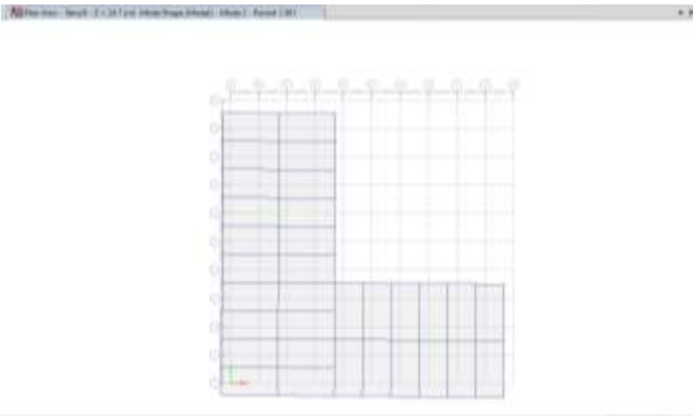

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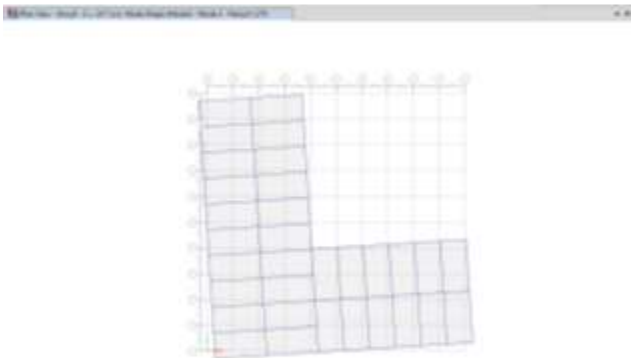
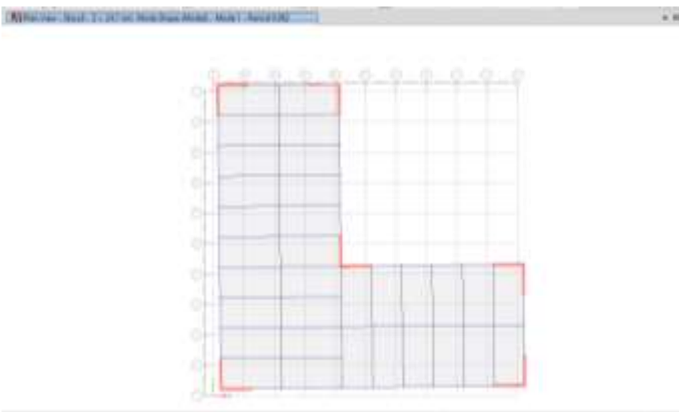


- Deflected Shapes for first three fundamental natural Period for Model 7 -

Mode 1



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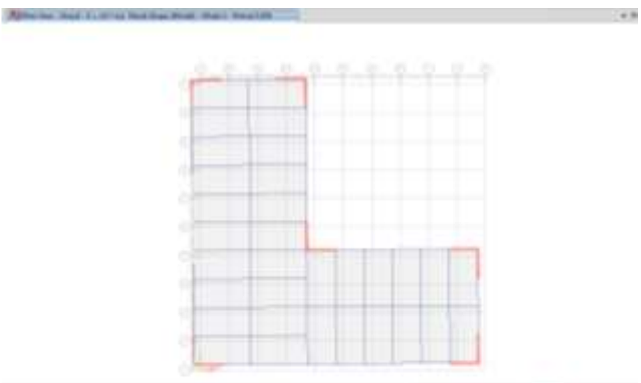
Mode 2



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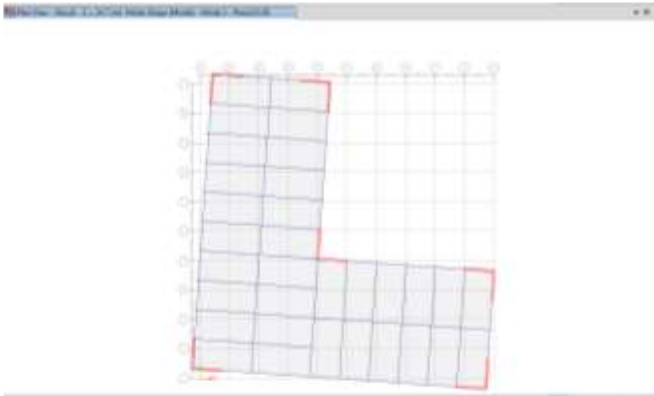

