# BEHAVIOUR OF MULTI STOREY BUILDINGS LOCATED ON SLOPING GROUND SUBJECTED TO LATERAL LOADS.

[1]CHAITRA H R,[2] Dr. VIJAYA GS
[1]PG Student, Dept. of civil Engineering, GSKSJTI, Bengaluru-560001, Karnataka, India
[2]Associate professor, Dept. of civil Engineering, GSKSJTI, Bengaluru-560001, Karnataka, India

***Abstract :*** As the cities are developing day-by-day, demand for the plain land has also increased. Due to urbanization there is shortage of availability of plain land for the construction therefore the demands of multi-storey buildings on hilly areas are increased. The main objective of this paper is to Study the behavior of multi-storey buildings when it is subjected to lateral loads such as Static load and time history load. Here I considered multi-storey buildings (20 storey), resting on gradually sloping ground with 45° and Steep slope condition with bare frame, with bracing and with shear wall. Further the behavior is also studied for lateral loads applied in different directions, i.e positive X, positive Y, negative X & negative Y. Modelling is done in ETABS software. Equivalent Static Analysis and time history analysis as per IS 1893-2000 is carried out to know the response of the buildings and the results are compared in terms of story displacement, base shear, story drifts and fundamental time period and are tabulated.

***IndexTerms* - Bare frame, Bracing, Equivalent Static Analysis, ETABS, Step-Back Building, Steep slope, Time history analysis, Shear wall**.

## 1. Introduction

In the present scenario, there is no availability of plain land due to several reasons. There are many instances, there will be an improvement of single city due to some factors and this leads to migration of population and expansion of cities results in lesser land availability for living space. In this case, there is solution to go for a multi storey construction. In our study we are interested to study the seismic behavior of the structures constructed on hilly areas. However, construction of structure on hilly region is not easy as on plain ground. However, the structures intended to construct over hilly areas are to be studied thoroughly and designed carefully. These buildings whether they are on sloping ground or on plain ground they are vulnerable for earthquake. Compare to the plain ground the earthquake effect is more in the sloping ground, so study of the seismic loading on R C building rested on sloping ground is necessary to understand effect caused on building during the earthquake.

Structures constructed in hilly areas have peculiar structural configurations. Successive floors of such buildings step back towards the hill slope as shown in the Figure1. The stepping back of building towards hill slope results in unequal column heights in the same story, which causes severe stiffness irregularities in along and across-slope directions. Another important type of structural form is the structure founded on hills is sudden slope of steep cuts as shown in Figure2. Here the founding levels will be at different levels, they may be one at the base of downhill and another at the road level.

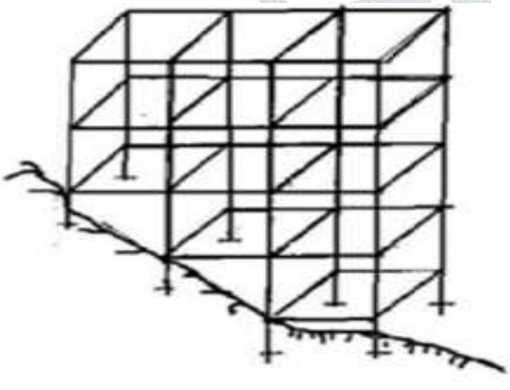

**Figure 1** Step-Back building on Sloping ground

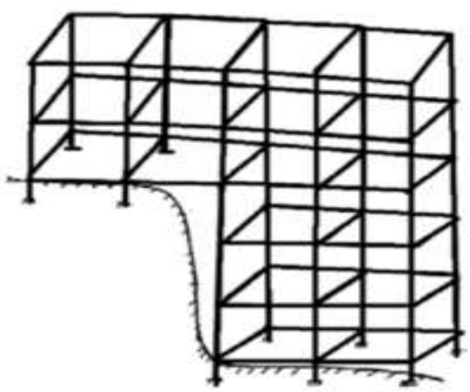

**Figure 2** Building configurations at vertical cuts Or steep slopes.

## 2. Materials and methods

*2.1 Preliminary data*

- 20 storey multi-storied building is analyzed here with storey height of 4m gradual slope of 45° is considered.
- Building Configurations that are consider here are Step-back Building on gradual sloping ground & building on vertical cuts.
- Seismic analysis of buildings is carried out by Equivalent Static Analysis and time history analysis as per IS1893-2000.
- In the analysis Zone III, SMRF and I=1 are considered. For this study ETABS Software used.

