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Seismic Non-Linear Time History Analysis of Building Resting On Sloping Ground with Special Study on Nepal Earthquake

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Abstract: *This study investigates the seismic performance of buildings situated in hilly areas, the buildings situated in hilly areas are generally irregular, torsionally coupled & hence, susceptible to serve damage when affected by earthquake ground motion. The building situated on sloping grounds have mass & stiffness varying along the vertical & horizontal planes, resulting the center of mass & center of rigidity do not coincide on various floors ,so for detailed earthquake analysis of such buildings the dynamic analysis such as response spectrum or time history analysis must be carried out. The main objective is to understand the behavior of building on sloping ground for various time history (dynamic analysis). For this different angle of slopes on ground is taken with different height of building and the seismic analysis of building is carried out by using Finite Element Software SAP-2000. These unsymmetrical buildings require great attention in the analysis & design. Analysis of building on sloping ground is somewhat different than the buildings on leveled ground, since the column of hill building rests at different levels on the slope. The shorter column attracts more forces & undergoes damage, known as short column effect when subjected to earthquakes.*

Keywords: *Bending Moment, Displacement, Finite Element Method (FEM), Non-Linear Dynamic Analysis, Seismic, Sloping Ground, Time History, Torsion.*

I. Introduction

The hilly area is more prone to seismic activity e.g. northeast region of India. The scarcity of plan ground in hilly areas compels construction activity on sloping ground resulting in various important buildings. The economic growth & rapid urbanization in hilly region has accelerated the real estate development. Due to this, population density in the hilly region has increased enormously. Also there is scarcity of ground in hilly regions so reinforced cement concrete buildings such as hospital buildings, residential buildings are constructed in the sloping areas, Hence construction of multi-storey R.C. Frame buildings on hill slope is the only feasible choice to accommodate increasing demand of residential & commercial activities. Since, the behavior of buildings during earthquake depends upon the distribution of mass and stiffness in both horizontal and vertical planes of the buildings. The presence of such typical constructions in seismically prone areas makes them exposed to greater shears and torsion as compared to conventional construction. Due to varying mass and stiffness along its elevation and different direction, the mass and stiffness changes so only static analysis is not sufficient for these building so in order to study the seismic behavior of buildings on sloping ground a buildings with different storey height and different ground slopes is considered in this study and dynamic analysis including time history analysis of this buildings has been carried out.

II. Nepal Earthquake

A major magnitude- 7.8 earthquake struck central Nepal on April 25, 2015 leaving catastrophic impacts across the country. It was the largest earthquake to strike Nepal in over 80 year. That tremor, plus subsequent aftershocks, left more than 9100 people dead and nearly 25000 other injured. Extensive damage was recorded though out Nepal, particularly in the capital city of Kathmandu. The main jolt was later followed by a magnitude-7.3 aftershock on May 12, 2015.

The combined death toll from both tremors stood at 8891 and the number of injured was 22302 in Nepal alone. A further 229 fatalities were registered in India, Bangladesh, china's Tibet, and Mount Everest. Nepal is located in the center of Himalayan concave chain, and is almost rectangular in shape with about 870 km length in NWW-SEE and 130-260 km in N-S direction. The main frontal thrust system consists of two or three thrust sheet composed entirely of Siwalik rocks, from bottom to top mudstone, multi storied sandstone and conglomerate. The Kathmandu valley, where the 2015 Nepal earthquake caused heavy damage, comprises of thick semi-consolidated fluvio-lacustrine quaternary sediments on the top of basement rocks.

III. Numerical Data Of Buildings

To study the effects of seismic forces on the building, different types of buildings are modeled on different ground slopes and in addition to this variation in storey of the building are also considered. As per our study soil of Nepal is heaving sedimentation composed of rock such as lime stone, dolomite, meta sand stone, quartzite (Piya 2004). Hence for accurate seismic response fixed condition at foundation, soil contact is considered. In this study the building is modeled on 15 degree slope with 5 stories and 10 storeys. 23 degree slope with 5 story and 10 storey and 35 degree slope with 5 stories 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 5mt. 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.