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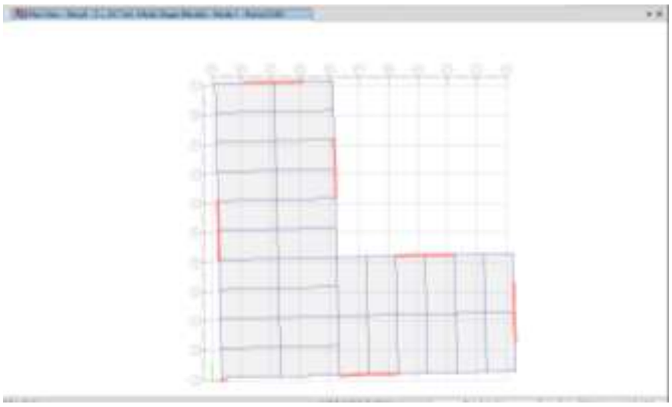
- Deflected Shapes for first three fundamental natural Period for model 8 -

Mode 1



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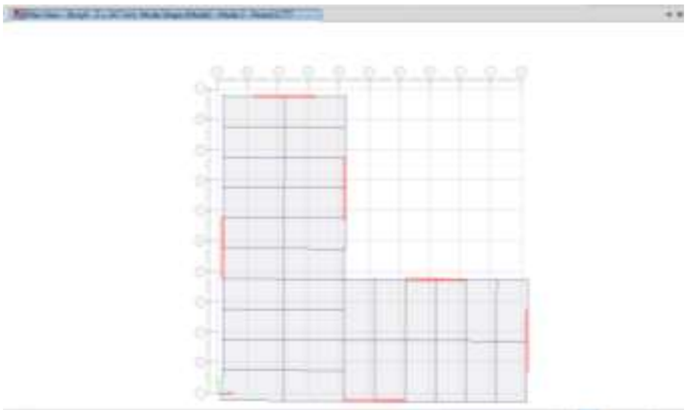

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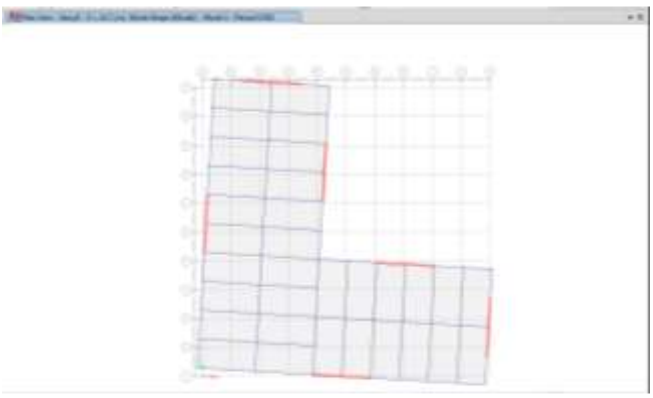
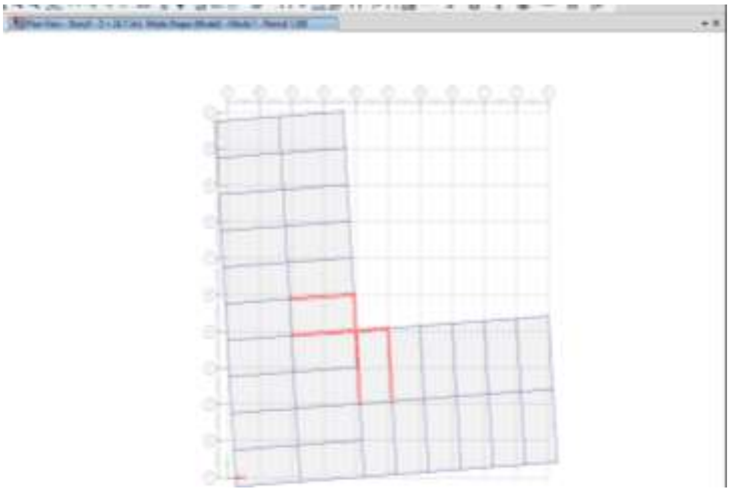