*2.2 Structural modelling*

The models are designated as Step Back Building.
Model 1 - Building on Sloping Ground.
Model 2 - Building on Sloping Ground with bracing.
Model 3 - Building on Sloping Ground with Shear wall.
Vertical Cuts.
Model 4 - Building on vertical cut or steep slope.
Model 5 - Building on steep slope with bracing.
Model 6 - Building in steep slope with shear wall.

## *3.* Methodology

The modelling is carried out using FEM based software ETABS, while the steps included in modelling are listed below.
Finalizing Grid data & Storey data.
Defining - Materials
Defining Frame sections & area Sections.
Defining Load Cases & Load combination.
Defining Mass source.
Draw Beam, Columns, and slabs.
Assigning support restrains.
Assigning Loads.
Analysis.
Result Extraction.

**Table 1** Building Description

| Sl. No. | Description | Data |
|---|---|---|
| 1. | Seismic Zone | III |
| 2. | Seismic Zone Factor (Z) | 0.16 |
| 3. | Importance Factor (I) | 1.0 |
| 4. | Response Reduction Factor (R) | 5 |
| 5. | Damping Ratio | 0.05 |
| 6. | Soil Type | Medium Soil (Type II) |
| 7. | Height of the building | 80m (20storey) |
| 8. | Story to story Height | 4.0m |
| 9. | Span Length | 4.0m |
| 10. | Column Size used | Concrete 375x375mm |
| 11. | Thickness of Slab | 150mm |
| 12. | Floor Finish | 1.5KN/m$^2$ |
| 13. | Live Load | 4.0KN/m$^2$ |
| 14. | Grade of Concrete (fck) | M 45 |

| | | |
|---|---|---|
| 15. | Grade of Structural Steel (fys) | Fe 350 |
| 16. | Grade of Reinforcing Steel (fyr) | Fe 500 |

