Comparative Analysis of RC Framed Structures under the Effect of Sloping Ground with Setback Configurations under Seismic Conditions - A Review

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Abstract — Since the population of world increases drastically from last few decades, due to this there is scarcity of land. In such conditions, most of the population have been located in hilly areas. Utmost of hilly regions in northern India where seismic actions are common, buildings are mandatory to be erected on sloping ground due to insufficiency of plain land. And in hilly regions, due to sloping land most of the structures has been constructed with step back and set back configurations. Such building having these configurations in hilly areas are much more susceptible to seismic environment. These building are generally irregular or torsion ally coupled and hence liable to severe damage when affected by earthquake ground motion. The main purpose of this study is to perceive the behaviour of such buildings with different configurations like step back and setback under sloping or levelled ground which helps structural engineer to understand its sustainability, its behaviour, its response against lateral and is to review further technologies for seismic damage which help to prevent or control the seismic damage. In this study, analysis of building located in hilly areas with varying sloping ground conditions with step back and setback configurations compared with the building on levelled ground, by using response spectrum method as per IS1893-2016 using ETabs has been carried out. This study helps to identify the response & behaviour for sloping and levelled ground, step back-setback building in severe earthquakes.

Keywords: Set Back Building, Step Back Building, Sloping Ground, Seismic Analysis, Levelled Ground, ETABS

I. INTRODUCTION

The insufficiency of plain ground in hilly areas has led to construction on sloping ground. The behaviour of building during earthquake depends on the mass and stiffness in both horizontal and vertical planes of the buildings. Most of the buildings constructed on hill slopes are irregular and asymmetric due to step back and set back type construction. Such buildings are disposed to have special structural and constructional difficulties such as shear, torsion and unequal column heights within a storey, which consequences in drastic distinction in stiffness of columns of the same storey. The short column attracts much higher lateral forces and is prone to damage. In order to highlight the differences in behaviour, which may further be influenced by the characteristics of the locally available foundation material, a parametric study has been conducted on five different buildings i.e step back and step back-set back buildings using SAP 2000. Indian Standard building codes including IS:1893 (Part 1):2002 and IS:1893 (Part 1):2016 propose detailed dynamic analysis of these type of buildings on different soil (hard, medium and soft soil) types. To asses' acceptability of the design it is important to predict the force and deformation demands imposed on structures and their elements by severe ground motions by means of static pushover analysis.

The monetary growth & rapid suburbanization in hilly region has enhanced the real estate expansion. Due to this, population density in the hilly region has amplified immensely. Therefore; there is prevalent & tenacious demand for the construction of multi - storey buildings on hill slope in and around the cities. Since level land in hilly regions is very inadequate, there is an insistent demand to build buildings on hill slope. Hence construction of multi-storey R.C. Frame buildings on hill slope is the only practicable choice to lodge growing demand of residential & commercial activities. It is observed from the past earthquakes, buildings in hilly regions have proficient high degree of demand leading to fall though they have been designed for safety of the occupants against natural hazards. Hence, while implementing practice of multi -storey buildings in these hilly & seismically vigorous areas, extreme care should be taken, constructing these buildings earthquake resistant.

II. OBJECTIVES OF THE STUDY

This study comprises of dynamic seismic analysis of a R.C. building considering the following aspects:

1) In the present work, Dynamic analysis has been regulated. In dynamic analysis Response Spectrum Analysis (RSA) is carried out.
2) Analysis is carried out on five different buildings located in hilly areas with different slopes of ground and compared with building located on levelled ground.
3) The Response Spectra as per IS 1893 (Part 1):2016 for medium soil is used.
4) The effect of sloping conditions on structural behaviour has been observed on the basis of time period, mass participations ratios, drift, displacement & base shear.

