DYNAMIC ANALYSIS OF BUILDINGS ON SLOPE: A REVIEW

Karan Singh, Manish Kumain, Jaibeer Chand
M.Tech in Structural Engineering, Faculty of Technology
Uttarakhand Technical University, Dehradun

ABSTRACT

Buildings constructed on slopes are different from those in plains. They may be irregular and unsymmetrical in horizontal and vertical planes, and torsion ally coupled. Hence, they are susceptible to severe damage when affected by earthquake ground motion. We can't avoid the future earthquakes but the preparedness and safe building construction practices for earthquakes can certainly reduce the extent of damage and loss of both property and life. Shear wall is one of the most commonly used lateral load resisting wall in buildings. Hence in the present work, an attempt is made to study the seismic behavior of the multi-storey buildings constructed on plain and various sloping ground with and without shear walls. The behavior of the building with different configurations of shear walls such as straight and symmetrical angle shape is also studied.

I. INTRODUCTION

In some parts of world, hilly area is more prone to seismic activity; e.g. northeast region of India. Inthis hilly regions, traditionally material like, the adobe, brunt brick, stone masonry and dressed stone masonry, timber reinforced concrete, bamboo, etc., which is locally available, is used for the construction of houses. A scarcity of plain ground in hilly area compels the construction activity on sloping ground. Hill buildings constructed in masonry with mud mortar/cement mortar without conforming to seismic codal provisions have proved unsafe and, resulted in loss of life and The economic growth and rapid urbanization in hilly region has accelerated the real estate development. Due to this, population density in the hilly region has increased enormously. Therefore, there is popular and pressing demand for the construction of multistory buildings on hill slope in and around the cities.

OBJECTIVE OF STUDY

To study the effect of vertical irregularity i.e. vertical geometric irregularity and stiffness irregularity due to sloping ground in high rise buildings under severe seismic zone considering parameters like displacement, fundamental natural period and base shear.

II. LITERATURE REVIEW

Farooq I. Chavan and S. K. Deshmukh (2008) In this paper, a G+6 storey building on sloping ground having an angle of 110& situated in Zone III, was analyzed using STAAD Pro & a comparison was done with the same building on plain ground. From the study, it is observed that the buildings which are resting on sloping ground are subjected to short column effect, attract more forces and are worst affected during seismic excitation. Hence, form design point of view, special attention should be given to the size, orientation, and ductility demands of short column.

K. S. L. Nikhila & B.Pandurangara (2010)-In this paper, the structures chosen for study are 4& 5 storied commercial complex buildings. The building is located in seismic zone IV on a rock soil site.

Ravikumar et al. (2012) studied two kinds of irregularities in building model namely the plan irregularity with geometric and diaphragm discontinuity and vertical irregularity with setback and sloping ground.

Sreerama and Ramancharla (2013) In their analysis they took five G+3 buildings of varying slope angles of 0, 15, 30, 45, 60° which were designed and analysed using IS-456 and SAP2000 and further the building is subjected and analysed for earthquake load i.e., N90E with PGA of 0.565g and magnitude of M6.7. They found that short column attract more forces due to the increased stiffness. The base reaction for the shorter column increases as the slope angle increases while for other columns it decreases and then increases. The natural time period of the building decreases as the slope angle increases and short column resist almost all the storey shear as the long columns are flexible and cannot resist the loads.

Patel et al. (2014) studied 3D analytical model of eight storied building was analysed using analysis tool ETabs with symmetric and asymmetric model to study the effect of variation of height of column due to sloping ground and the effect of concrete shear wall at different locations during earthquake. In the present study lateral load analysis as per seismic code was done to study the effect of seismic load and assess the seismic vulnerability by performing pushover analysis.

Birajdar and Nalawade (2004) performed 3D analysis of 24 RC buildings with three different configurations like set back, step back and step set back building. Response spectrum analysis including the torsional effect has been carried out. The dynamic properties which are top storey displacement, base shear and fundamental time period have been studied considering the suitability of buildings on sloping ground. In this study three types of configuration mentioned above are used in two (step back and step set back building) are on sloping ground while the third one (set back) is on plain ground. The sloping angle is taken as 27 degrees.

Sanjaya Kumar Patro&Susanta Banerjee (2010)-In their work, the authors studied torsionally coupled& irregular buildings in hilly areas & concluded they undergo more damage. Dynamic characteristics of hill buildings are somewhat different than the buildings on flat ground. Torsional effect on such buildings demands for having different stiffness and mass along horizontal and vertical plane during earthquake ground motion. Short column of

RC frame building suffers damage because of attracting more forces during earthquake.