*3.1 Modelling Description*

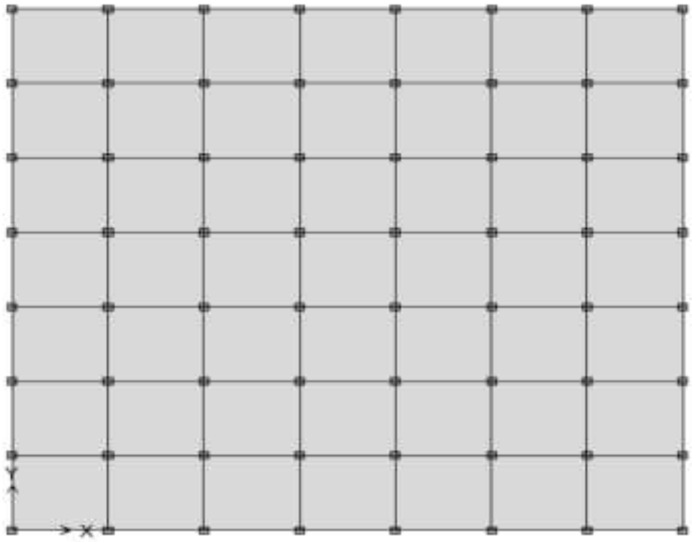


**Figure 3** Plan View

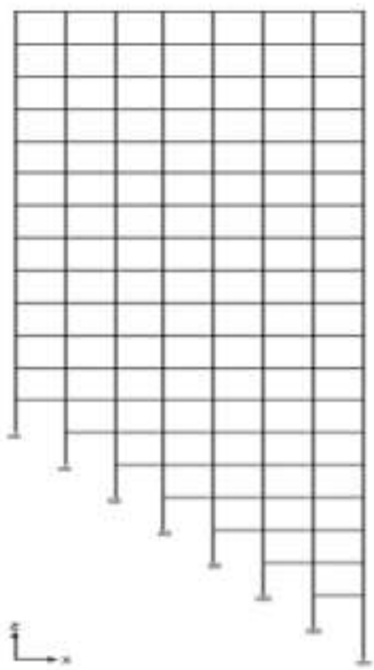

**Figure 4** Model 1-Building on Sloping Ground

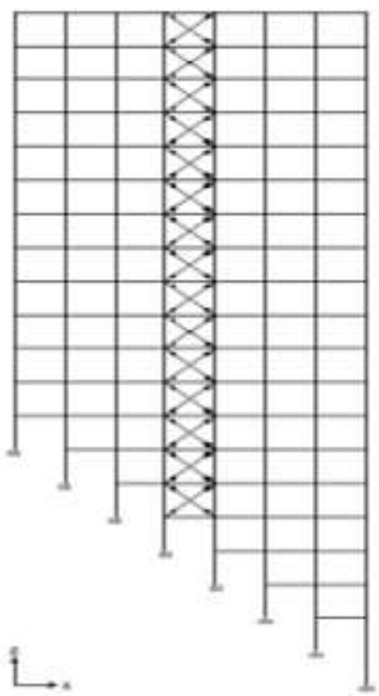

**Figure 5** Model 2-Building on Sloping Ground with bracing.

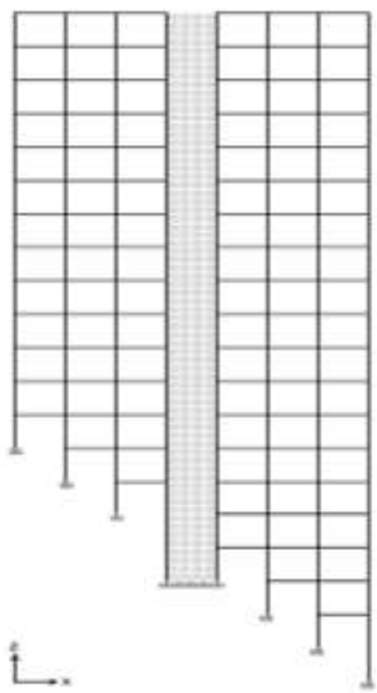

**Figure 6** Model 3-Building on Sloping Ground with Shear wall.

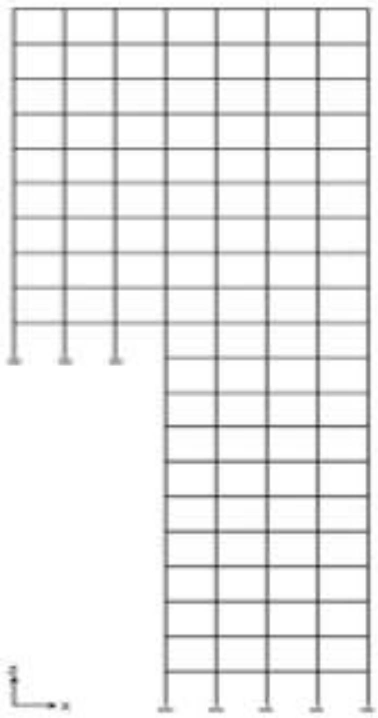

**Figure 7** Model 4-Building on Vertical Cut/Steep Slope

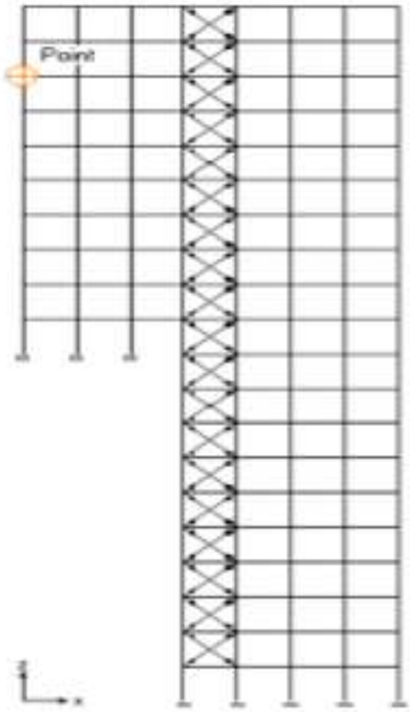


**Figure 8** Model 5-Building on Steep Slope with bracing.

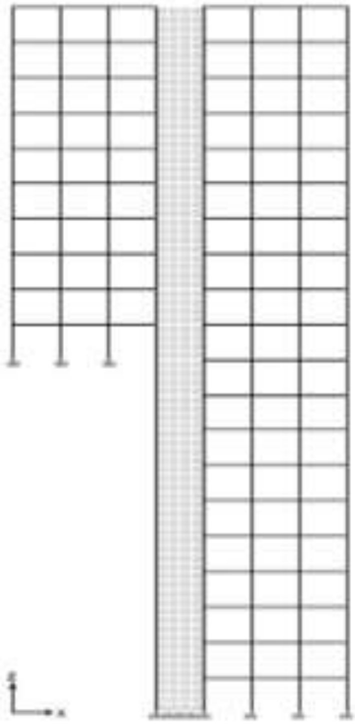

**Figure 9** Model 6-Building on Steep Slope with Shear wall.

**4. Results and discussion**

*4.1 Equivalent Static Analysis (ESA)*

*4.1.1. Displacement and Storey Drift EQXP (positive X direction)*

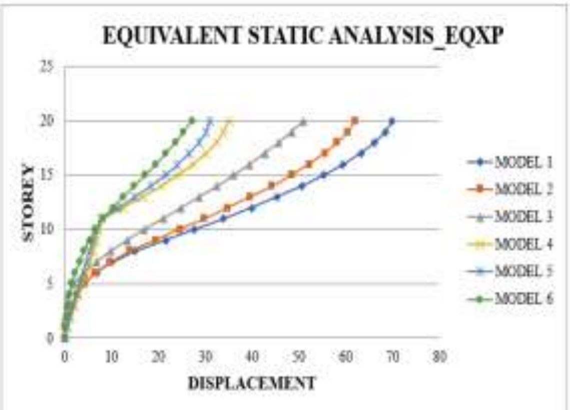


**Chart 1** Displacement vs Storey in X Dir.EQXP

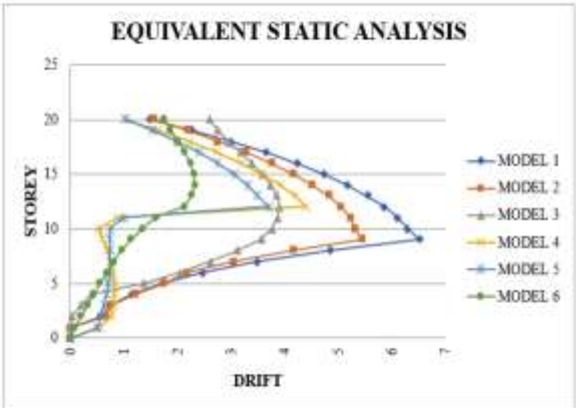


**Chart 2** Storey Drift vs Storey in Dir.EQXP

Maximum permissible storey displacement and permissible storey drift calculated from IS: 1893-2002 and IS: 456-2000. Maximum permissible storey displacement is limited to H/500. Where, H- total height of building. Maximum permissible storey drift is limited to 0.004 