- Deflected Shapes for first three fundamental natural Period for Model 9 -

Mode 1



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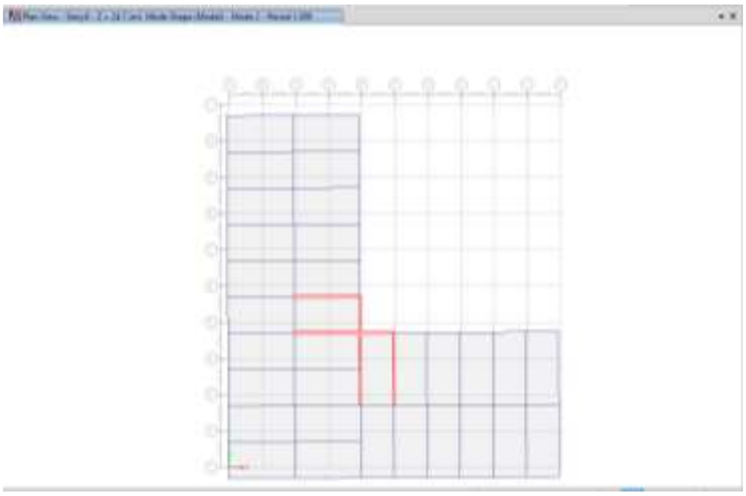

