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Free Vibrating Analysis of Building Resting on Sloping Ground with Different Mode Shapes

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Abstract: **This study investigates the dynamic properties of the buildings situated in the hilly area. When any building is constructed in hilly area its response to the lateral forces such as earthquake and wind depends on the dynamic properties of the building. The response of building constructed on sloping ground is different from buildings constructed on the plain grounds. 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.**

Keywords: **Dynamic response, Mode shapes, Seismic, Sloping ground, Time history.**

I. INTRODUCTION

The economic growth & rapid urbanization in hilly region has accelerated the real estate development. In India various hill stations such as Dargiling, Sikkim, Simla, Mount Abu, Nainital, Uttarakhand, Saputara are situated in the hilly area, now due to development of the hill stations there is scarcity of land in this regions, so it is required to construct the residential as well as commercial buildings having 5 to 10 stories. Recently due to natural disasters in the Uttarakhand huge loss of life was occurred in these hilly regions, In 2011 Sikkim earthquake was strucked and many building were demand result gred loss to properly as well as to the life of the people, before constructing high rise buildings in this region it is required to study the dynamic properties of buildings. It is also required to study as response of building due to various lateral loads such as earthquakes.

The buildings constructed in the hilly regions has different mass and stiffness at each floor as well as due to this irregularity the center of mass and center of stiffness will also change at each level of building. In case of earthquake this eccentricity between center of mass and centre of stiffness results in the torsion in the building. So it is required to design the buildings constructed in sloping ground for this additional torsion. The torsion developed due to this eccentricity has different value at each level so it is strongly recommended to perform the dynamic analyzed of such buildings.

II. NUMERICAL DATA OF BUILDINGS

To study the dynamic properties such as frequency and time periods of building situated in hilly regions, different types of buildings are modeled on different ground slopes and in addition to this variation in storey of the building are also considered. In this study the building is modeled on 15 degree slope with 5 storeys and 10 storeys. 23 degree slope with 5 storeys and 10 storeys and 35 degree slope with 5 storeys and 10 storeys. The details of size of beam column are shown in the table.

Table 1: Details of Building

Geometry of Building		
Size of Column:-300mmx850mm, Size of Beam:- 230mmx500mm, Live load:- 3 KN/M^2		
Sr no.	Ground Slope	No of storey
1	15º	G + 05
2	15º	G + 10
3	23º	G + 05
4	23º	G + 10
5	35º	G + 05
6	35º	G + 10

The typical size of each bay considered is 7mtX 5 mt. the height of floor is taken as 3.5 meter. All the columns and beams are modeled as frame element in FEM software SAP 2000. The slabs are modeled as shell element and the discretisation of all elements are done to transfer the loads of slabs to beams and columns. The size of mesh taken according to convergence conditions. The static analysis is carried out for all six models and total dead loads and live loads are calculated at the footing level. The modal analysis of the building is carried out in such a way that total modal participation factor is more than 90 percentage. After performing and checking all the modals the acceleration time history of Bhuj, Chamoli, Uttarkashi and recent Nepal earthquake of 2015 is applied at the base of building. Modal linear analysis is carried out for all the buildings.

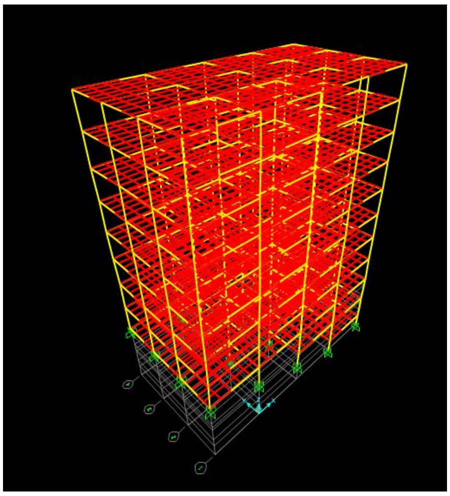

Fig.1: Building Model in SAP 2000

Fig.1 shows the FEM model of 10 storey high building prepared on 23 degree ground slope in software SAP 2000. In this building first the time periods, frequencies for different modes are studied. The modal participation factor is studied and number of modes are considered in such a way that modal participation factor is more than 90 percentage. The nonlinear acceleration time history of various earthquakes are applied at the base of footing and appropriate live loads as per IS 1893-2002 is considered for the analysis.