h. Where, h- height of storey. The above graph explains the differences in displacement values for various models. The model 1 is having highest displacement in case of structure on gradual slope. The values are reducing in case of bracing system and shear wall system. The Model resisting on steep slopes are lesser than structure resting on gradual slopes. The drift values look lesser in case of all models, however, in comparison with models, the structures resting on sloping ground exhibits highest drift values in comparison with structures on steep slope.

*4.1.2. Displacement and Storey Drift EQXN (negative X direction)*

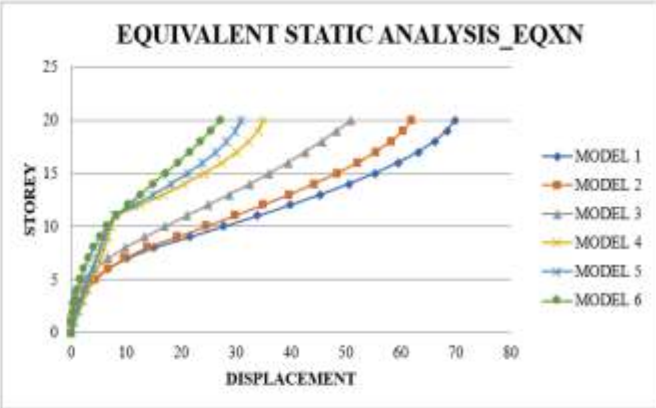


**Chart 3** Displacement vs Storey in X Dir. EQXN

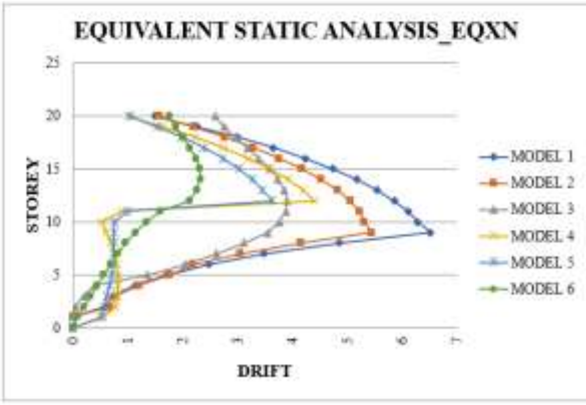


**Chart 4** Storey Drift vs Storey in X Dir. EQXN

The models rest on sloping ground exhibits highest displacement compared with structure on steep cut. However, at steep cut portion, there is a dip noticed at that particular level. The displacement can be reduced by using bracings and greatly reduced by shear wall system. The drift values look lesser in case of all models, however, in comparison with models, the structures resting on sloping ground exhibits highest drift values in comparison with structures on steep slope.