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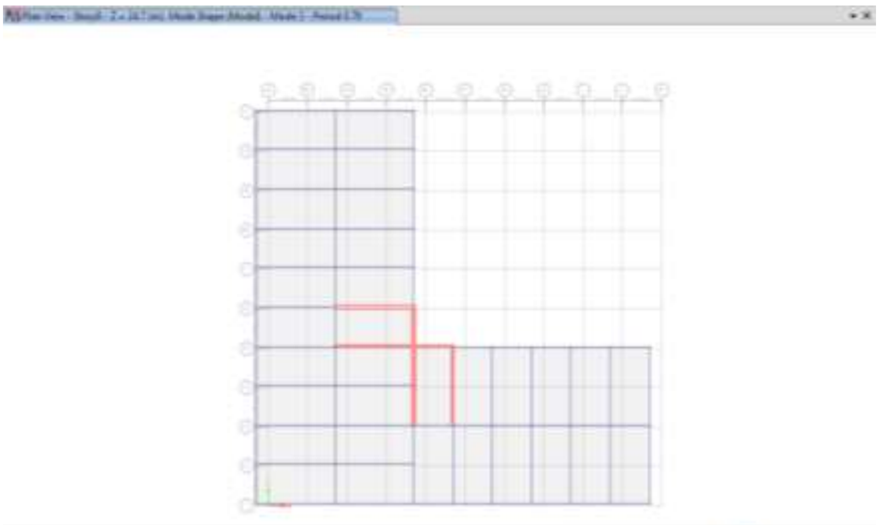