III. METHODOLOGY

It is observed from past earthquakes that the buildings on slopes serve more damage and collapse occurs. This paper aims to analyse the dynamic characteristics of these type of buildings with three different configuration such as a) Regular Building b) Step back & c) Step back-Setback

Model Details –

- Model 1 – G+5 storeys building on levelled ground
- Model 2 - G+5 storeys building on levelled ground with setback configuration
- Model 3 - G+ 5 storeys building on sloping ground of an angle 5^{o}

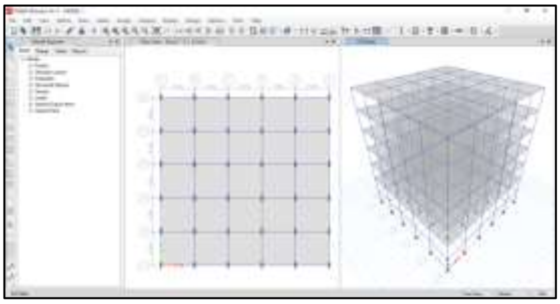
– Model 4 - G+ 5 storeys building on sloping ground of an angle 5º with setback configuration
– Model 5 - G+ 5 storeys building on sloping ground of an angle 10º
– Model 6 - G+ 5 storeys building on sloping ground of an angle 10º with setback configuration
– Model 7 - G+ 5 storeys building on sloping ground of an angle 15º
– Model 8 - G+ 5 storeys building on sloping ground of an angle 15º with setback configuration
– Model 9 - G+ 5 storeys building on sloping ground of an angle 20º
– Model 10 - G+ 5 storeys building on sloping ground of an angle 20º with setback configuration
– Model 11 - G+ 5 storeys building on sloping ground of an angle 25º
– Model 12 - G+ 5 storeys building on sloping ground of an angle 25º with setback configuration

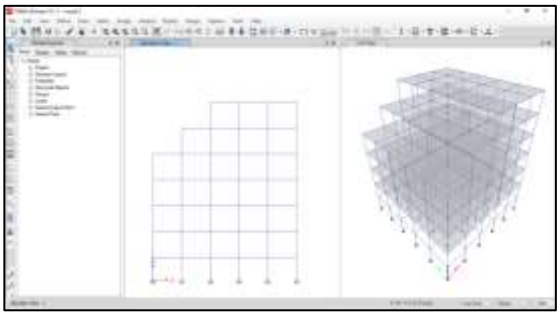
IV. MODELLING DESCRIPTION

The space frame has been modeled in E-Tabs software. The descriptions of the structure are listed in Table below. The connections between all the members are assumed to be fixed. The arrangement idealization and member segment property details of all cases are shown in Table below. Various plans and 3D views are shown in subsequent figures. Since when using E-Tabs software, user has to define the properties to tell the software that which material is going to use with its size in a particular model. Such properties which are used in this work are mentioned below: -

General Properties	
No. of storeys	G+5
Typical Storey Height	3.6 m.
Size of Column	300 mm x 900 mm
Size of Beam	300 mm x 450 mm
Thickness of Slab	150 mm.
Thickness of Wall	230 mm.
Material Properties	
Grade of Concrete	M 30
Grade of Steel Rebar	Fe 500
Type of Loading	
Wall Load	13.5 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)