❖ **The following assumptions are made in the analysis.**

a) Material is homogenous, isotropic and elastic.

b) The values of modulus of elasticity and Poisson's ratio are 25000 N/mm2 and 0.20, respectively.

c) Secondary effect P-delta, shrinkage and creep are not considered.

d) The floor diaphragms are rigid in their plane.

e) Axial deformation in column is considered.

f) Each nodal point in the frame has six degrees of freedom, three translations and three rotations.

g) Torsion effect is considered as per IS: 1893 (I) –2002.

In addition to time history analysis of all building the response spectrum analysis of all building is also carried out the following data are used for response spectrum analysis.

1) **Seismic zone :** zone V
2) **Zone Factor :** 0.36.
3) **Importance Factor :** 1.0
4) **Response Reduction Factor :** 5
5) **Soil type :** Medium

For each building case minimum **12** modes were considered.

III. RESULTS AND DISCUSSION

All the buildings on sloping ground are analyzed for the dynamic loads and time history loads applied on the buildings. The absolute displacement of top most joint of the building is checked for all the buildings Fig. shows the deflection at the top of building for various building configurations.

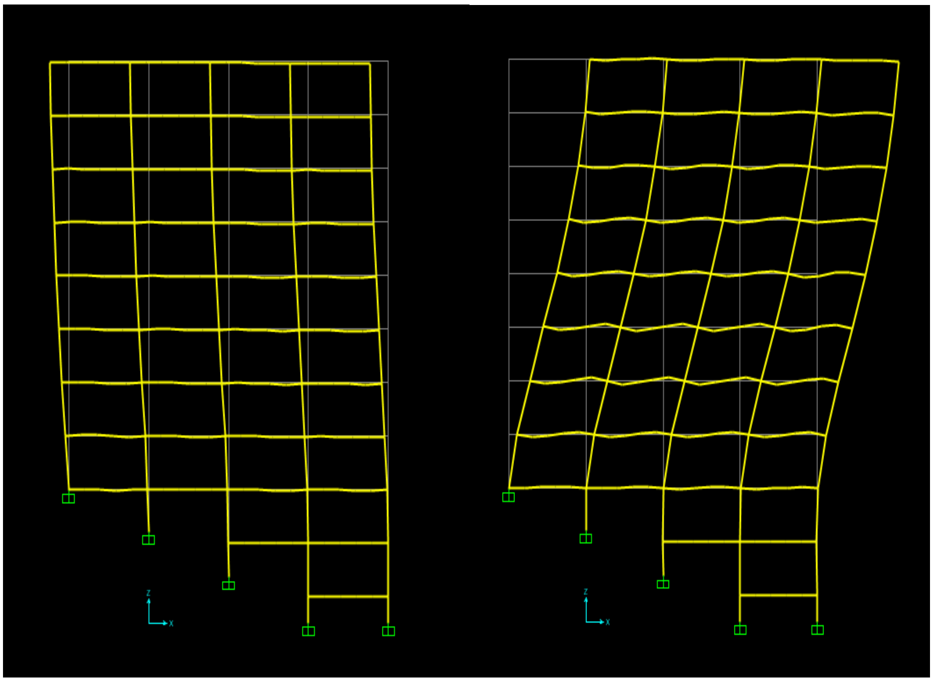

Fig.2: Mode 1 and Mode 2 of the Building, Lateral Cantilever Type Displacement

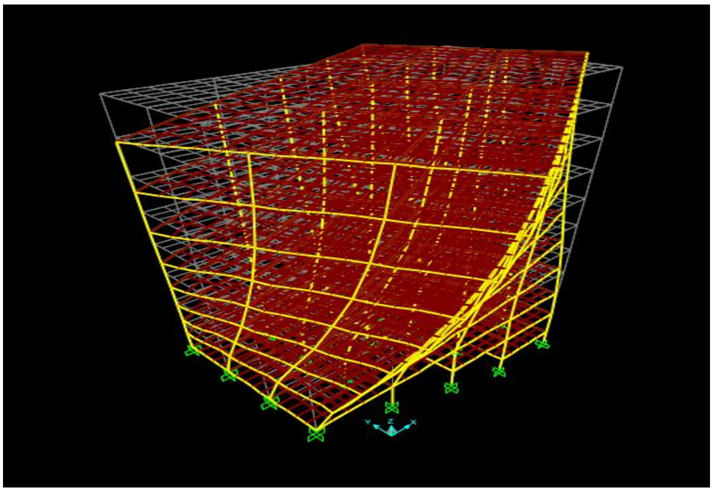

Fig.3: Torsional Mode of Building

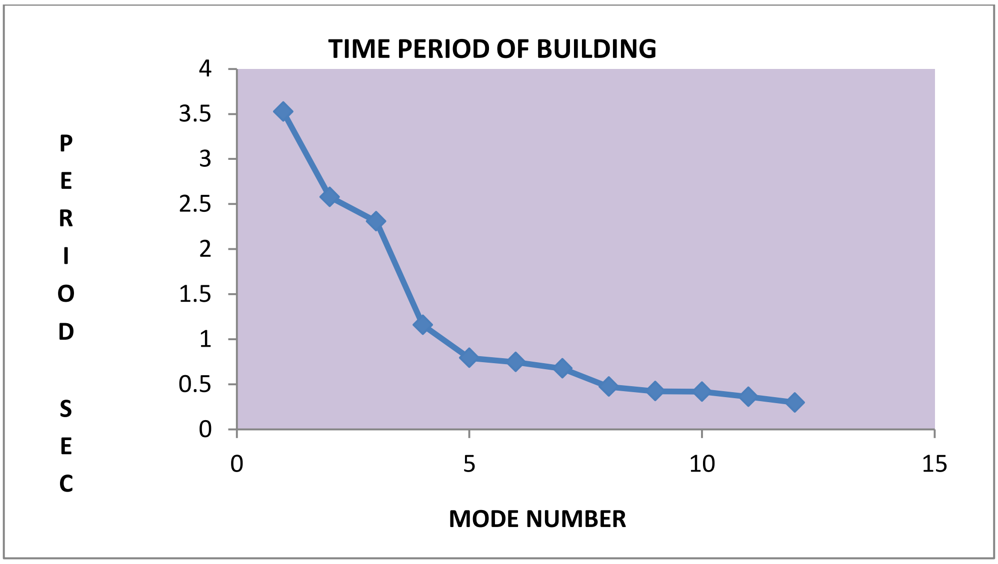

Fig.4: Time Period For 15 degree 10 storey