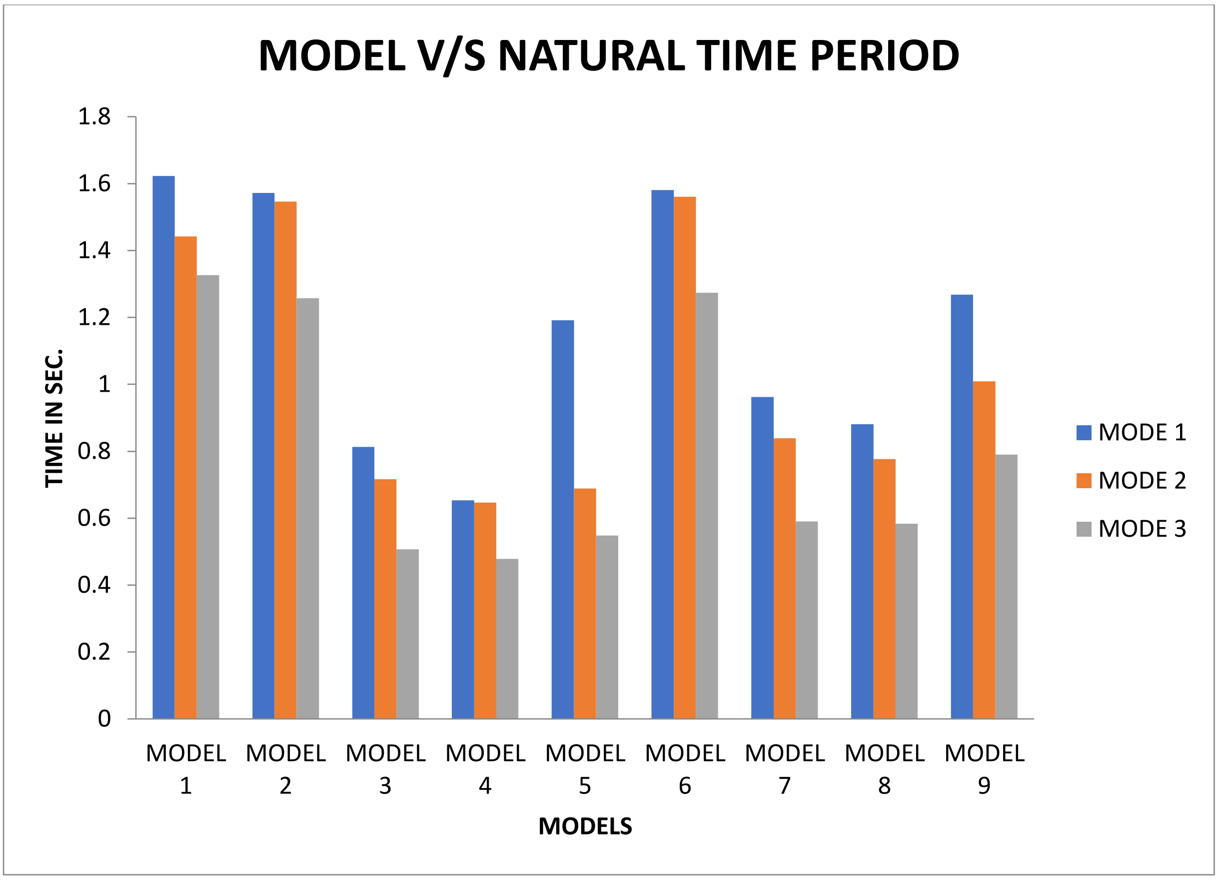
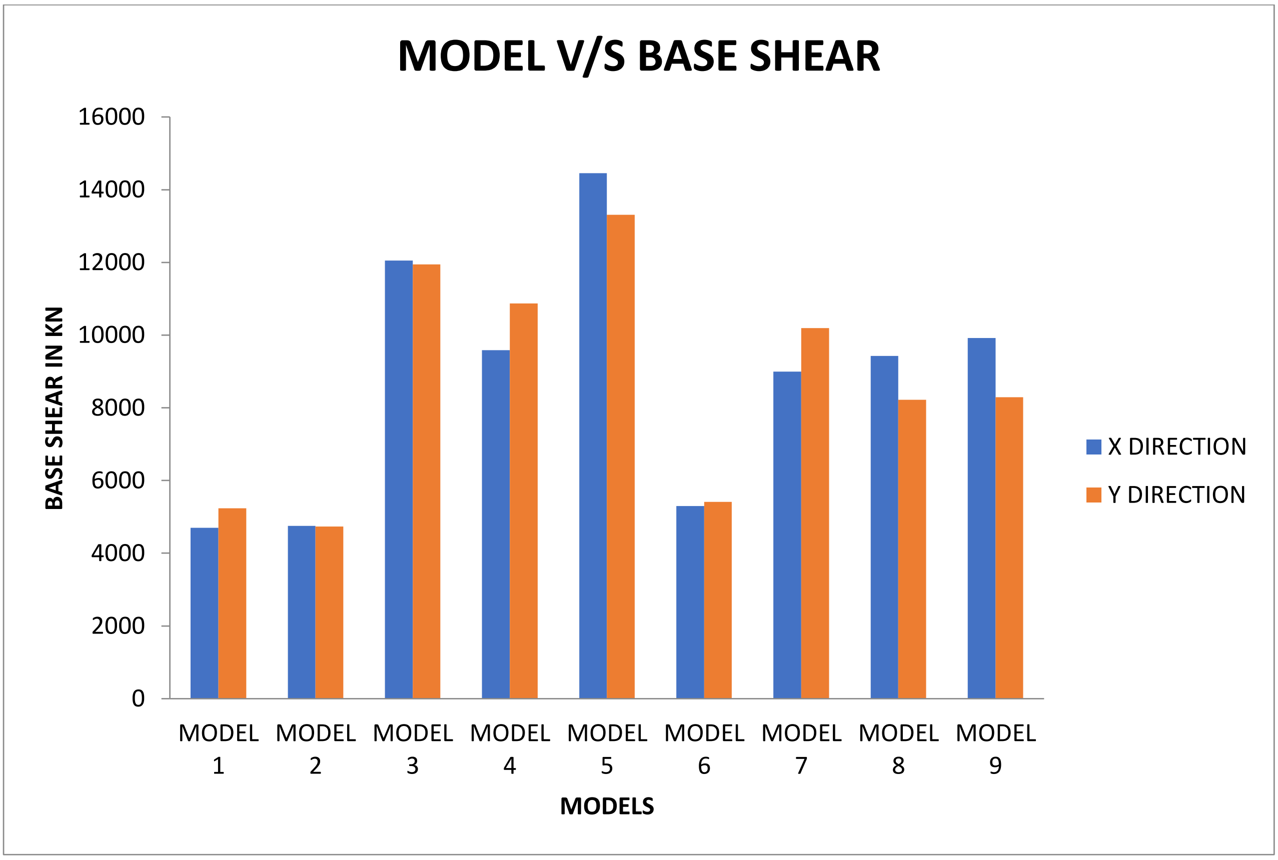