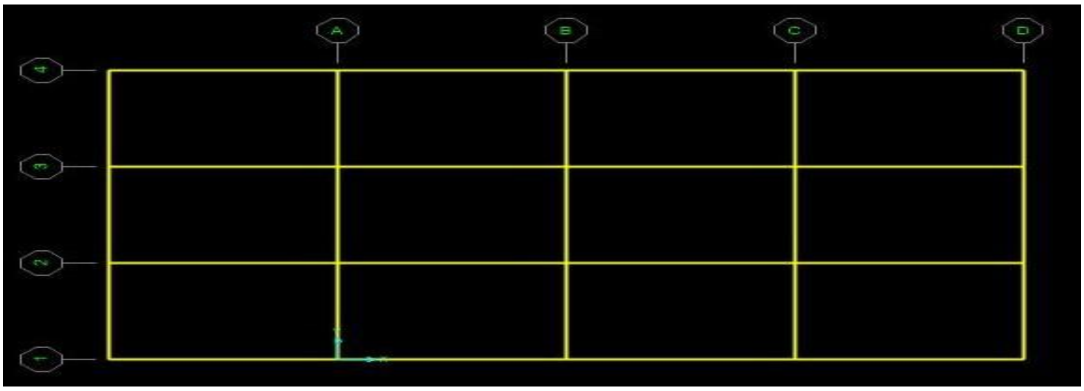

Fig.1 plan

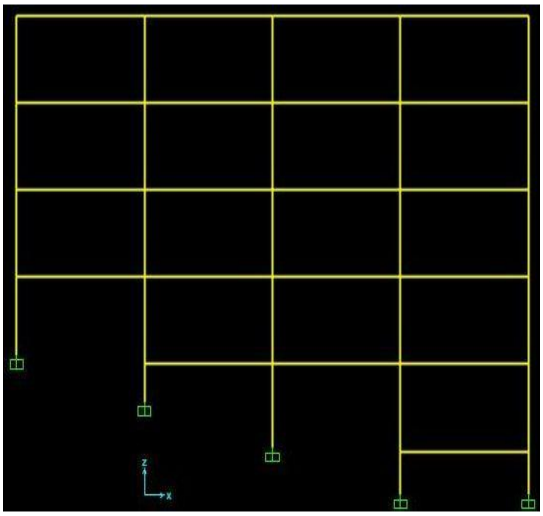

Fig.2 15degree 5 storey

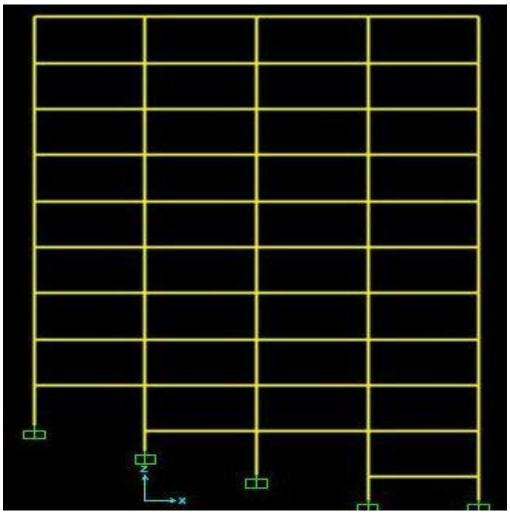

Fig.3 15degree 10 storey

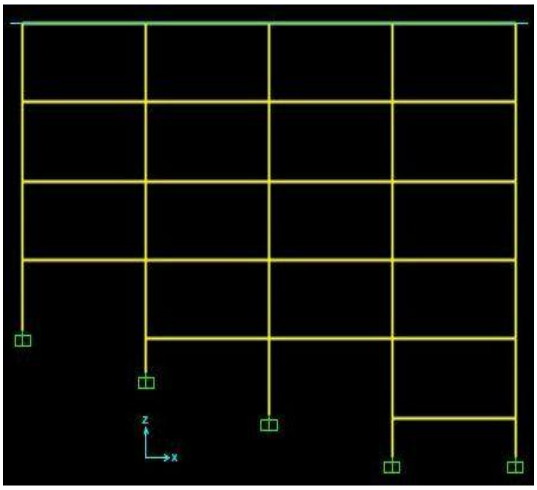

Fig.4 23degree 5 storey

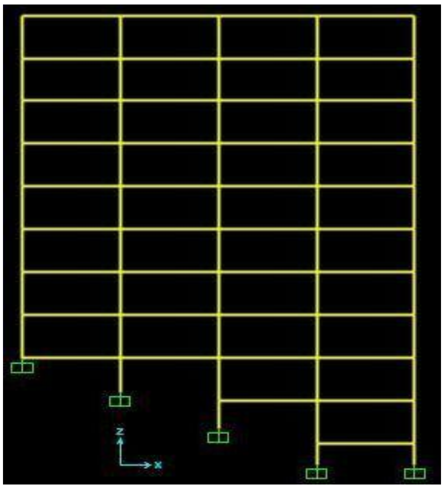

Fig.5 23degree 10 storey

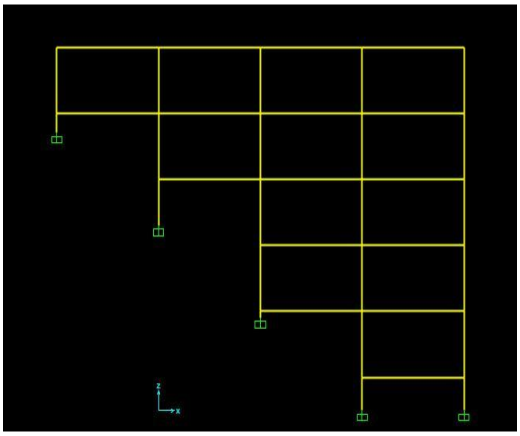

Fig.6 35degree 5 storey

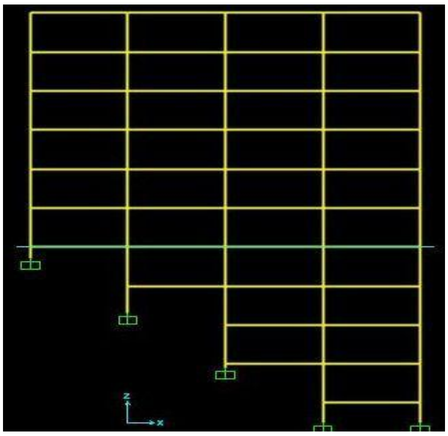

Fig.7 35degree 10 storey

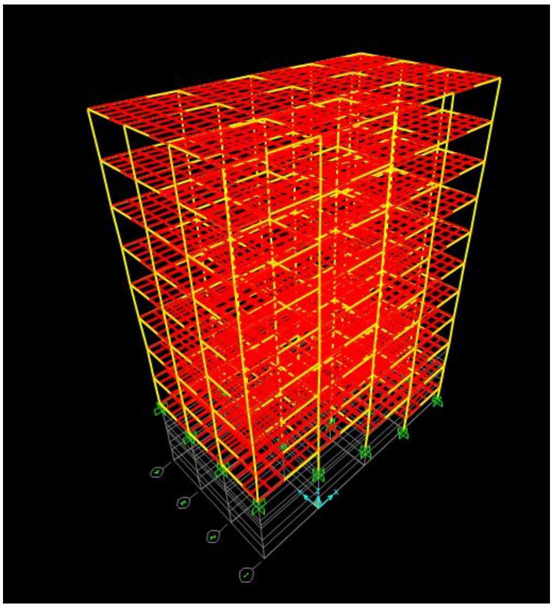

Fig.8 Building Model in SAP 2000

Fig.8 shows the FEM model of 15 storey high building prepared on 23 degree ground slope in software SAP 2000. In this building 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. Fig.9 shows the details of acceleration time history of Nepal Earthquake.

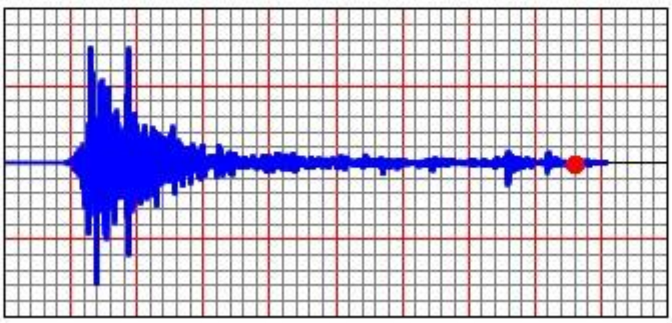

Fig.9 Details of Nepal time history
Max. P.G.A : 0.3 g
Duration : 362.4729 sec

- **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 and 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.

IV. 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 3 to 8 shows the deflection at the top of building for various building configurations.