Singh et al. (2012) carried out an analytical study using linear and nonlinear time history analysis. They considered 9 story RC frame building (Step back) with 45 degrees to the horizontal located on steep slope. The number of storeys was 3 and 9 and 7 bays along the slope and 3 across the slope.

Prashant and Jagadish (2013) studied the seismic response of one way slope RC building with a soft storey. They have focussed their work to the buildings with infill wall and without infill wall i.e., bare frame. They carried out pushover analysis in a 10 storey building which include bare frame with and without infill wall. The buildings were situated at an inclination of 27 degrees to the horizontal and having 5 bays along the slope. Frame system considered was specially moment resisting frame (SMRF).

Halkude et al. (2013) conducted seismic analysis of buildings resting on sloping ground by varying number of bays and slope inclination. They studied the dynamic characteristics of the building i.e., base shear, top storey displacement and natural

AshwiniBidari et.al has done the analysis and design of high-rise steel building frame with braced and without braced under effect of earthquake and wind .And the software used for all analysis s Sap2000. Dynamic analysis is carried out by using Equivalent Static method and Response spectrum method for earthquake zone V as per Indian code. The Natural period, Design Base shear, lateral Displacements are compared for the different silo supporting models .The braced system gives the economical results as compared to un braced system in terms of frequency and displacement.

KasliwalSagar K. et.al has investigated tha the present work two multi storey building both are sixteen storeys have been modeled using software package ETABS and SAP2000 for earthquake zone V in India. The paper also deals with the Dynamic linear.

Pralobh S. Gaikwad et al Response spectra method and static non-linear pushover method The analysis is carried on multi-storey shear wall building with variation in number and position of shear wall. The author have concluded that the shear walls are one of the mosteffective building elements which resist the lateral forces during earthquake. The shear wall in proper position can minimized effect and damages due to earthquake and winds.

Mayuri D. Bhagwat et.al studied dynamic analysis of G+12 multistoried practiced RCC building considering for Koyna and Bhuj earthquake is carried out. The time history analysis and response spectrum analysis and seismic responses of such building are comparatively studied. The modeled with the help of ETABS software is made. Two time histories (i.e. Koyna and Bhuj) have been used to develop different acceptable criteria (base shear, storey displacement, storey drifts).

III. THEORY OF RESEARCH

Buildings constructed in hilly areas have peculiar structural configurations. Successive floors of such buildings step back towards the hill slope and sometimes, the buildings also set back, as shown in the below figure. The stepping back of building towards hill slope results in unequal column heights in the same storey, which causes severe stiffness irregularities in along- and cross-slope directions.The torsional behaviour of these buildings is much more complex than that of buildings on flat ground due to shifting of Centre of stiffness and Centre of mass with floor level. Under along-slope excitation, the buildings having a symmetric configuration are not subjected to torsion, but the shorter columns on uphill side of a storey take the major share of the storey shear, which is usually much higher than their capacity and may result in shear failure.Another common type of structural configuration that is found on hills where buildings are located on steep slopes/vertical cuts, is shown in Figure below In this case, the foundations of the building are provided at two levels above: (i) at the base downhill, and (ii) at the road level. These buildings have a few storeys above the road level and several storeys below. ope direction, and the short columns at road level.

EXPERIMENTAL MODELING

Details of Laboratory Equipment's

- Three Mild Steel Plates
- Four Threaded Rods
- Nuts and Washers
- Wooden logs and Planks
- Shake Table
- Vibration Analyzer
- Control Panel
- Personal Computer
- Accelerometer

Experimental Setup

The holes of 8 mm diameter are driven in the plates 4 nos. through which threaded bar passes. The holes are made at a radial distance of 5√ cm from each corner of the plate. In plate 3 slot cut of 2 cm is done at a radial distance of 5√ cm from each corner of base plate which is connected to platform of shake table. A slot cut of 5 cm is made on base plate to accommodate slope angle of 15°, 20° and 25° at a distance of 41 cm from slot cut of connected leg. The threaded rods are passed through these slots and holes and are fixed to the platform using nuts and washers. Now the base plate is fixed maintaining the slope angle of 15°, 20° and 25° (one at a time). Now the Plate 1 and 2 are fixed at a clear distance of 51 cm and 92.5 cm from connected end of base plate respectively. The screw is tightened well to ensure proper fixity. The wooden logs are inserted in between base plate and platform to achieve firm base similar to that of a sloping ground. Now three accelerometers are connected to the plates, two of them with plate 1 and one with plate. These accelerometers are connected with the vibration analyzer and this analyzer is connected to the computer. The readings obtained due to the vibration are recorded through the accelerometer. One LVDT (Linear Variable Displacement Transducer) is also used to record the displacement of the shake table at the time of forced vibration. The maximum amplitude of the ground motion is kept 5 mm.