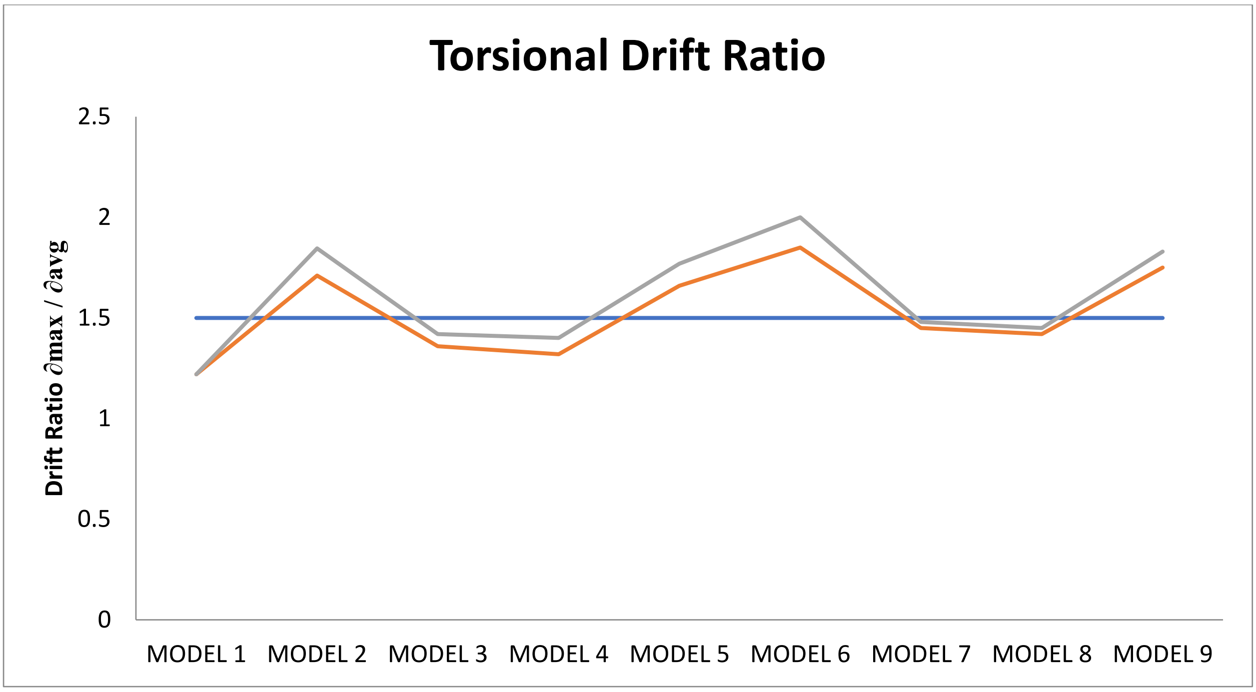
` **Time Period –**



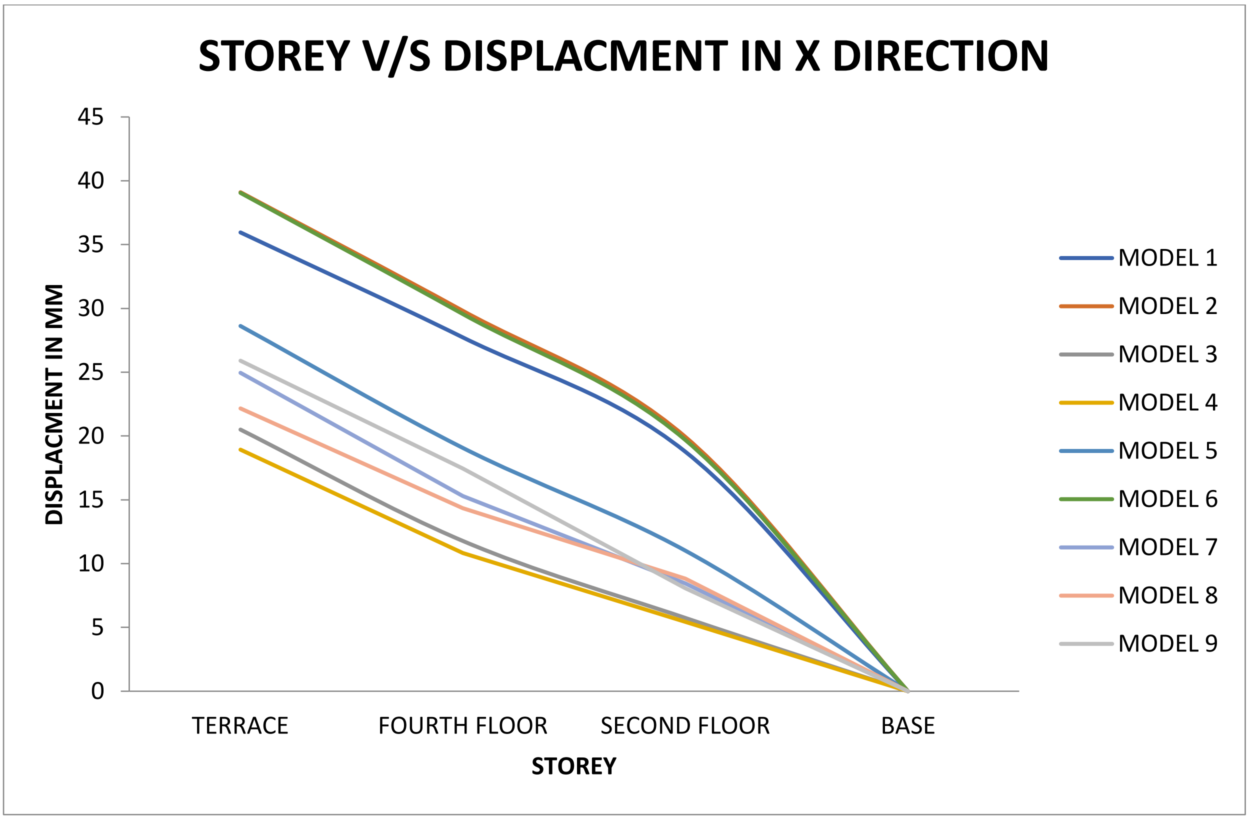

Base Shear

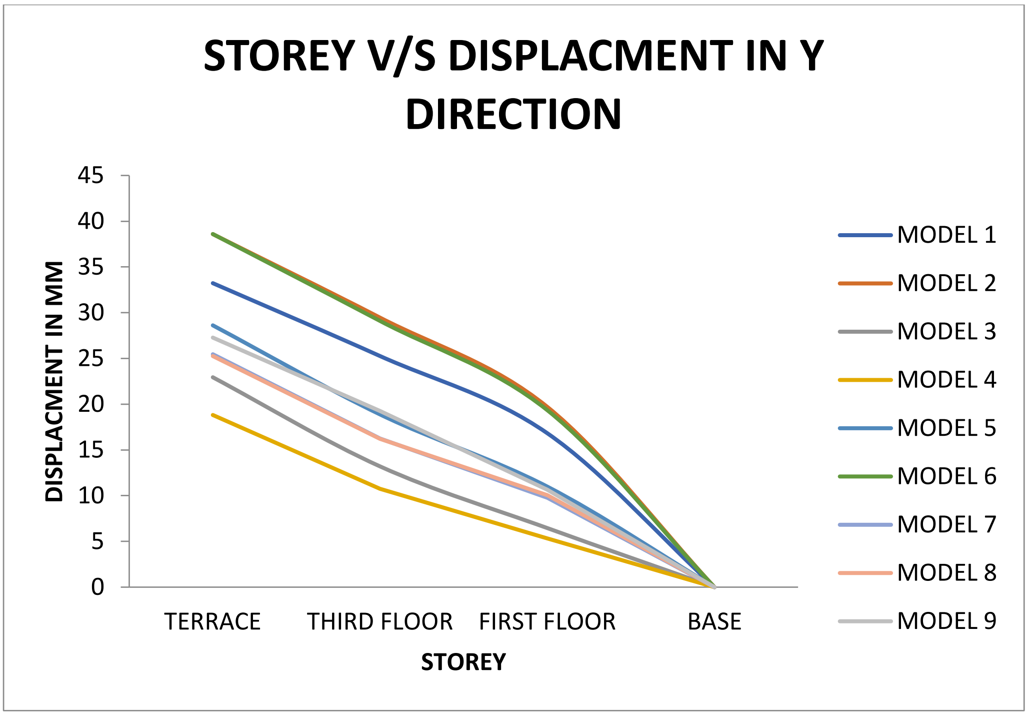


Torsional Drift Ratio

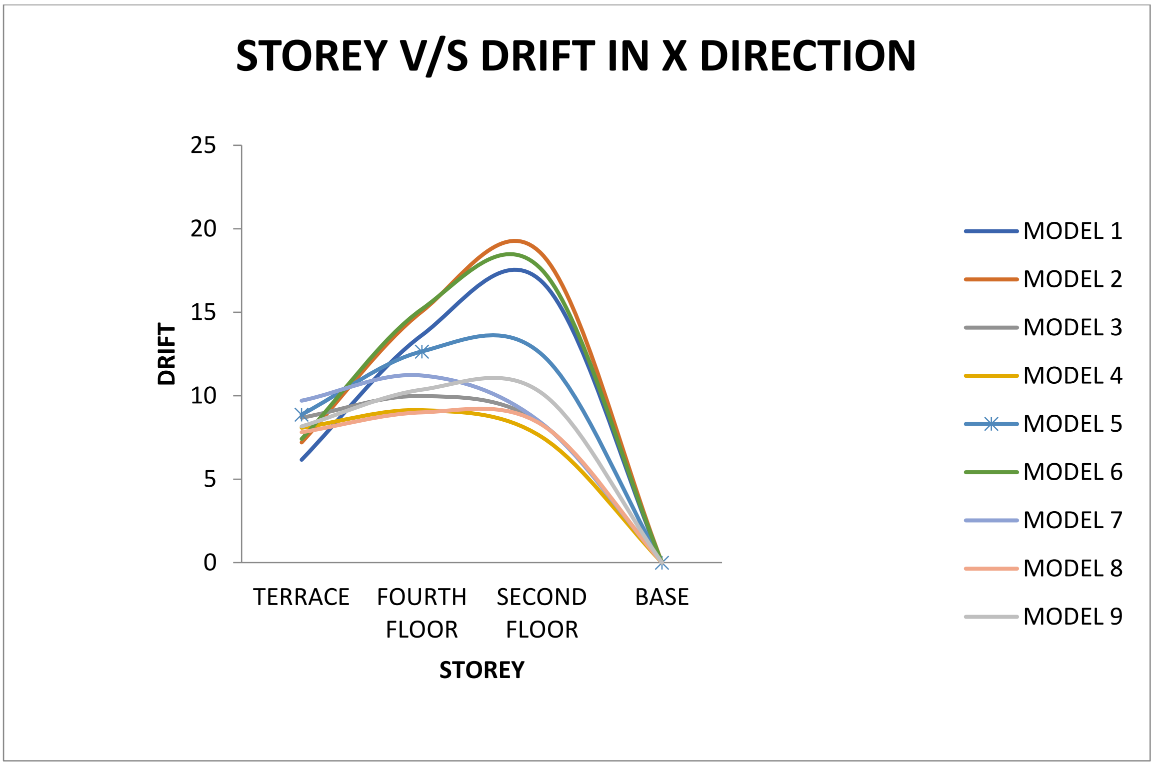



Displacement -




STOREY V/S DISPLACMENT IN Y DIRECTION
DISPLACMENT IN MM
45
40
35
30
25
20
15
10
5
0
TERRACE
THIRD FLOOR
FIRST FLOOR
BASE
STOREY
MODEL 1
MODEL 2
MODEL 3
MODEL 4
MODEL 5
MODEL 6
MODEL 7
MODEL 8
MODEL 9

