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ANALYSIS AND DESIGN OF EARTHQUAKE RESISTANT MULTISTOREY RCC BUILDING RESTING ON SLOPING GROUND

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Abstract – *The principal aim of this paper is to study the Analysis and Design of Earth-quake Resistant Multi-storey reinforced cement concrete Building of G+6 stories by using ETABS. In India for different earthquake zones different design criteria is adopted. Since Bangalore comes under earthquake* ***zone II*** *but for metro cities it is recommended to design for higher zone therefore considered* ***zone III****. Generally the structural buildings are constructed on plane ground; however the building construction activities has been started on the sloping grounds due to scarcity of flat level ground. In this study G+6 storey's RCC structural building resting on the sloping ground having slope of 20° has been contemplate for analysis and design. A distinguish have been done by considering structural building situated on plane grounds. The modeling, analysis and design of structural building have been done by using structural building analyzing software ETABS 2015, to learn the effects during earthquake of differing heights of the columns in basement floor at different positions. The results were acquired in the form of Base shear, top story displacements, time period and story drifts.*

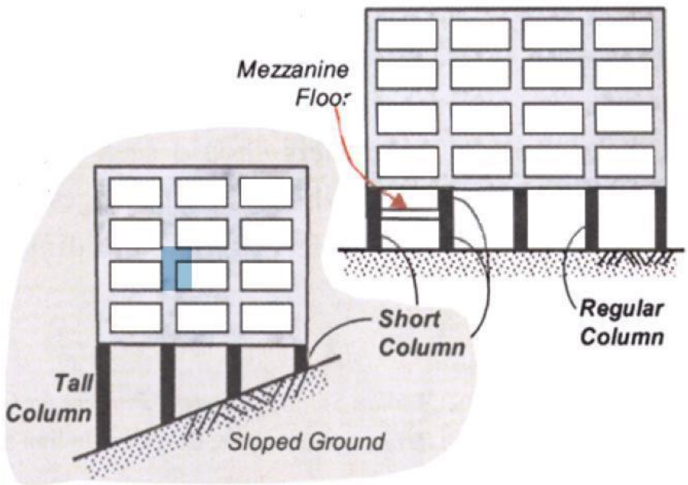
Key Words: **E-tabs, Sloping ground, Storey drifts, Base shear, Top Story displacements, Time periods, Bending moment and shear forces.**

1. INTRODUCTION

In natural hazards the most dangerous hazard is earthquake. The enormous amount of energy which is released in a very less seconds due to the sudden movement of the tectonic plates results earthquakes. The effect of this feature is maximum dangerous as it impacts large surrounding area, and which happens surprising and unpredictable. It causes huge scale loss of property and life and damages the important essential services of live hood such as, water supply, sewerage systems, transport, power, and communication etc. The result leads to weaken the financially viable and social structure of the country except destroying towns, cities and villages. Hence we need to find out proper seismic performance of the structural building to avoid such losses.

Building are present in hilly areas are very different from those in plain ground; in hilly areas they are irregular and unsymmetrical. Hence, when affected by earthquake it leads to severe damage to the structure, because in hilly regions the structure is constructed with different column heights, and the short columns will have more damage effects when compare to the long column during earthquake.

The two examples of frame structures with short columns in structure on a sloping ground and structure with a mezzanine floor can be seen in the figure given below.



1.1 Objectives

The objectives are mentioned as below:

1. Analysis and designing of earth-quake resistant building structure for G+6 storey building under zone-III.
2. To analyze the G+6 building under seismic load for flat level ground and the ground having slope of 20°.
3. To optimize the behaviour of structures especially RCC buildings against seismic attacks using modern techniques.
4. To prevent such deflections that would produce the collapse of elements structures.
5. Having adequate knowledge and safety precautions to optimize its dangers.
6. Comparison of results of sloping ground and flat level ground.
7. To study the variations of top storey displacements, storey drifts, base shear, time period due to variations in sloping angle for different configurations of frames.

2. LITERATURE REVIEW

2.1 Shivakumar Ganapati et, al.(2017):

In this study **"R.C.C Frame Structure resting on Sloping Ground with Floating Column was analyzed using Push over analysis"**. They have considered a model of 10 storey building structure consists of 3bays in both directions X and Y having 5m dimension in both the directions and the floor height is taken as 3m. The column size is taken as 600x850mm and beam size is taken as 300x450mm and slab is of 125mm thickness. The building is located on medium soil in seismic zone 5. For this study the concrete grade of M20 and M25 and HYSD Fe-500 steel grade is considered and the live load and floor finish load is assumed as 1Kn/m2 and 3kN/m2. In ETABS using push over analysis method models were analyzed. They found that without floating column on step back building on sloping ground has more storey displacement than the set back and step back building structures resting on a sloping ground. Hence in this study they concluded that in building structures at any floor provision of floating columns at corner positions has poor performance than other cases. For floating columns more attention should be provided and unless at most critical cases floating columns at corners should be considered.

2.2 Sujit Kumar et al (2014):

Studied on **"Effects on Structural performance of RCC Structure on Sloping Ground under Seismic load"**. The study work includes the behaviors of structural frames resting on sloping ground for different slope angles (7.5^0, 15^0) under the forces of earthquake. The comparison between flat level ground and sloping level ground structure is made under earthquake seismic forces. In these study **G+ 4 storeys** is considered for comparison of behavior of three buildings which are subjected to same live loads. The structural frames are subjected to vibrations due to earthquake hence seismic analysis is necessary for all three structural frames. The **STAAD Pro** Software is used to analyze the three structural building frames by providing fixed ends under seismic zone IV. Hence for conclusion the behavior of three structural buildings is observed for interpretation and representation of results. They concluded that compared to plane ground the bending moment forces in column significantly increases for sloped grounds (15^0) and in footing the bending moment and critical horizontal force increases with respect to increasing ground slope.

2.3 Ravikumar C.M et al (2012):

In this study they focused on to **"Study of Rcc building performance with irregular type of configurations"**. They studied that in structures the vertical irregularities such as geometric irregularities and the structure situated on sloping ground having two types of configurations on both the directions X and Y is considered. The structure building consists of 3 storey which is located in seismic **zone V** and has 5 and 4 bays with respect to x and y direction. The linear and non linear analysis is done using respective codes to study the performance of the structure (ATC 40 and IS 1893 part-1 2002). It is noted that the vulnerability of structures resting on slippery grounds is very effective which deforms moderately with massive pulling force. Top storey displacement was moderately higher than the other building structure which is about 83.4mm and the base shear of building structure resting on the sloping ground was found to be more than 2555%than other structure which is about 6019.2kN. They found that in X-direction of sloping ground structure the performance as expected was not achieved as achieved in Y-direction after point of collapse. Hence they concluded that structural buildings situated on a plane ground are more less endangerd to earthquakes when distingued to structural buildings situated on a sloping grounds.

2.4 Sripriya Arjun and Arathi. S (2015):

In this study the, **"Behaviors of frame structure consist of G+3 storey resting on sloping ground was analyzed having set back step back configurations"** for the sinusoidal ground vibration having varying ground sloped angles i.e., 30.96°, 26.57°, 21.8° and 16.7° using **STAAD Pro** structural software . As per **IS: 1893 (part 1): 2002** by using Response Spectrum analysis. Due to earthquake the short columns are more effected compare to long columns. Base shear and storey displacements were obtained in the form of results. Due to the results of analysis it is found that the set and step back building structure configurations is suitable for the building structure situated on a sloping ground.