Table 1: Description of parameters taken for analysis


MODEL – 1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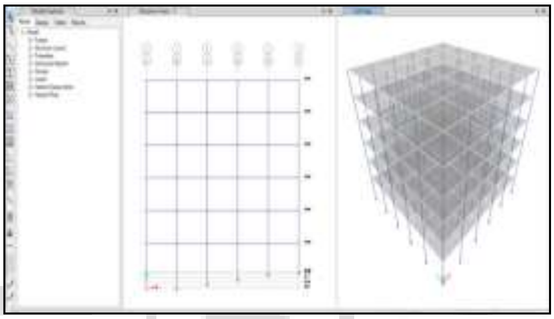
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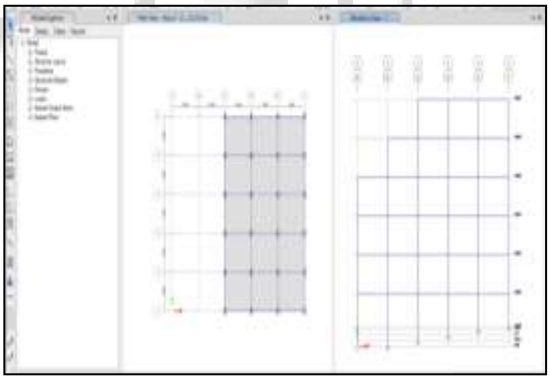
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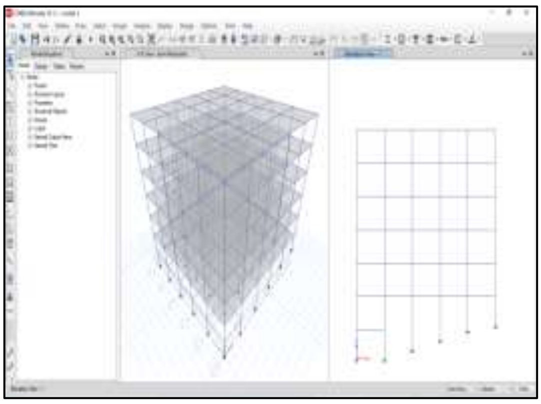
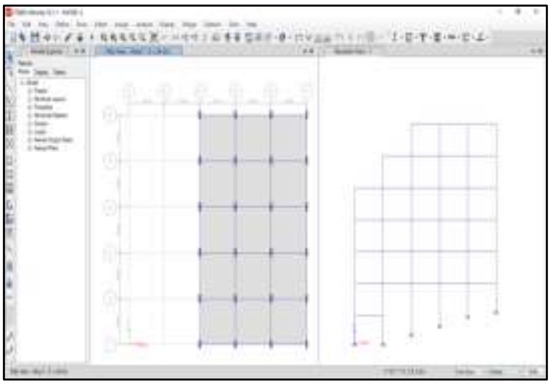
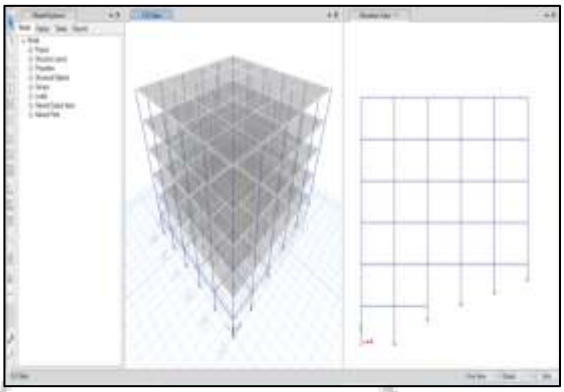
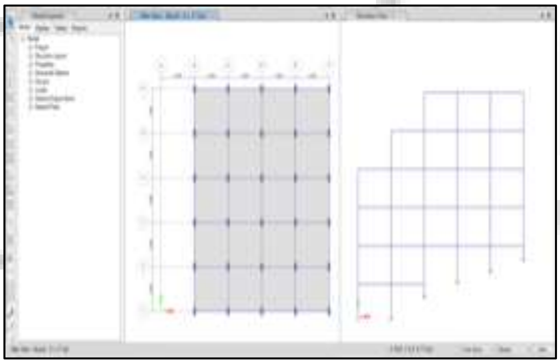