Since ESA is a formula based analysis when the seismic event takes place the software will calculate the displacement of how much the center of gravity has displaced irrespective of directions hence the displacement and drift value of positive and negative x direction is similar.

*4.1.3. Base Shear in EQXP*

Base shear is the shear force at base or foundation level.

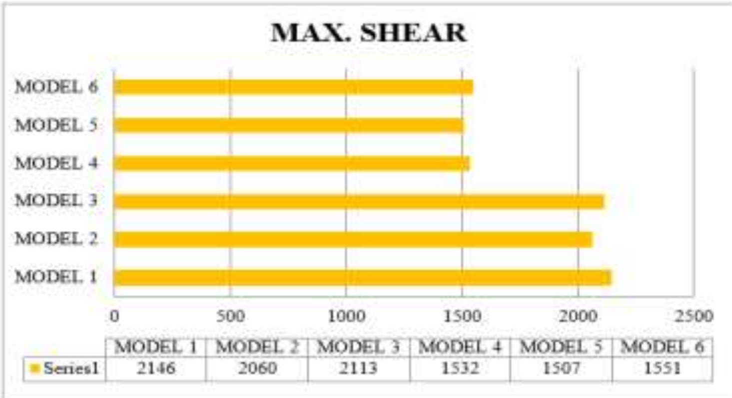


**Chart 5** Base Shear

The base shear values are found higher in case of models resting on sloping ground. However, it is reducing in case of structures on steep slope. In static analysis, the bare frame model is found to be more base shear than bracings and shear wall.

*4.1.4. Base Shear in EQYP*

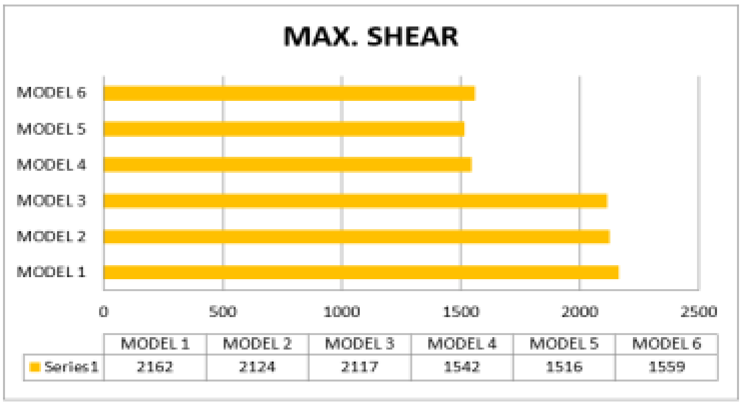


**Chart 6** Base Shear

The base shear values are found higher in case of models resting on sloping ground. However, it is reducing in case of structures on steep slope. In static analysis, the bare frame model is found to be more base shear than bracings and shear wall.