2.5 S.P. Pawar et al (2016):

In this paper they focused on **"Structural building behaviors to the seismic forces with shear walls situated on a sloped ground".** It is found that the building structures on sloping ground have different seismic behavior compare to building structure on flat ground. In this type of structures the various storey's of the building step backs towards the hill slopes. In many of the studies it is noted that short columns allure additional forces compare to long columns and undergo more damages when subjected to earthquakes and also the building situated on the flat level ground has lower base shear and top storey displacements than situated on sloping grounds. For seismic stimulation the step back building structure will be more endangered compare to others. They concluded that the shorter columns on sloping grounds have more stiffness. Along in the direction of slope the base shear and top story displacements are more than the other traverse directions. For resting of lateral displacement the straight or rectangular shaped configuration of shear walls are more effective than other configurations.

3. METHEDOLOGY

At present works G+6 Reinforced Cement Concrete Earthquake Resistant Building is consider for different storey height. The structure Model, Design & Analysis is done by using ETABS software of computer aided design. The steps are as below:

1. Planning of G+6 Building by AUTOCAD Software.
2. Modelling for G+6 Storey RCC Frame.
3. Analyzing the Beam, Column, Walls, and Slabs by using ETABS applications.
4. Analysis the gravity (DL+LL) and Seismic load under Zone III using ETABS.
5. Listing out frames in different member's i.e. axial load and Moments.
6. Designing of elements as per obtained forces and moments by using ETABS.
7. Plotting the Drawings.
8. Comparison of results for Sloping Ground and Plain Ground.

4. TECHNIQUES FOR EARTHQUAKE RESISTANT BUILDINGS

Modern construction Techniques for Earth-quake Resistant Buildings;

1. *Base isolation's*
2. *Seismic Dampers*
3. *Steel Plate Shear walls*
4. *Carbon Fibre*

5. MODELLING DESCRIPTIONS

A rectangle structural building is considered to analyze which is asymmetric in elevation and plan. The measurements of the structural building plan to be modeled are 13m × 26m.

5.1 Geometric Properties

Plan size	: 13m×26m
Floor height	: 3m
Beam sizes	: 200×600mm
Column sizes	: 300×750mm
Slab thickness	: 150mm
No. of stories	: G+6
Poisons ratio	: 0.17

5.2 Material Properties

Concrete Grade	: M20 and M25
Compressive strength of concrete	: 20000KN/m^2
Steel	: Fe500
Characteristic strength of steel fy	: 41500KN/m3
Density of concrete	: 25000N/m3

5.3 Gravity Loads

i. Dead load : Self weight is calculated by the software based on material constants and section properties provided.
ii. Floor finish load : 1.5 KN/m^2
iii. Live imposed load : 2 and 4 KN/m^2

5.4 Models considered for the study

In this present study, we have taken two models for G+ 6 story RCC structure building such as:

- Model on Plain ground
- Model on 20° Sloping ground

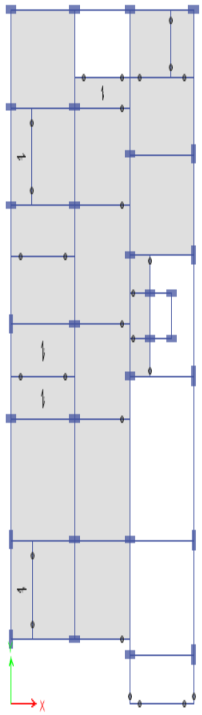


Fig 1: Plan of normal and sloped ground building

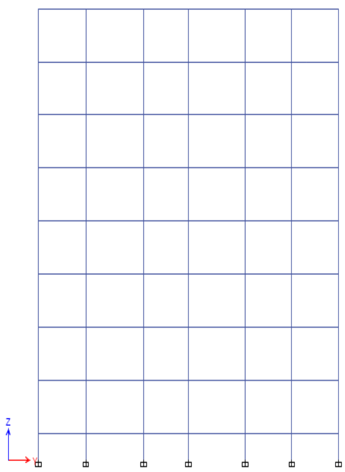


Fig 2: Front side view of normal building structure

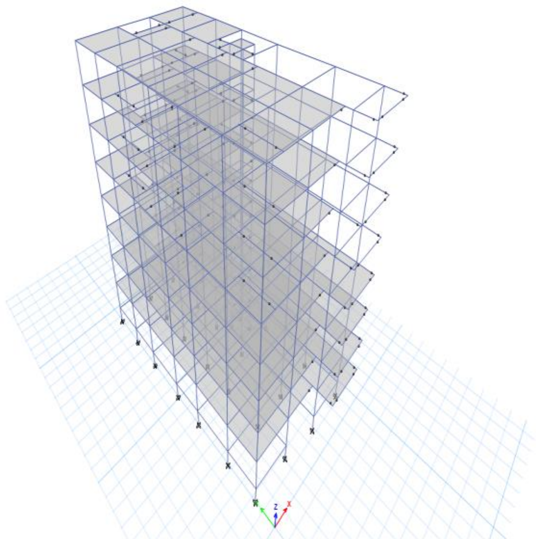


Fig 3: 3D model view of normal structure building

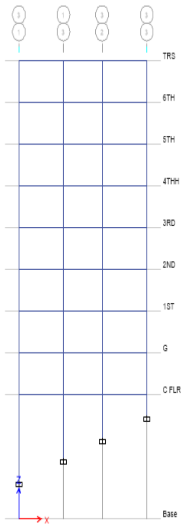


Fig 4: Front view of model with sloped ground

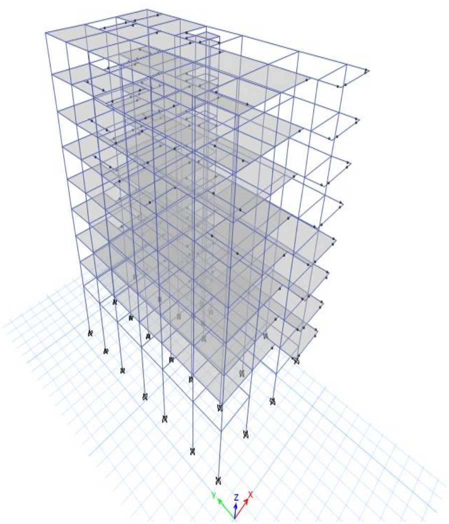


Fig 5: 3D model view of sloped ground building structure

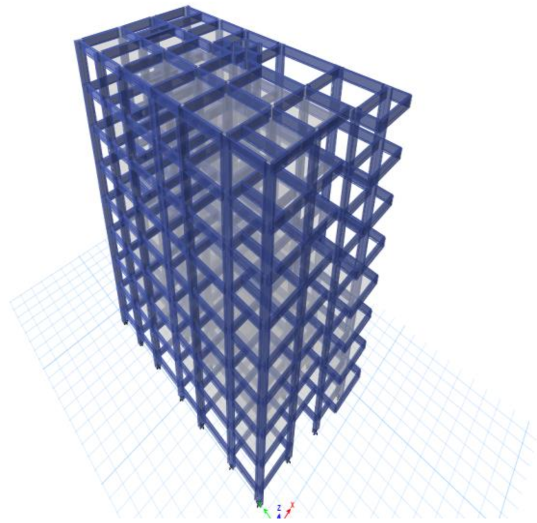


Fig 6: Extrude view of regular model

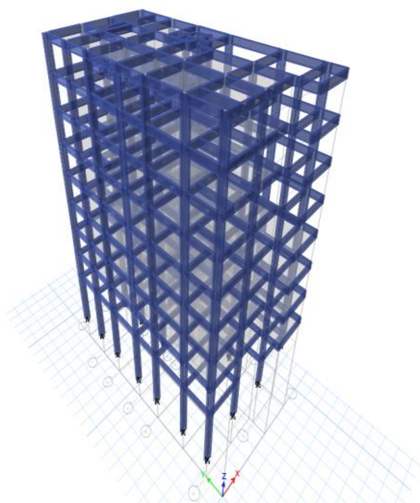


Fig 7: Extrude view of Slopping ground Model

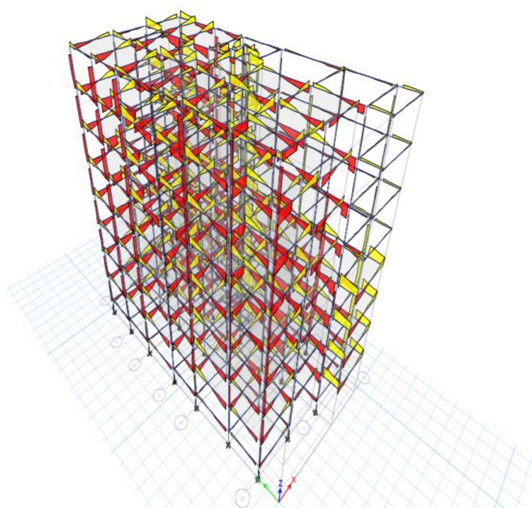


Fig 8: SFD of regular model for 1.5DL+1.5LL

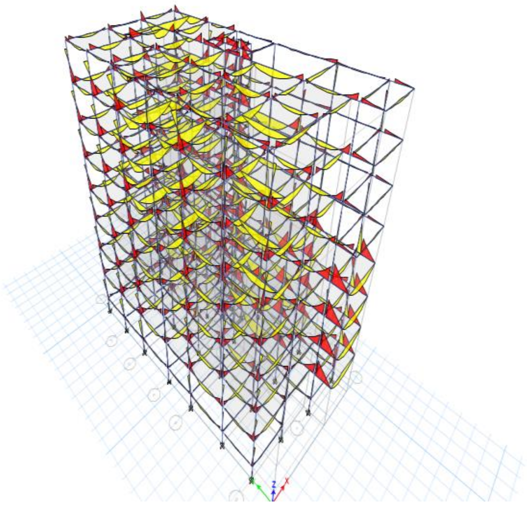


Fig 9: BMD of regular model for 1.5DL+1.5LL

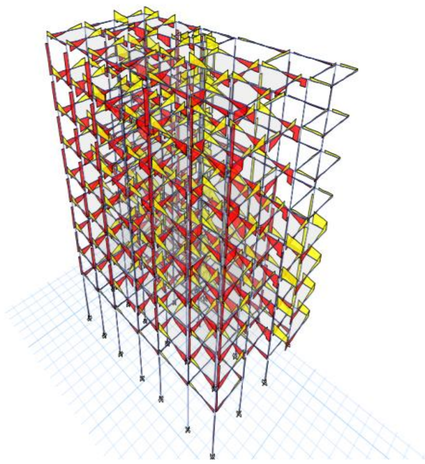


Fig 10: SFD of slopping ground model for 1.5DL+1.5LL

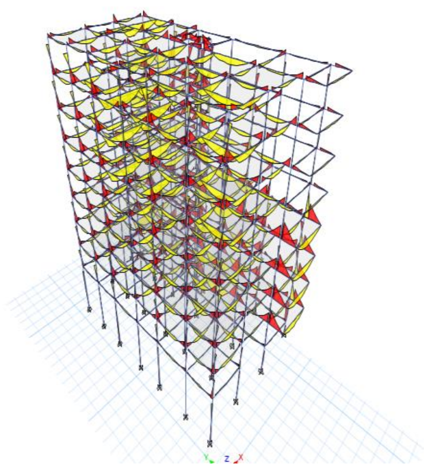


Fig 11: BMD of slopping ground model for 1.5DL+1.5LL

6. DESIGN PROCEDURE

G+6 multi-storey building have designed by computer aided application using E-tabs software.

6.1 Behavior of structures to ground motions

Ground motions during the earthquake causes inertia forces at the location of mass in the structural building. This inertia force reaches the foundation of the structure by travelling through roofs and walls. The main component of structures which are most endangered to damages caused due to earthquake horizontal forces are walls. The main prominence is making on that this inertia forces reaches the ground without causing any collapse and any other major losses due to damages.

6.2 Design loads

The loads which are considered for the design are as shown below:

- Self-load of the building structure
- Floor finish loads
- Wall loads
- Typical imposed loads
- Roof imposed loads
- Earthquake Seismic loads

6.3 Load combinations

The building frames are designed by using Self-weight, imposed loads and wind loads or earthquake seismic loads.

1. 1.5(DL+LL)
2. 1.5(DL+EQX)
3. 1.5(DL-EQX)
4. 1.5(DL+EQY)
5. 1.5(DL-EQY)
6. 1.2(DL+LL+EQX)
7. 1.2(DL+LL-EQX)
8. 1.2(DL+LL+EQY)
9. 1.2(DL+LL-EQY)

7. RESULTS AND DISCUSSION

In this present study a G+6 structural buildings was analyzed and designed. The above all models are checked for top story displacements, time periods and storey drift. The comparison was drawn between them and the following results were obtained.

7.1 Displacements

From the obtained displacement results it is found that the maximum decrease in lateral displacements is seen in a with slopped ground along X direction. The reduction along X direction for static, time history and response spectrum analysis is (20.23%, 12.62%, and 15.07%) for zone II, for zone III (20.26%, 9.46%, and 14.09%) and for zone IV (20.26%, 18.85%, and 13.29%).

Along Y direction maximum increase in storey drift is seen in model with slopped ground in X- direction The increment along Y direction for static, time history and response spectrum analysis is (20.70%, 8.28%, and 28.25%) for zone

II, for zone III (20.66%, 12.23%, and 21%) and for zone IV (20.58%, 10.86%, and 22.29%).

Table -1: Max displacement values for zone II, III and IV for static analysis in x-direction

Sl no	Model for ground	Max Displacement (mm) zone 2	Max Displacement (mm) zone 3	Max Displacement (mm) zone 5
1	Plain ground	13.69	21.91	32.87
2	Sloping ground	10.92	17.47	26.21

Chart -1: Graph of displacement variations

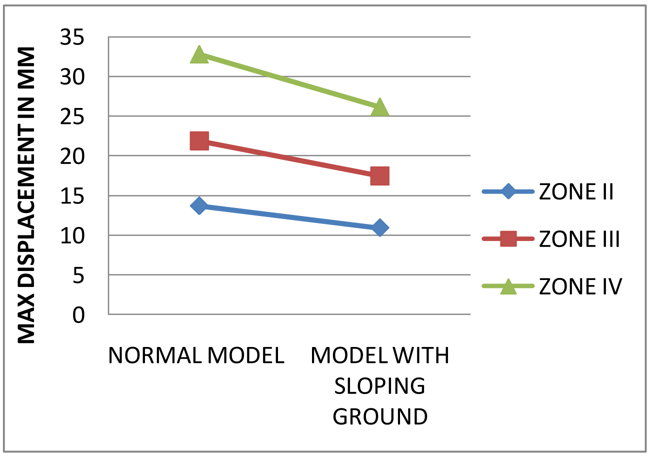


Table - 2: Max Displacement values for Zone II, III and IV, for static analysis in Y-direction

Sl no	Model for ground	Max Displacement (mm) zone 2	Max Displacement (mm) zone 3	Max Displacement (mm) zone 5
1	Flat ground	15.97	25.55	37.23
2	Sloping ground	15.93	25.50	37.25

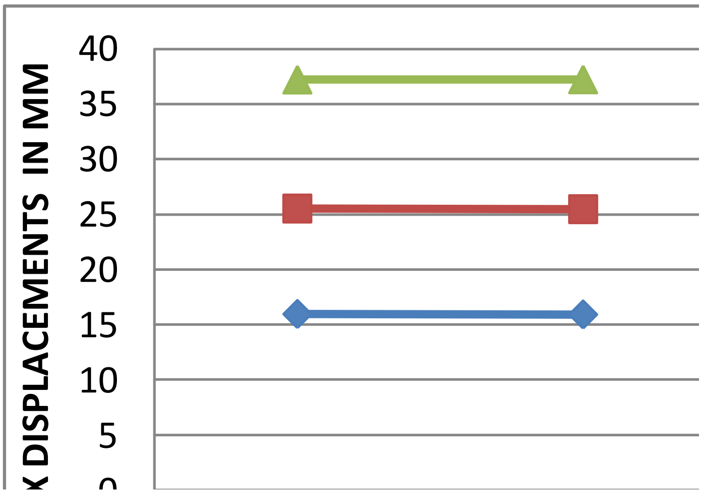


Chart -2: Graph of displacement variations

Table 3: Max Displacement values for Zone II, III and IV, for Response spectrum analysis in X-direction