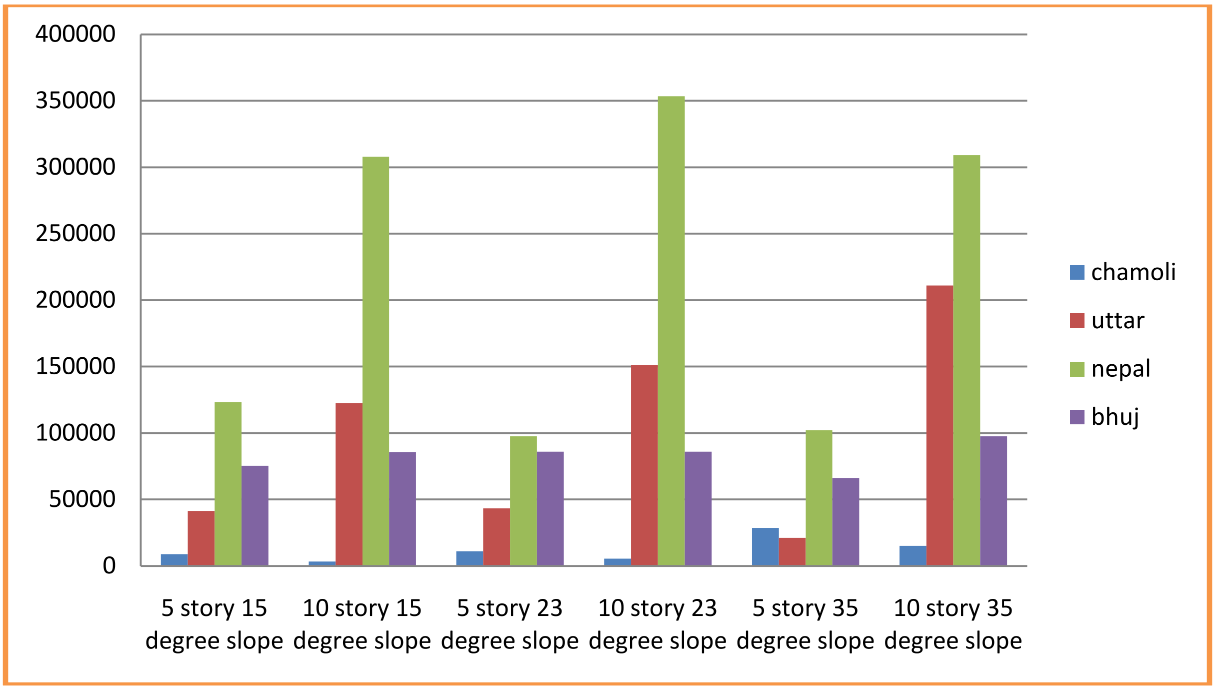

Chart .1 BENDING MOMENT COMPARISON (KN*M)