*4.2 Time History Analysis (THA)*

*4.2.1. Displacement and Storey Drift THX*

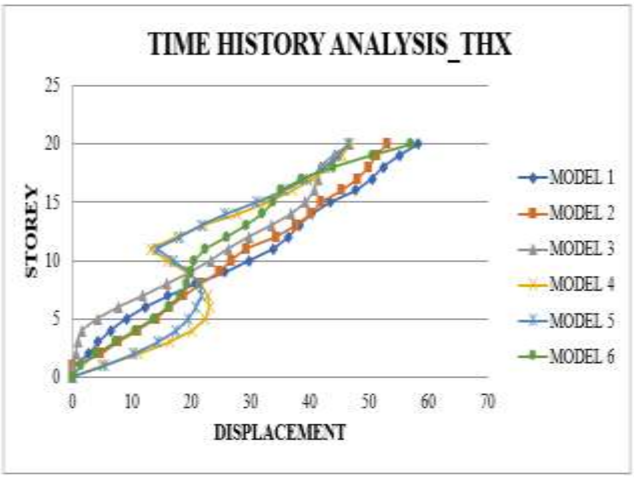


**Chart 7** Displacement vs Storey in X Dir.THX

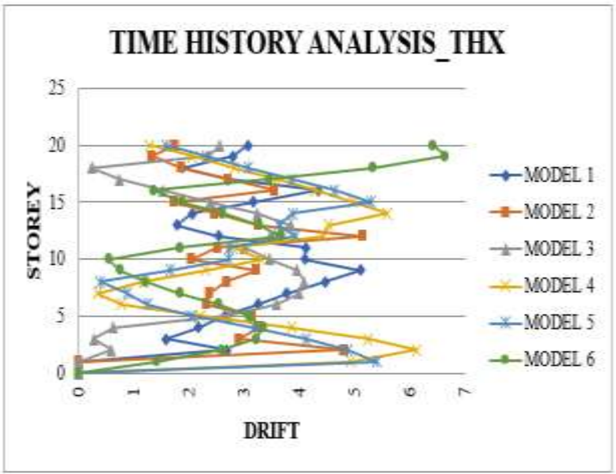


**Chart 8** Drift vs Storey in X Dir.THX

From the graph, it is found that all models are having same displacement. However, the models with shear wall reduces the displacement values comparatively. The floor displacement reduces at steep slope level. It is difficult to compare the storey drift values for all the models. However, it can be analyzed for individual level. The values are not so parallel to each other because of the nonlinear behaviour of the models. However, all the drift values are with in allowable limit.

*4.2.2. Displacement_ THY*

The displacement in the Y direction for all the models are very nominal an all the models are equally one and the same due to its higher stiffness.

The drift values are negligible and results cannot be able to compare because of its nonlinear behaviour.

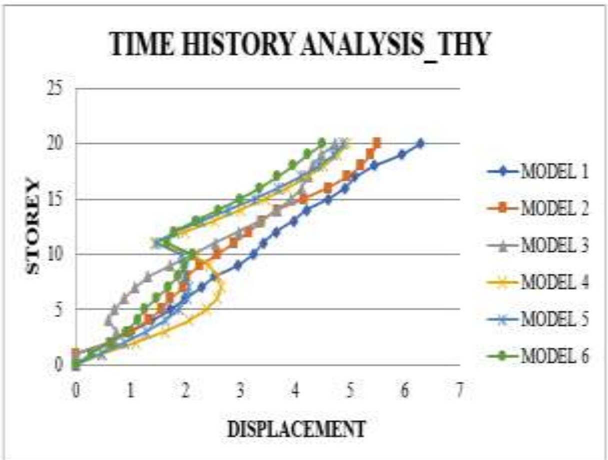


**Chart 9** Displacement vs Storey in Y Dir.THY

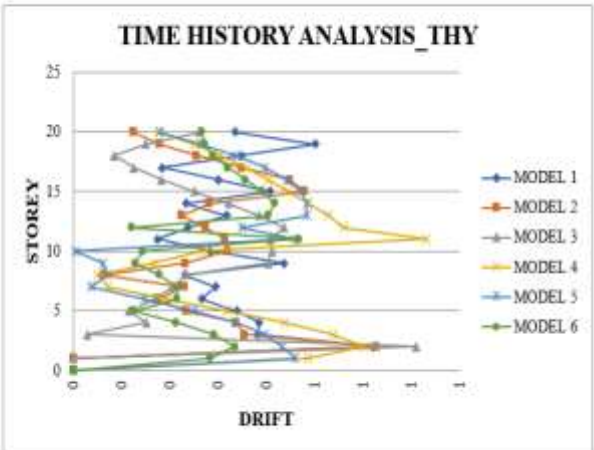


**Chart 10** Drift vs Storey in Y Dir.THY

*4.2.3. Base Shear THX*


**Chart 11** Base Shear THX

The base shear value of model 6 is found to be more compared to all other models because of the higher stiffness in case of models on steep slope. However, it also true for models resting on sloping ground as well.

*4.2.4. Base Shear THY*

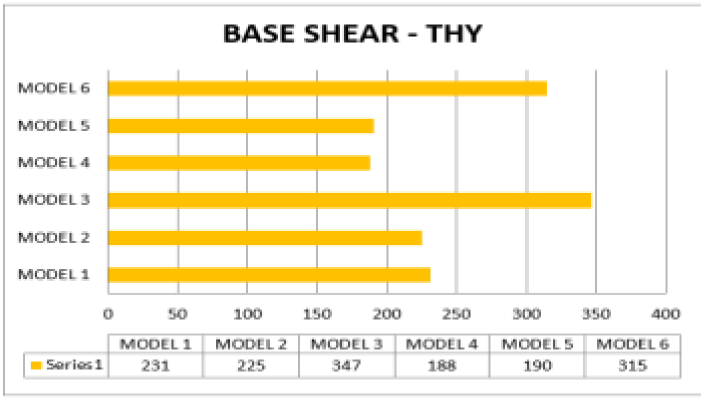


**Chart 12** Base Shear THY

The base shear value of model 6 is found to be more compared to all other models because of the higher stiffness in case of models on steep slope. However, it also trues for models resting on sloping ground as well.