Sl no	Model for ground	Max Displacement (mm) zone 2	Max Displacement (mm) zone 3	Max Displaceme nt (mm) zone 5
1	Flat ground	14.06	22.49	34.39
2	Sloping ground	17.43	27.89	43.37

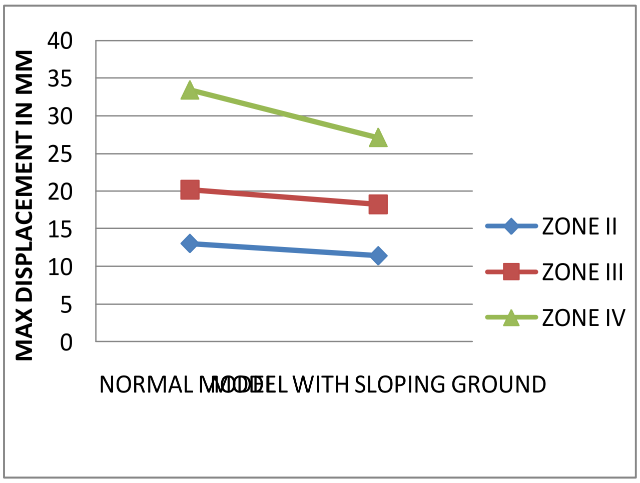


Chart -3 Graph of displacement variations

Table - 4: Max Displacement values for Zone II, III and IV for Response spectrum analysis in Y-direction

Sl no	Model for ground	Max Displacement (mm) zone 2	Max Displacement (mm) zone 3	Max Displacement (mm) zone 5
1	Flat ground	13.07	20.19	33.46
2	Sloping ground	11.42	18.28	27.15

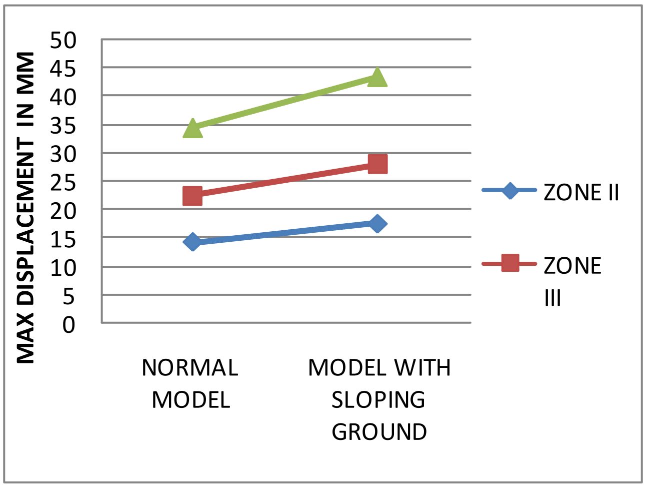


Chart -4 **Graph of displacement variations**

Table -5: Max Displacement values for Zone II, III and IV for time history analysis in X-direction

Sl no	Model for ground	Max Displacement (mm) zone 2	Max Displacement (mm) zone 3	Max Displacement (mm) zone 5
1	Flat ground	14.73	23.48	35.32
2	Sloping ground	12.51	20.17	30.40

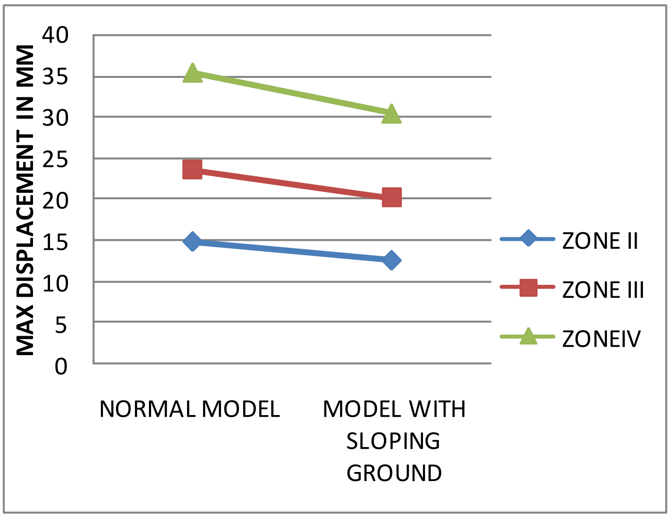


Chart -5 Graph of displacement variations

Table - 6: Max Displacement values for zone II, III and IV for time history analysis in Y-direction

Sl no	Model for ground	Max Displacement (mm) zone 2	Max Displacement (mm) zone 3	Max Displacement (mm) zone 5
1	Flat ground	14.79	23.86	35.08
2	Sloping ground	18.16	23.29	49.08