MODEL – 5



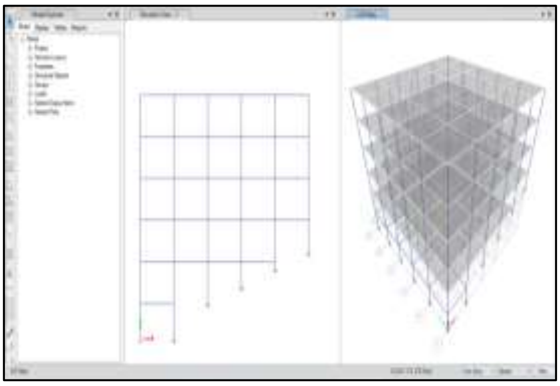
MODEL – 6



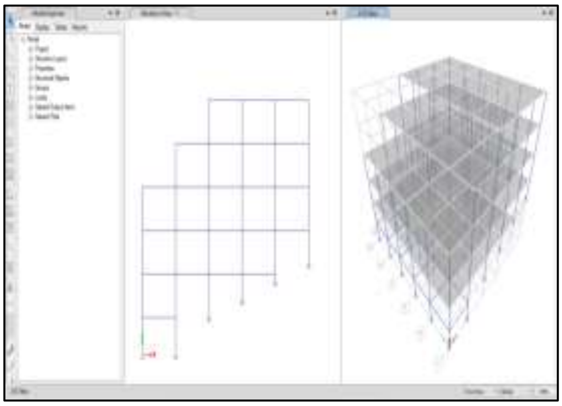
MODEL – 7



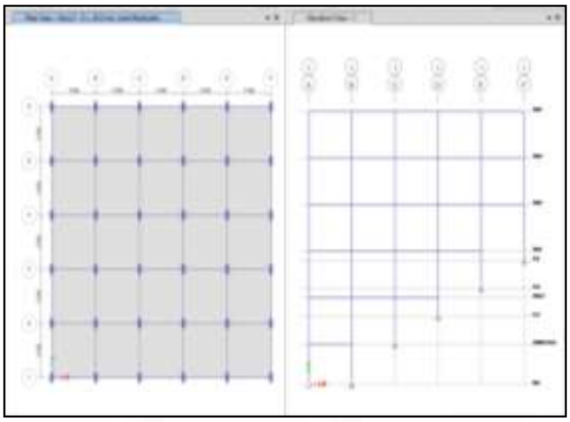
MODEL – 8



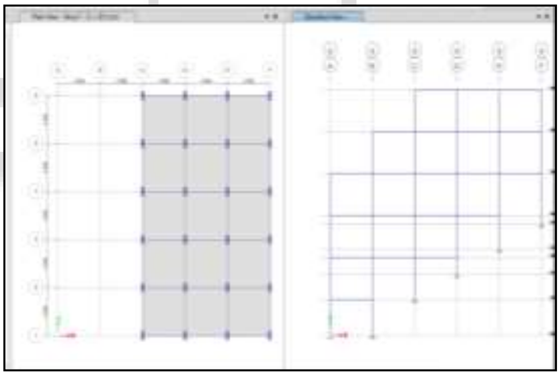
MODEL – 9



MODEL – 10

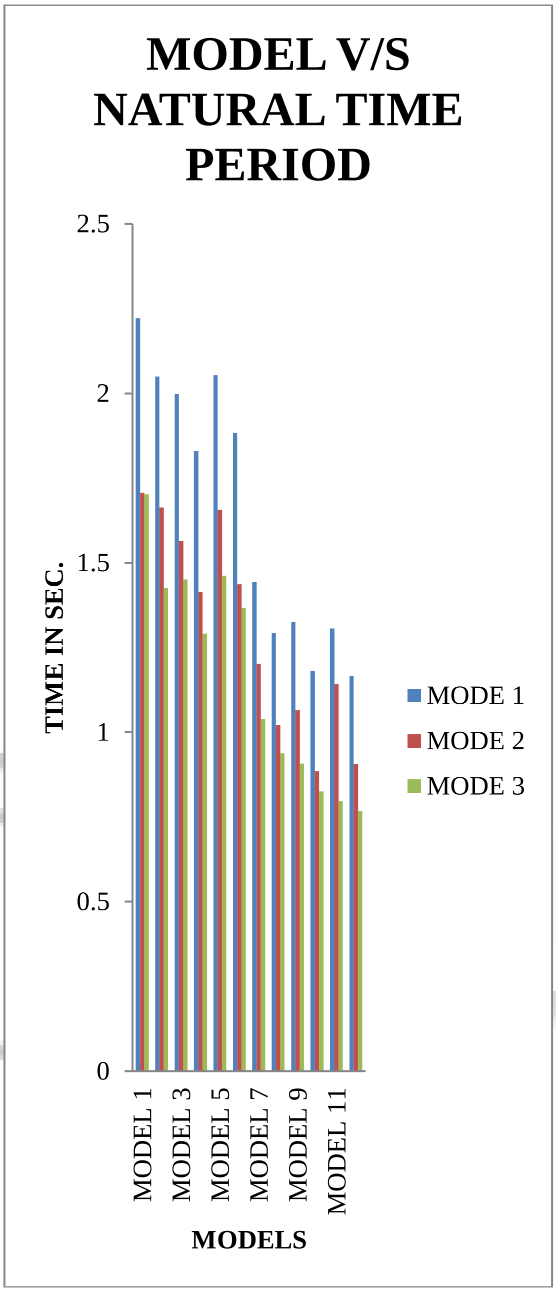


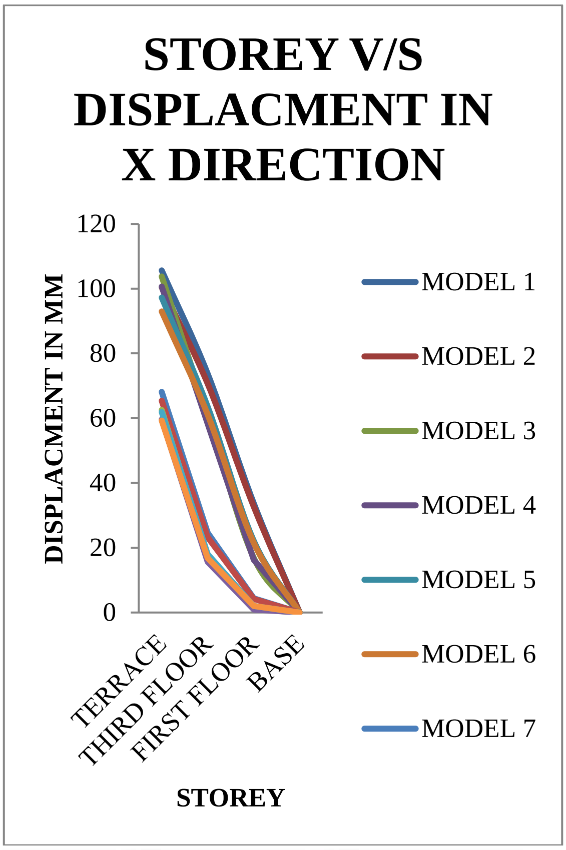
MODEL – 11

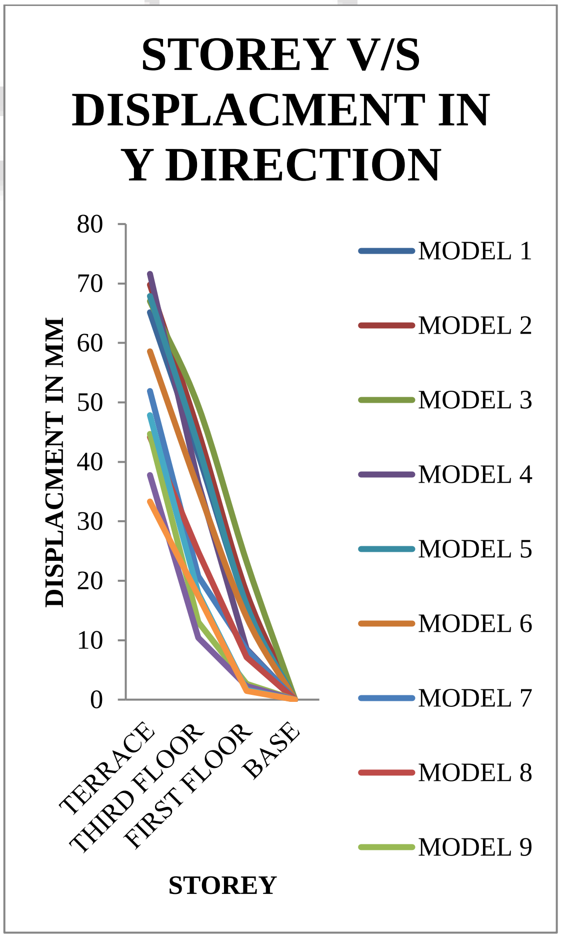


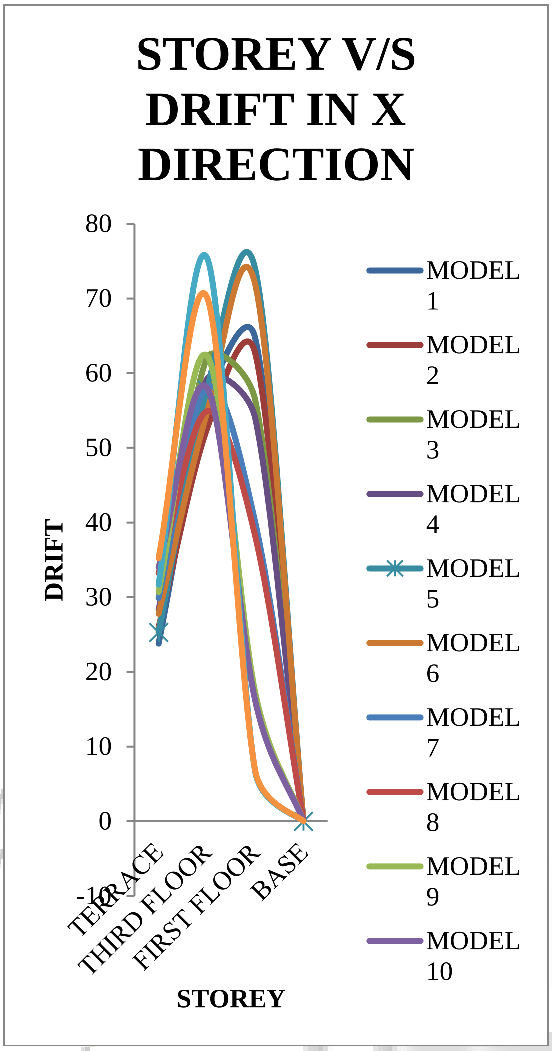
MODEL – 12

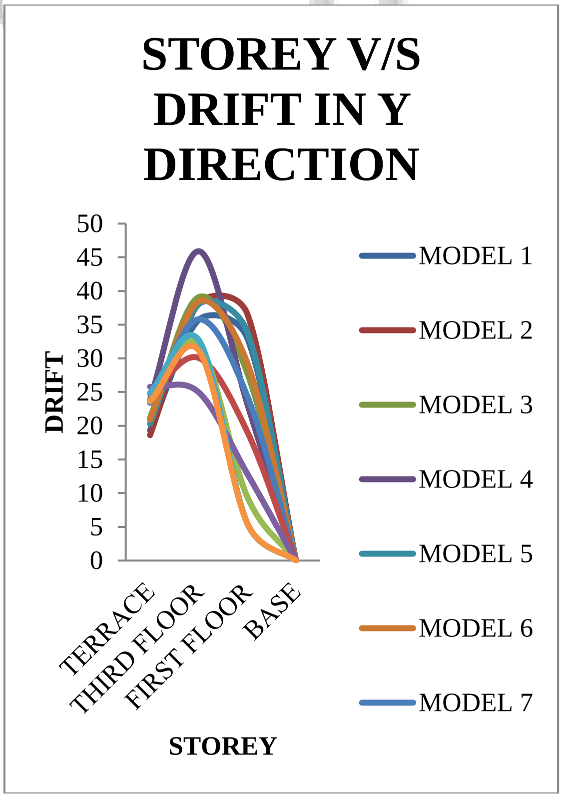
V. RESULTS

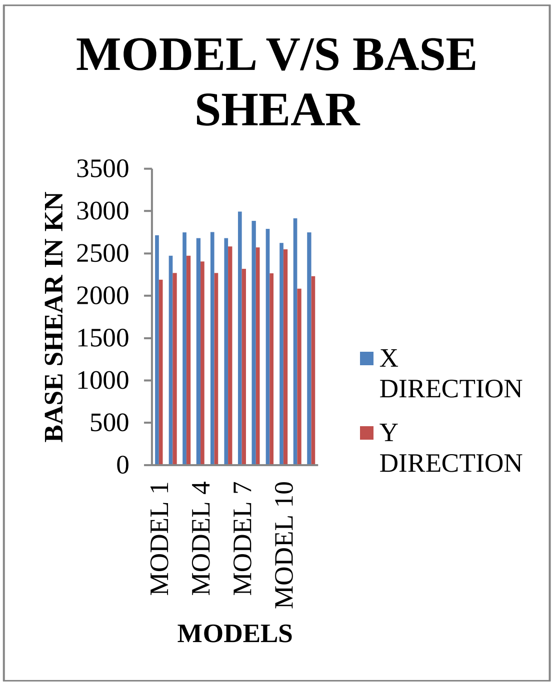

MODEL V/S NATURAL TIME PERIOD
TIME IN SEC.
2.5
2
1.5
1
0.5
0
MODEL 1
MODEL 3
MODEL 5
MODEL 7
MODEL 9
MODEL 11
MODELS
MODE 1
MODE 2
MODE 3


STOREY V/S DISPLACMENT IN X DIRECTION
DISPLACMENT IN MM
120
100
80
60
40
20
0
TERRACE
THIRD FLOOR
FIRST FLOOR
BASE
STOREY
MODEL 1
MODEL 2
MODEL 3
MODEL 4
MODEL 5
MODEL 6
MODEL 7


STOREY V/S DISPLACMENT IN Y DIRECTION