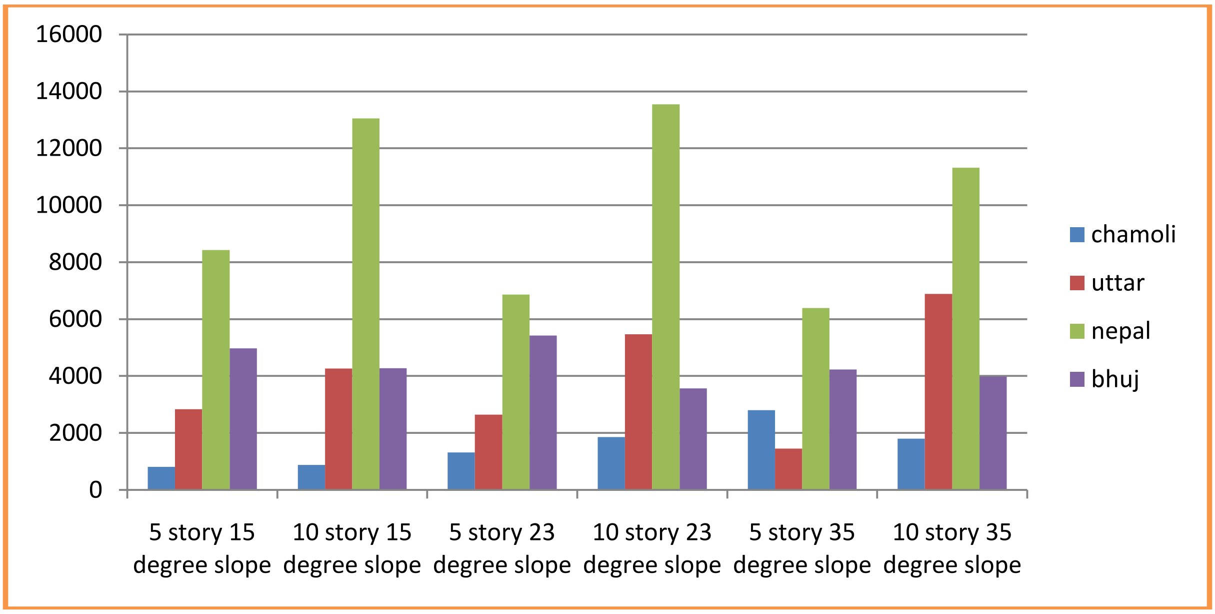

Chart.2 SHEAR FORCE COMPARISON (KN)

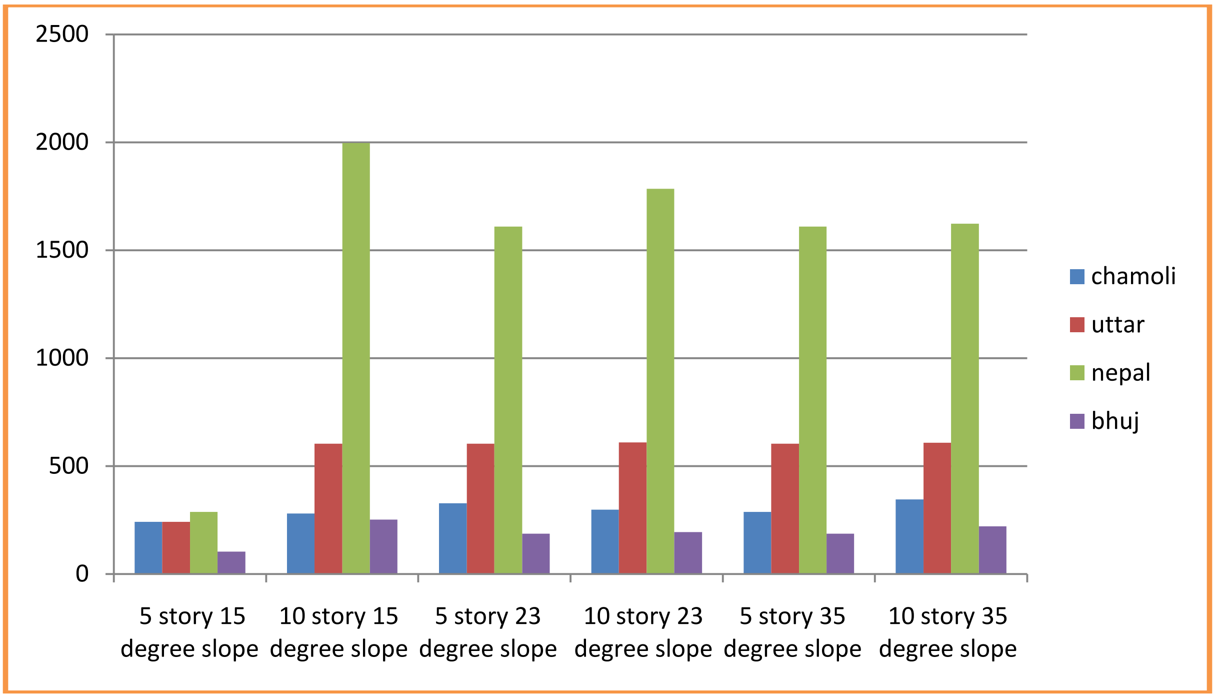

Chart.3 DISPLACEMENT COMPARISON (MM)

V. Conclusion

1.) As compare to building on level ground, building response on slopes required very special care for safety.
2.) The displacement response of building in Nepal for earthquake is more as compared to others, such as Chamoli, Uttarkasi and Bhuj.
3.) The bending moment and displacement increases as the slope of ground increase, for all type of earthquake.
4.) The shear force, bending moment and displacement increases as the height of building increases.
5.) We are getting maximum displacement, bending moments and shear force for Nepal time history for all the cases so we can conclude that Nepal earthquake occurred in 2015 has very severe effect on all the buildings constructed on sloping grounds.

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