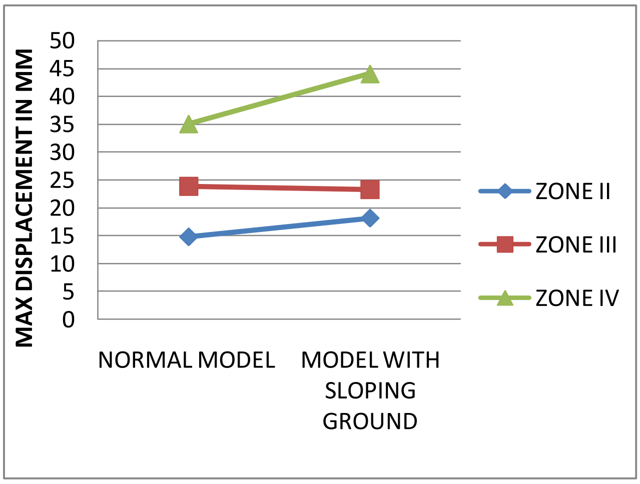


Chart -6 Graph of displacement variations

7.1.1 Static analysis: Maximum storey displacement for normal model.

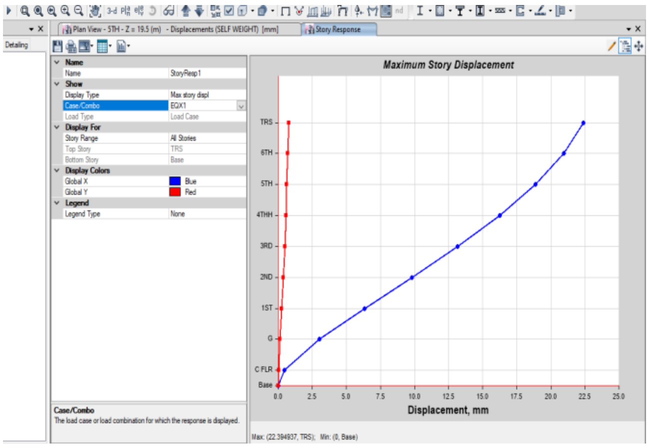


Chart -1: Displacements along X-direction

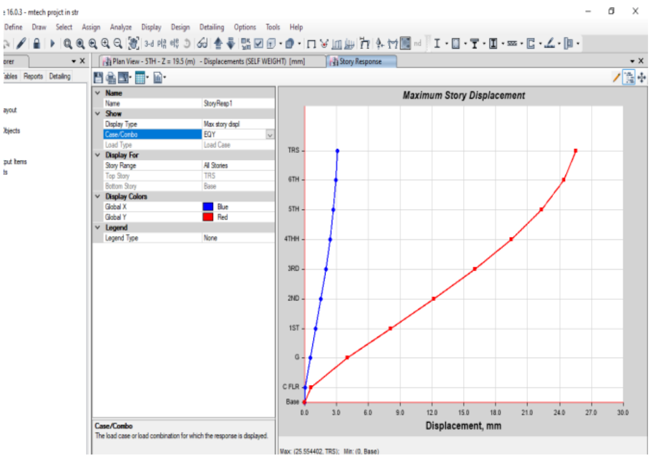


Chart -2: Displacements along Y-direction

7.1.2 Static analysis: Maximum storey displacement for model with 20° slopping ground.

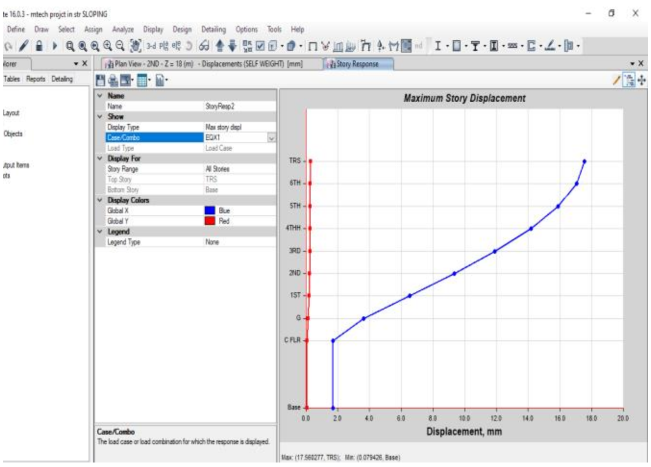


Chart -1: Displacements along X-direction

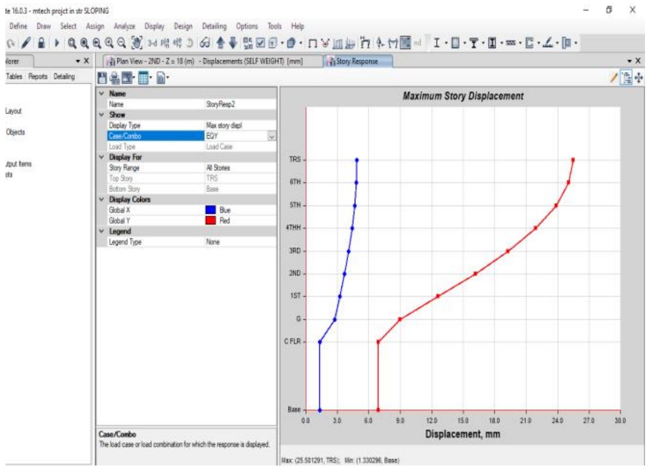


Chart -2: Displacements along Y-direction

7.1.3 Response spectrum analysis: Maximum storey displacement for normal Model.

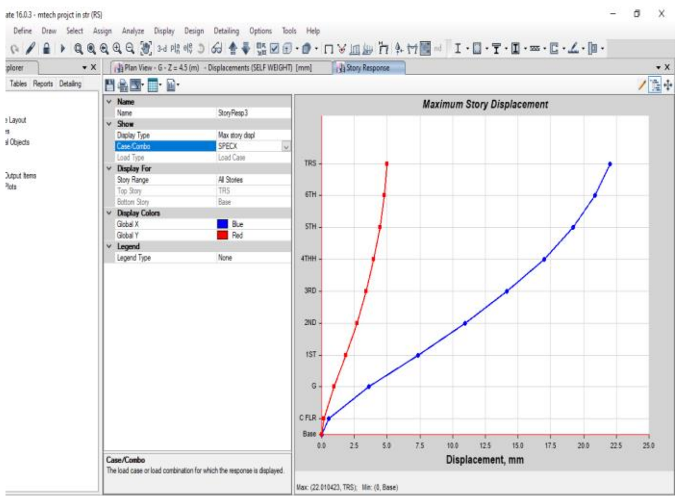


Chart -1: Displacements along X-direction

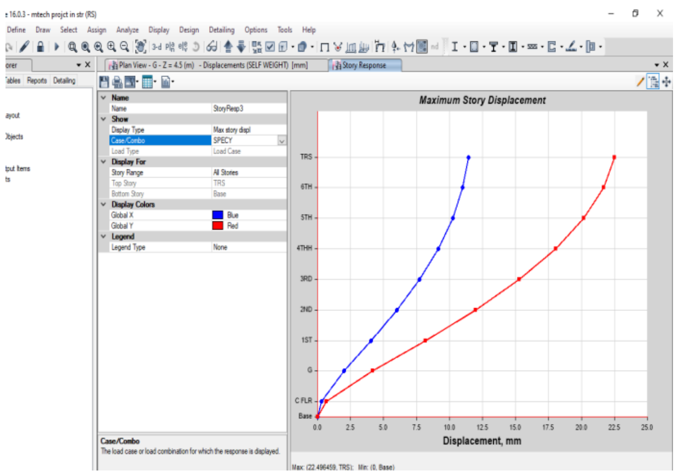


Chart -2: Displacements along Y-direction

7.1.4 Response spectrum analysis: Maximum storey displacement for Model with 20° sloping ground.

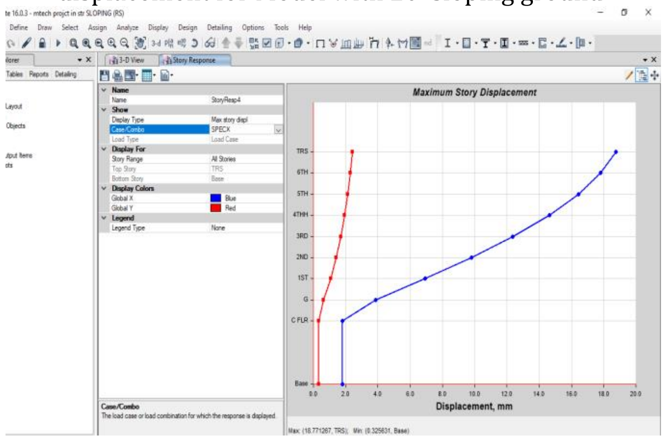


Chart -1: Displacements along X-direction

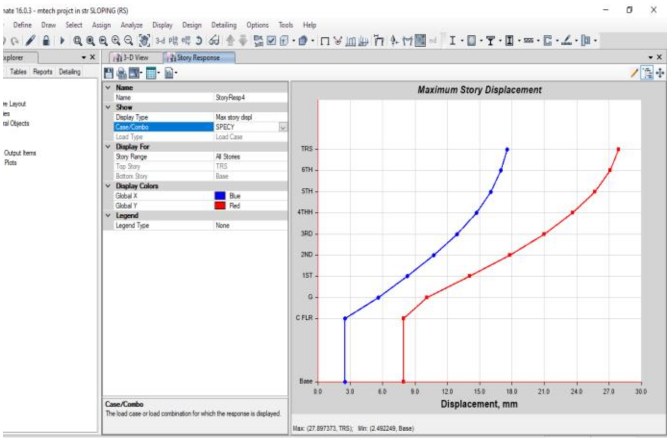


Chart -2: Displacements along Y-direction

7.2 Time period

From the given below table and graph the time periods of regular models has a lesser time periods. It is found that in regular models the time periods is for the building in zone 2, zone 3 and zone 4 has 13.65% lesser time periods compared to the models on a sloping ground.