.Drift


STOREY V/S DRIFT IN X DIRECTION
DRIFT
25
20
15
10
5
0
TERRACE
FOURTH FLOOR
SECOND FLOOR
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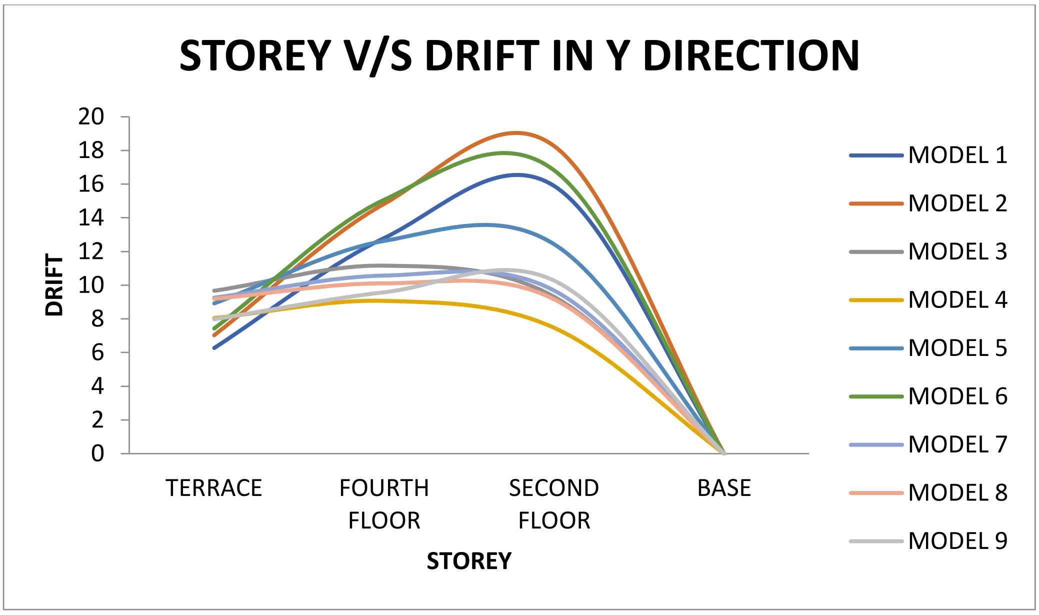
MODEL 5
MODEL 6
MODEL 7
MODEL 8
MODEL 9




## 5. Conclusion –

According to the study mentioned above –

1. The building's Natural Time period value is 8% higher for irregularly shaped buildings than for normal ones.

2. In comparison to leveled land, the time period value increased by 13% for irregular structures situated on sloping ground. Higher frequencies result in greater component displacement, which increases the component's susceptibility to fatigue damage.

3. All of the models' principal modes are translational, with the exception of irregular structures with core walls, which suggests that the core wall's placement is inappropriate for irregular structures and that adjustments are necessary.

4. The mass participation ratios for regular structures are 40% higher than those for irregular structures, indicating that the building's mass and stiffness function as intended.

5. A building lying on level ground experiences less base shear than one resting on sloping land. Base shear increases by 12% in the X direction and 13.5% in the Y direction for buildings that are situated on sloping terrain. The shear wall may be positioned appropriately for such a system since the base shear value is 5% lower for models with the shear wall in the middle of the building's outer perimeter.

6. IS 1893(part-1):2016 states that ΔMax/ΔMin cannot be greater than 1.5. For models with L-shaped structures with shear walls at the center and corners, the permissible torsional irregularity ratio was found to be below the allowable limit. This suggests that when designing such structures in seismically active areas, the proper placement of the shear wall is also a crucial consideration.

7. Because of the change in the stiffness of the support, the top storey displacement for irregular structures increased by 10% compared to regular structures, but the value reduced by 8% compared to the structure on sloping ground.

8. Because of the uneven height and lateral stiffness supported by beams, the storey drift additionally increases by 15% when a slope gradient is involved.

9. Because it increases their stiffness, hilly buildings respond effectively when bottom ties are used as a beam element and shear walls are introduced up to the bottom base of the slope.

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