*4.2.5. Acceleration*

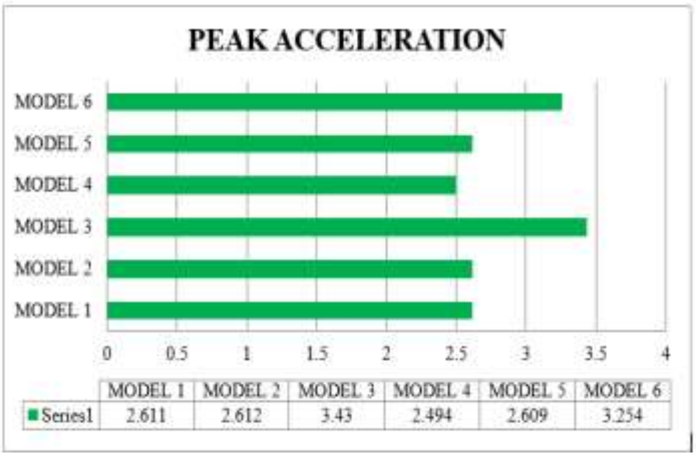


**Chart 13** Acceleration for Various Models

It is observed from the results, it is understood that, models with shear walls are exhibiting highest acceleration values. However, the models present on gradual sloping ground are subjecting to more acceleration than structures resting on steep slope.

*4.3 Modal Analysis*

*4.3.1. Time Period_ ESA*

It is the time taken by each mode to complete one oscillation.

The models resting on steep slope are much rigid than models resting on gradual slope. The models resting on sloping ground are flexible and exhibits highest time period.

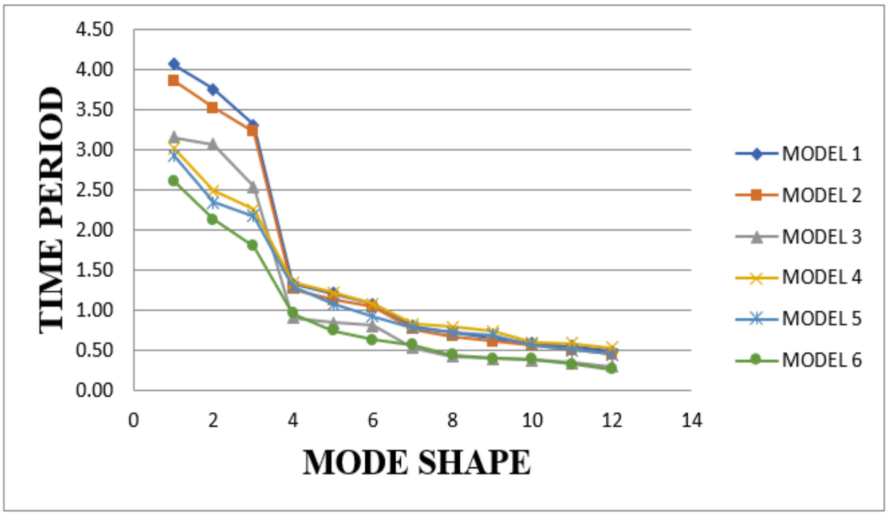


**Chart 14** Time Period vs Modes

*4.3.2. Frequency ESA*

The frequency shows the number of times an activity performed during a second time. The following table shows the frequency for various modes.

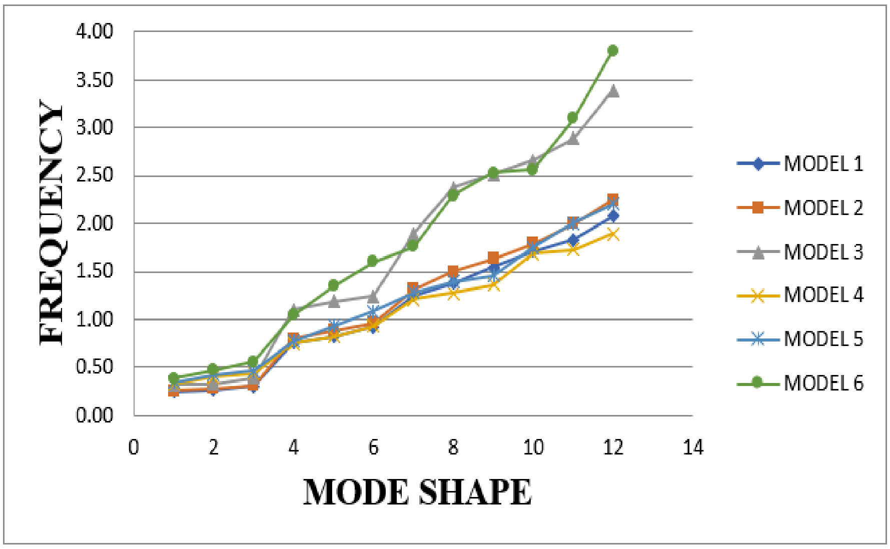


**Chart 15** Frequency vs Modes

The models 6 and 3 are having lesser flexibility compared to other models and hence highest frequency values.