Table -1: Time period values for different Models

Sl no	Model for ground	Max Time period (secs) zone 2	Max Time period (secs) zone 3	Max Time period (secs) zone 4
1	Flat ground	1.138	1.138	1.138
2	Sloping ground	1.318	1.318	1.318

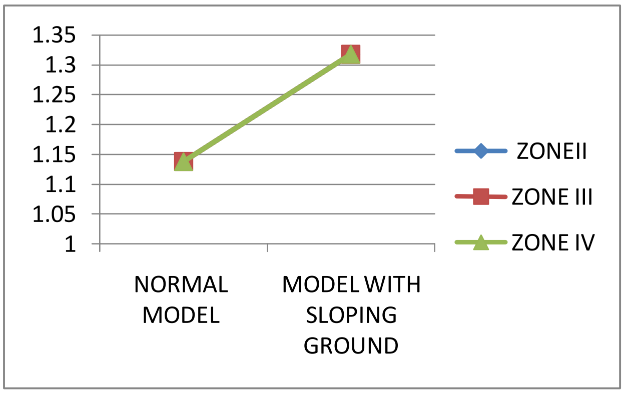


Chart -1: Graph of variations in time periods

7.3 Base Shear

From the given below tables and graphs of the base shear it is found that maximal decrease in bases shear is in a models with slopped ground along X and Y direction. The reduction along X and Y direction for static, time history and response spectrum analysis is (5.04%) for zones 2, 3 and 4.

Table -1: Max Base shear values for Static, Time history, Response spectrum analysis for Zone II along X-direction

SL no	Model for ground	Max Base Shear (kN) zone 2	Max Base Shear (kN) zone 3	Max Base Shear (kN) zone 4
1	Flat ground	708.91	1134.25	1701.38
2	Sloping ground	673.14	1077.02	1615.54

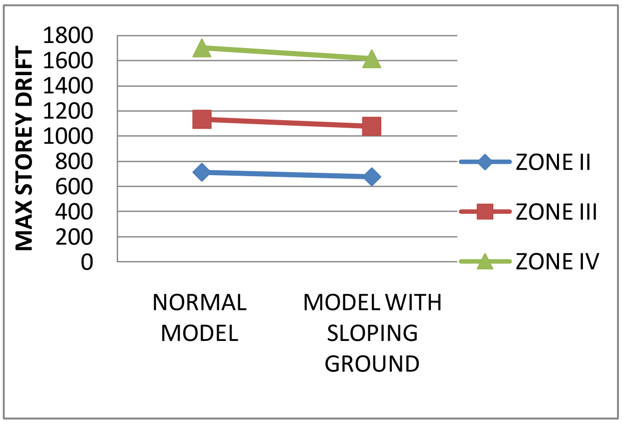


Chart -1: Graph of Base shear

Table -2: Max Base shear values for Static, Time history, Response spectrum analysis for Zone II along Y-direction

Sl no	Model for ground	Max Base Shear (kN) zone 2	Max Base Shear (kN) zone 3	Max Base Shear (kN) zone 4
1	Flat ground	820.98	1313.57	1970.35
2	Sloping ground	779.55	1247.29	1870.94

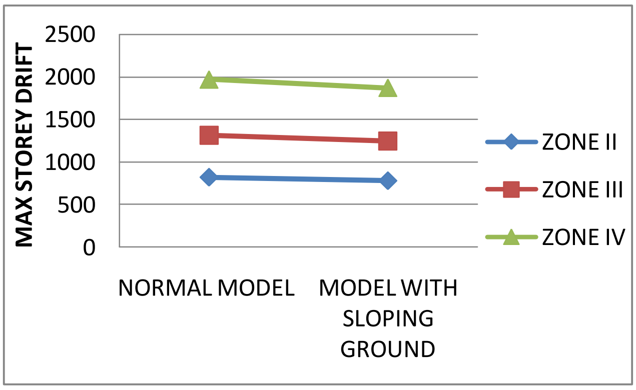


Chart -2: Graph of Base shear

7.4 Storey drift

From the given below tables and graphs of storey drifts it is found that the maximum decrease in lateral storey drifts is in models with slopped ground along X direction. The reduction along X direction for static, time history and response spectrum analysis is (11.38%, 13.36%, and 37.24%) for zone II, for zone III (11.30%, 13.48%, and 37.51%) and for zone IV (11.00%, 15.46%, and 38.51%).

Table -1: Max Storey drifts values for Zone II, III, and IV for Static analysis in X -direction

SL no	Model for ground	Max Storey Drift zone (2)	Max Storey Drift zone (3)	Max Storey Drift zone (4)
1	Flat ground	0.000720	0.00115	0.00172
2	Sloping ground	0.000638	0.00102	0.00153

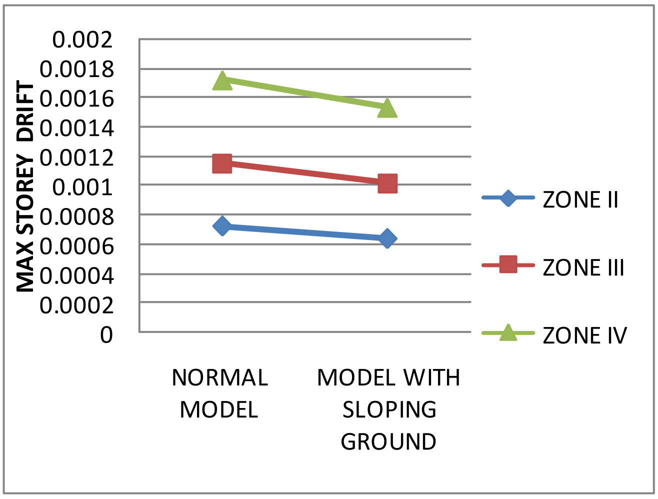


Chart -1: Graph of Storey drifts variations

Table -2: Max Storey drifts values for Zone II, III and IV for Static analysis in Y-direction

SL no	Model for ground	Max Storey Drift zone (2)	Max Storey Drift zone (3)	Max Storey Drift zone (4)
1	Flat ground	0.000850	0.001360	0.00153
2	Sloping ground	0.001026	0.001641	0.00246

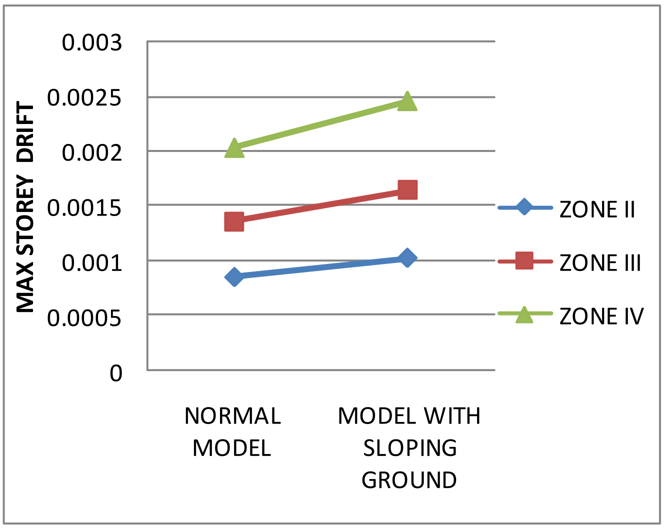


Chart -2: Graph of Storey drifts variations

Table -3: Max Storey drifts values for Zone II, III and IV for Response Spectrum analysis in X-direction

SL no	Model for ground	Max Storey Drift zone (2)	Max Storey Drift zone (3)	Max Storey Drift zone (4)
1	Flat ground	0.000778	0.001246	0.001894
2	Sloping ground	0.000674	0.001078	0.001601