DISPLACMENT IN MM
80
70
60
50
40
30
20
10
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







VI. CONCLUSION

The results obtained for the building carried out through response spectrum analysis approach. Following conclusions are made on the basis of the study –

1) Base shear of building resting on plain ground is less than that of building resting on sloping ground. For building resting on sloping ground, base shear is increased by 2% in X direction and 3.5% in Y direction with respect to the increase of 5º in slope. Base Shear of setback building is less than that of step-back building.
2) As the slope of ground increases base shear, top storey displacement decreases as it gives less movement structure due to the stiffness of support. But after the slope of 20 degree, the value of displacement increases due to low values of stiffness of short columns.
3) The storey drift also increases with the increase of slope gradient up to the 25 degree due to uneven height and lateral stiffness supported by beams.
4) Natural Time period of the building also decreases with the increment in the slope of ground. Due to which the natural frequency of the structure is high which is not desirable as the higher frequencies have higher displacement of the component which incurs higher fatigue damage to the component.
5) Time period of step-back building resting on plain ground decreases by 7.5 % than that of setback building and for sloping ground it is 8 %. Time period of building resting on sloping ground is decreased by 7% than building resting on plain ground
6) Top storey displacement of setback building is less than that of step-back building.
7) Use of bottom ties gives effective response of hilly building, it gives them higher stiffness.

VII. RECOMMENDATION

In sloping or hilly areas, structures are subjected to more vulnerable to seismic forces. 25 degree sloped frame experiences maximum storey displacement due to low value of stiffness of short column while the 5 degree frame experiences minimum storey displacement. The base shear of all the buildings are nearly the same with little variations but their distribution on columns of ground storey is such that the short column attracts the majority (75% approx.) of the shear force which leads to plastic hinge formation on the short column and are vulnerable to damage. Proper design criteria should be applied to avoid formation of plastic hinge. Hence it is necessary to design such structures with bottom ties and without set back as it incurs less damage to the structure.

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