EXPERIMENTAL RESULTS

Frequency Response Analysis:

Graph3 shows the response of frequency (Hz) on X-axis with Top storey displacement (mm) on Y-axis for all three slope angles. In this plot the displacement is decreasing due to the increase in frequency and slope angle and the increased stiffness of short column on hill side.

IV. CONCLUSION

- 15 degree sloped frame experiences maximum storey displacement due to low value of stiffness of short column while the 25 degree frame experiences minimum storey displacement.
- 15 degree sloped frame experiences nearly the same storey velocity as of 20 degree and 25 degree in the top storey but the velocity is maximum for the storey level of first floor while for 25 degree frame velocity is minimum for level of first floor.
- 15 degree sloped frame experiences maximum storey acceleration for the top floor with little variations with the 20 degrees and 25 degrees model but for the storey level of the first floor, acceleration is maximum and is minimum for the storey level of the first floor for 25 degrees frame.
- The natural frequencies of the sloped frame increases with the increase in the slope angle.
- The number of modes considered in the analysis is satisfying the codal provisions.
- The modal mass participation of the sloped frame model are decreasing for the first mode and increasing for the second mode with the increase in slope angle.

For all the three frame models, time history response of the top floor acceleration is maximum at resonance condition i.e., when excitation frequency matches with fundamental frequency.

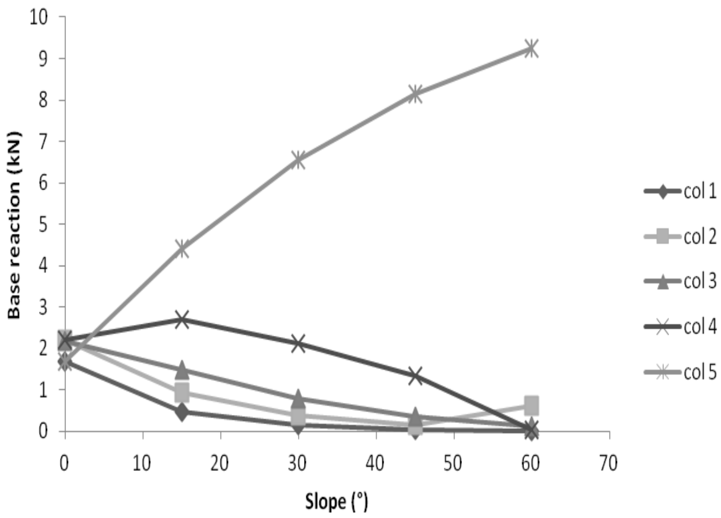
V. RESULT

Short column attract more earthquake forces and clearly above graphs prepared by observations shows that less angles same frequencies have more displacements and cause huge destructions. This is only case study work which is taken by much research paper. Hence this review paper consist only compare many great researcher work based on analysis of buildings on slope when earthquake occur.