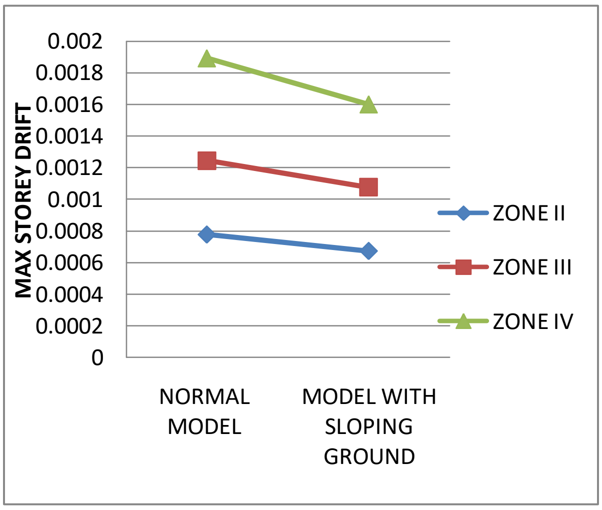


Chart -3: Graph of Storey drifts variations

Table -4: Max Storey drifts values for Zone II, III, and IV for Response Spectrum analysis in Y-direction

SL no	Model for ground	Max Storey Drift zone (II)	Max Storey Drift zone (III)	Max Storey Drift zone (IV)
1	Flat ground	0.000850	0.0013480	0.002062
2	Sloping ground	0.000785	0.001536	0.002286

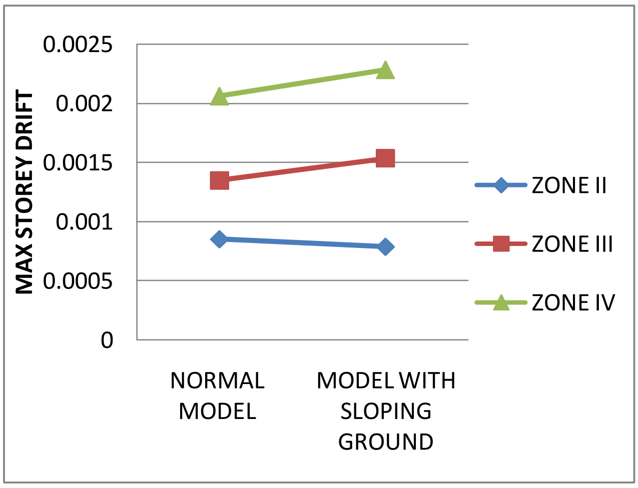


Chart -4: Graph of Storey drifts variations

Table -5: Max Storey drifts values for Zone II, III, and IV for Time History analysis in X-direction

SL no	Model for ground	Max Storey Drift zone (2)	Max Storey Drift zone (3)	Max Storey Drift zone (4)
1	Flat ground	0.000780	0.000638	0.001869
2	Sloping ground	0.001243	0.001021	0.001935

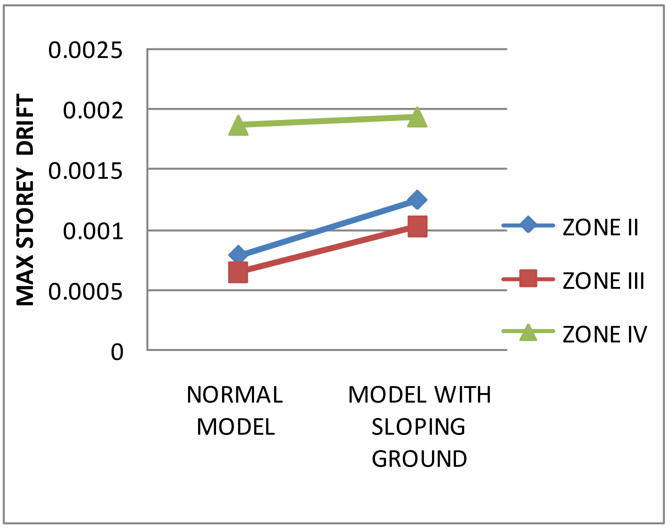


Chart -5: Graph of Storey drifts variations

Table -6: Max Storey drifts values for Zone II, III, and IV for Time History analysis in Y-direction

SL no	Model for ground	Max Storey Drift zone (2)	Max Storey Drift zone (3)	Max Storey Drift zone (4)
1	Flat ground	0.000800	0.001304	0.001956
2	Sloping ground	0.001026	0.001266	0.002392

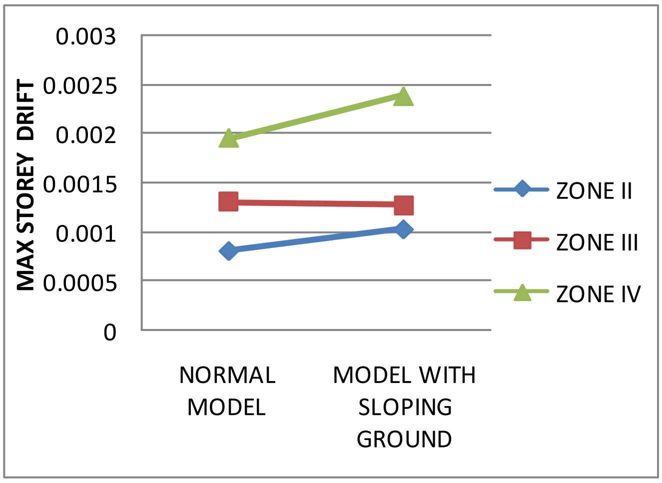


Chart -6: Graph of Storey drifts variation

7.4 .1 Static analysis: Maximum storey drift for normal model.

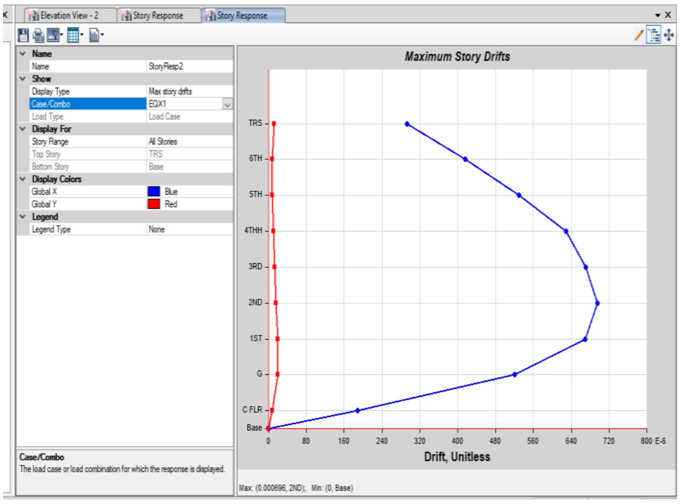


Chart -1: Storey drifts along X-direction

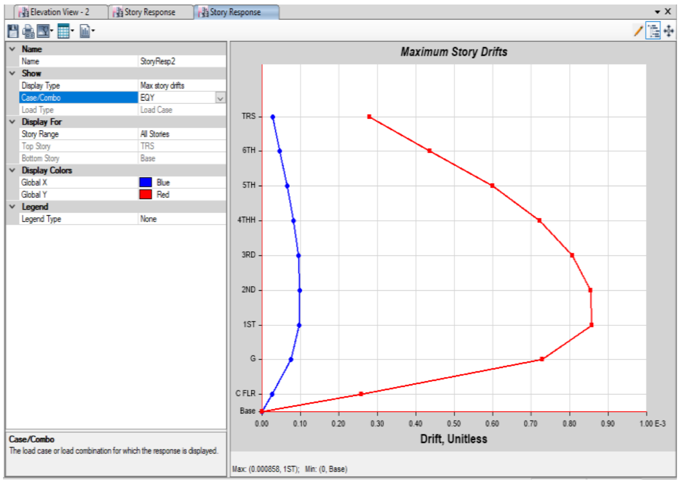


Chart -2: Storey drifts along Y-direction

7.4 .2 Static analysis: Maximum storey drift for Model with slopping ground.