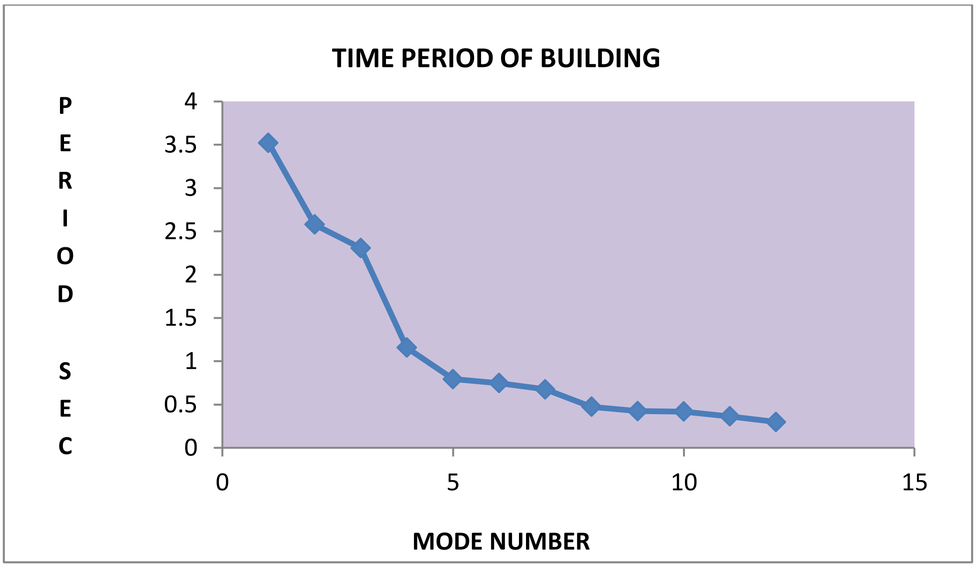

Fig.5: Time Period For 23 Degree 10 Storey

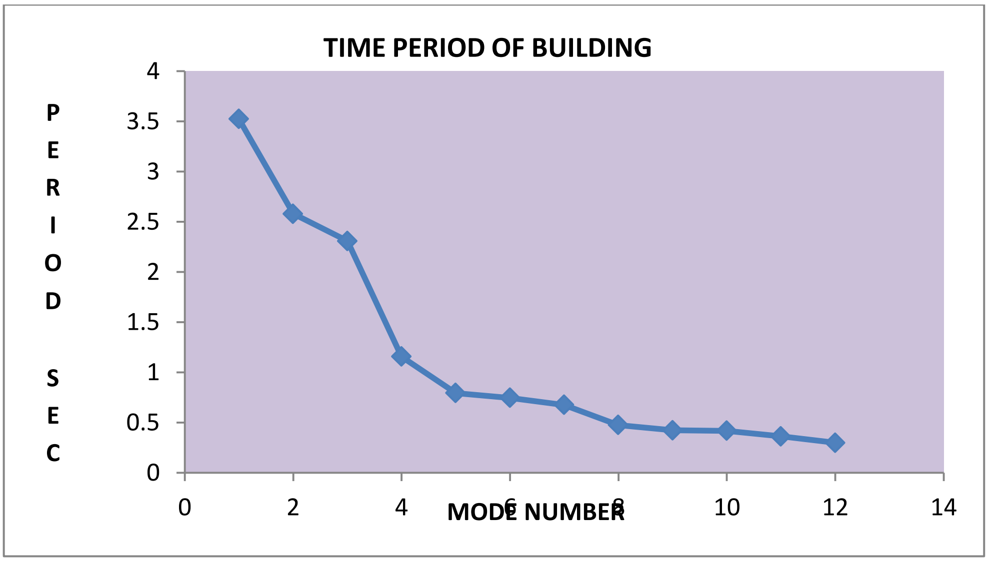

Fig.6: Time Period For 35 Degree 10 Storey

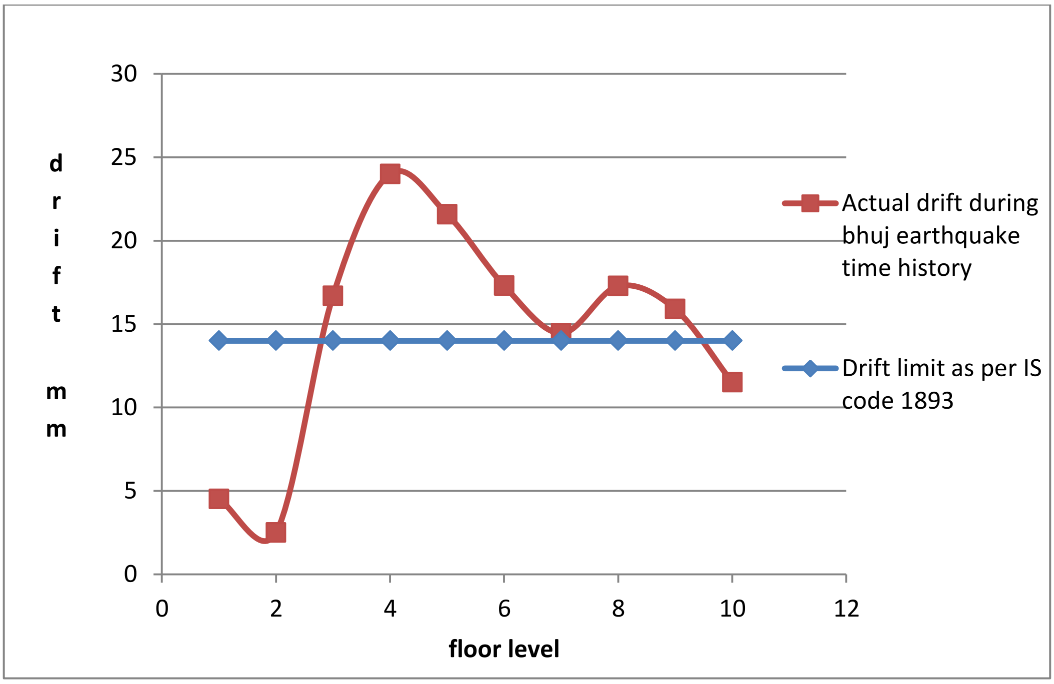

Fig.7 Storey Drifts for 23 Degree 10 Storeys for Bhuj EQ

IV. CONCLUSION

1) The deflection response of 5 storey building is less compare to 10 storey high buildings

2) In some cases as the slope of ground increase from 15 degree to 35 degree the deflection at the top joint also increase

3) We are getting more storey drift for Bhuj earthquake in building for floors between 3rd storeys to 9th storey so it is required to limit this storey drift by increasing the stiffness of the columns.

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