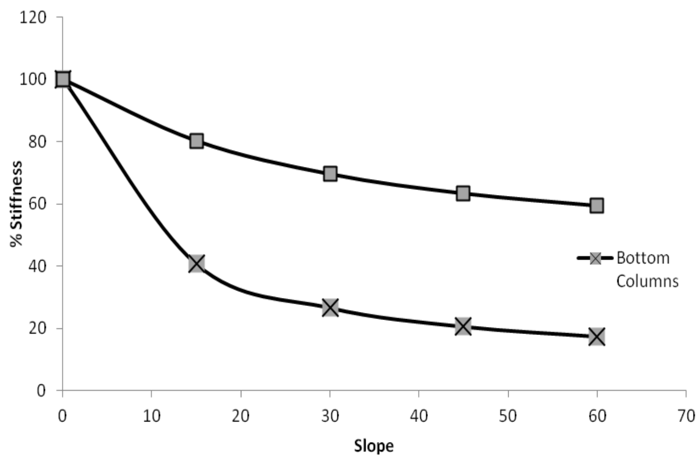
REFERENCES

[1]. BirajdarBG, Nalawade SS (2004) Seismic analysis of buildings resting on sloping ground. In: 13th world conference on earthquake engineering, Vancouver, B.C., Canada, paper no. 1472.
[2]. Nagargoje SM, Sable KS (2012) Seismic performance of multi-storeyed building on sloping ground. Elixir Int J 53: 11980–11982.
[3]. Singh Y, Gade P, Lang DH, Erduran E (2012) Seismic behavior of buildings located on slopes—an analytical study and some observations from Sikkim earthquake of September 18, 2011. In: 15th world conference on earthquake engineering journal 2012.
[4]. Farooque Patel MU, Kulkarni AV, Inamdar N (2014) A performance study and seismic evaluation of RC frame buildings on sloping ground. IOSR J Mech Civil Eng 51–58. e-ISSN:2278-1684, p-ISSN:2320-334X
[5]. Prashant D, Jagadish Kori G (2013) Seismic response of one way slope RC frame building with soft storey. Int J Emerg Trends Eng Dev 5(3)
[6]. Siddiqui RUH, Vidyadhara HS (2013) Seismic analysis of earthquake resistant multi bay multi storeyed 3D—RC frame. Int J Eng Res Technol 2(10). ISSN:2278-0181
[7]. Babu NJ, Balaji KYGD, Gopalaraju SSSV (2012) Pushover analysis of unsymmetrical framed structures on sloping ground. Int J Civil Struct Environ InfrastructEng Res Dev 2(4):45–54. ISSN:2249-6866
[8]. Ravikumar CM, Babu Narayan KS, Sujith BV, Venkat Reddy D (2012) Effect of irregular configurations on seismic vulnerability of RC buildings. Archit Res 2(3):20–26. doi:10.5923/j.arch.20120203.01
[9]. Halkude SA, Kalyanshetti MG, Ingle VD (2013) Seismic analysis of buildings resting on sloping ground with varying number of bays and hill slopes. Int J Eng Res Technol2(12). ISSN:2278-0181

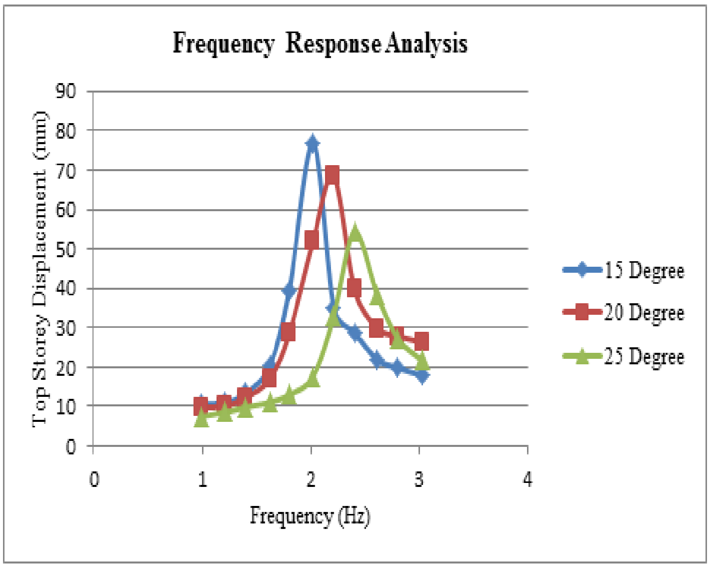
OBSERVATION



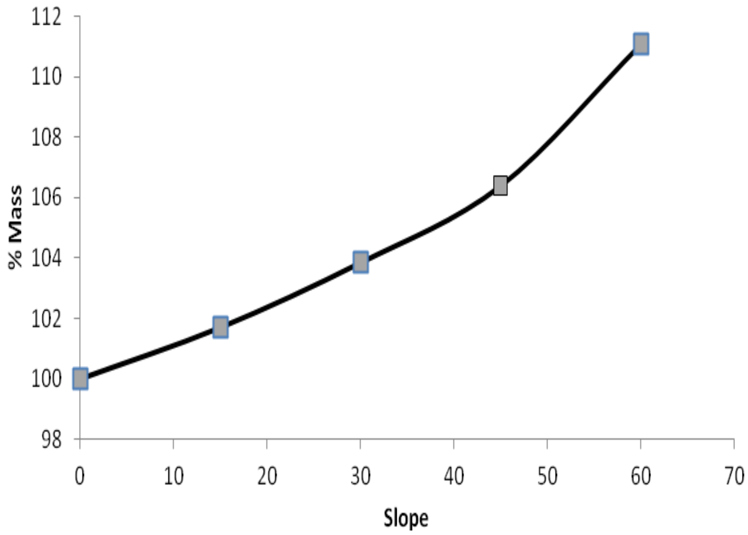
Graph1:Base Reaction Vs Slope



Graph2: % Stifness Vs Slope



Graph3: Frequency Response Analysis



Graph4: %Mass Vs Slope