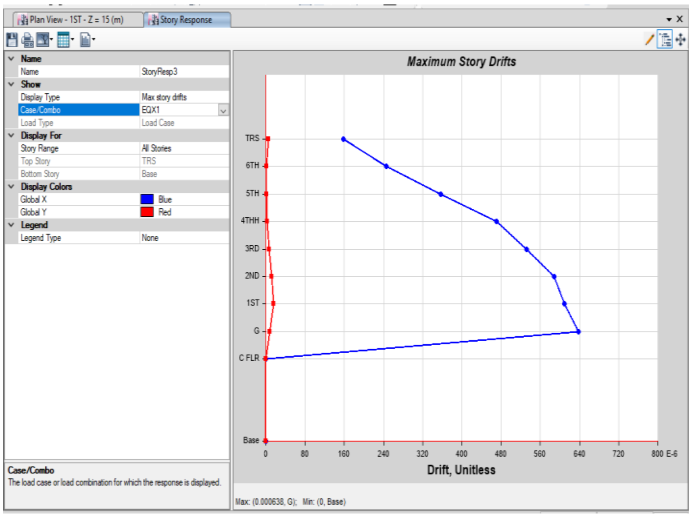


Chart -1: Storey drifts along X-direction

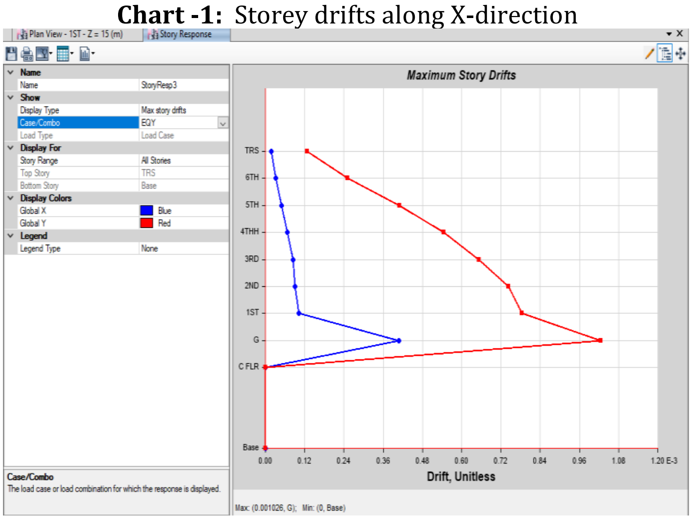


Chart -2: Storey drifts along Y-direction

7.4 .3 Response spectrum analysis: Maximum storey drift for normal model.

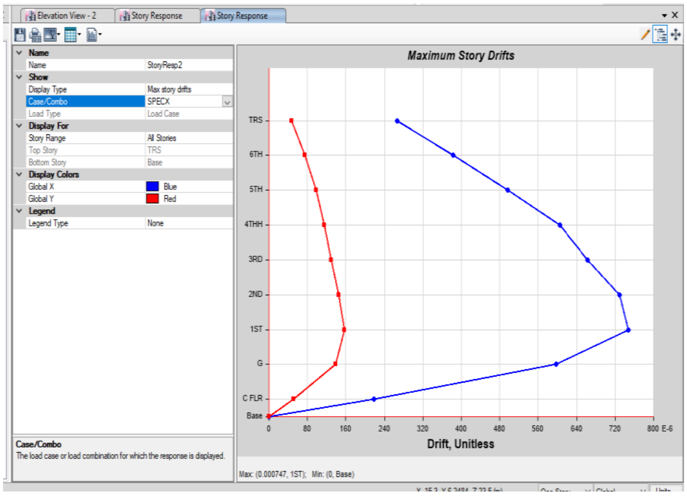


Chart -1: Storey drifts along X-direction

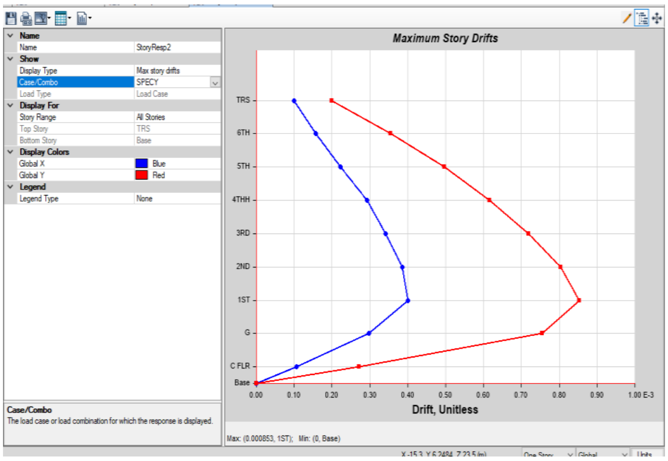


Chart -2: Storey drifts along Y-direction

7.4 .4 Response spectrum analysis:

Maximum storey drift for model with slopping ground.

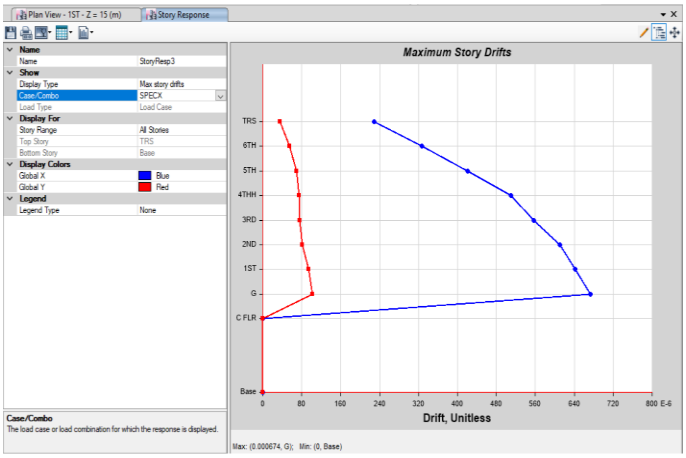


Chart -1: Storey drifts along X-direction

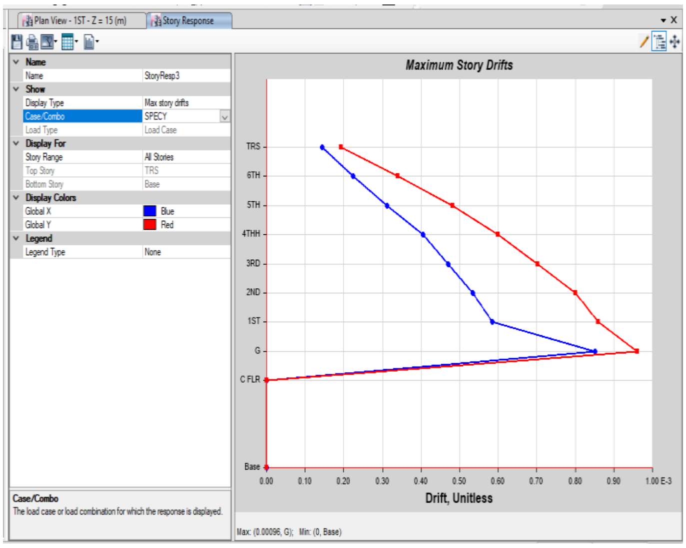


Chart -2: Storey drifts along Y-direction

8. CONCLUSIONS

1. Displacement for building constructed on sloped grounds is lower than compare to those on flat level grounds along the direction of the slope but tend to have a larger displacement perpendicular to the direction of the slope.

2. Structures constructed on sloping ground have higher time period compared to those on plain ground.

3. Story drift for building constructed on sloped grounds is lower than compare to those on flat level grounds along the direction of the slope but tend to have a larger story drift perpendicular to the direction of the slope.

4. Base shear of plain ground structural building is higher than compare to the sloped ground structural building.

5. The RCC buildings constructed on sloped grounds are more endangered to the earthquake forces than the RCC buildings constructed on flat level grounds.

6. During the earthquake short columns are more affected compared to long columns.

7. During design lateral forces and good flexibility joints between the beams and columns should be considered.

8. To ensure good performance of the building during earthquakes high quality of structure construction should be provided by conforming related IS codes such as IS 1893, IS 13920.

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