## 5. Conclusion

1. In case of static analysis, the models resting on sloping ground exhibits highest displacement compared with structure resting on steep slope. There is a 50% reduction in displacement values when compared each other.
2. There is a reduction in displacement values in the models with bracing and shear wall by a percentage of 11%, 27% when it is compared with bare frame structure.
3. The drift values are more in case of models resting on gradual sloping ground. However, it is less in case of steep slope.
4. In static analysis, the base shear values are very nominal at base level. However, it is more at slope location columns. The models resting on sloping ground experiences more shear forces compared with steep slope. This reduction is about 30%.
5. In the present model the slope lies from positive to negative x direction. However, the floor displacement is found to be same for static earthquake acting in both positive and negative earthquakes. This case is even true for drift and base shear values as well.

6. The displacement in Y direction is found to be more when compared with displacement in X direction. It is due to the fact that, the stiffness in X direction seems to be slightly more comparatively.

7. Similarly, the base shear value for Y direction also found slightly higher when it is compared with models analyses for X and Y direction.
8. In case of time history analysis, the models are exhibiting almost same displacement values. However, these values are lesser when it is compared with static analysis. It is found that there is a reduction of 17% values in comparison with static and dynamic analysis.
9. The storey drift values are within the allowable limits. However, the values cannot be able to compare with each other. This behaviour is due to non-linearity. The models can be compared only at individual level.
10. The base shear values along Y direction is very less compared with X direction. Even in this case the base shear values are lesser in case of structures situated at steep slope.
11. The displacement value in Y direction is very nominal even in case of time history analysis. And hence the drift values are negligible. However, it is due to fact that, the stiffness along Y axis is much higher comparatively. This stiffness is result as the ground slope is aligned in X direction only.
12. The base shear values along Y direction is very less compared with X direction. Even in this case the base shear values are lesser in case of structures situated at steep slope.
13. It is understood that, models with shear walls are exhibiting highest acceleration values. However, the models present on gradual sloping ground are subjecting to more acceleration than structures resting on steep slope.
14. From the result, it is observed that, the models resting on sloping ground exhibits highest flexibility compared with models resting on steep slope. The frequency is found more in case of models with highest stiffness i.e., models with shear walls model 3 and 6.
15. From overall results it is found that, the time history results should be considered to assess the non-linear behaviour of the structure.
16. The floor displacement is found to be same in case of earthquake irrespective of directions.
17. Base shear values are found accurate in case of time history results than static analysis results.
18. The drift values are found more at the location of slope and steep slope.

## 6. References

[1] Thomas, Dheekshith K, "Experimental Study of RC Framed Building on Sloping Topography Subjected To Seismic Forces"
[2] Rahul Ghosh, Rama Debbarma, "Efect of slope angle variation on the structures resting on hilly region considering soil–structure interaction".
[3] Miss. Chaitrali Arvind Deshpande, "Effect of Sloping Ground on Step- Back And Setback Configurations of R.C.C.Frame Building".
[4] K Divya, A Srikanth, T Sreedhar Babu, "Effect of Ground Slope on Dynamic Performance of G + 5 Building".
[5] B.G. Birajdar1 , S.S. Nalawade, "Seismic Analysis Of Buildings Resting On Sloping Ground".
[6] Krishna Kumar, "Dynamic Study of Step Back And Set Back Building".
[7] Mr. Anil Sagar S, "Behavioural Study of Dynamic Properties Of Step Back Buildings With And Without Corewalls Situated On Sloping Ground".
[8] Chidanand Bidnalamath1 , Sabyath Shetty2 , Shanmukha Shetty3 , Thushar Shetty4, "Seismic Behavior of Different configuration of MultiStorey RC Buildings on Sloping Ground: A Review".
[9] Inguva Sai Surya Prakash1 Adireddy Siva Satya Vara Prasad2 R Rama Krishna3, "A Study on Comparative Analysis of RCC Building Resting on Plain and Hilly Terrain".
[10] Ankit Dane, Umesh Pendharkar, "Effective Positioning of Shear Wall in G+5 Storey Building on Sloping Ground".