DYNAMIC ANALYSIS OF SLOPED BUILDINGS: A REVIEW

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ABSTRACT

This study summarizes the knowledge in the seismic response of buildings on hill slopes. The dynamic response of the structure on hill slope has been discussed. A review of studies on the seismic behavior of buildings resting on sloping ground has been presented. It is observed that the seismic behavior of buildings on sloping ground differ from other buildings. The various floors of such buildings step backs towards hill slope and at the same time buildings may have setbacks also. Most of the studies agree that the buildings resting on sloping ground has higher displacement and base shear compared to buildings resting on plain ground and the shorter column attracts more forces and undergo damage when subjected to earthquake. Step back building could prove more vulnerable to seismic excitation. Dynamic response properties like time period, displacement and base shear actions induced in columns have been studied with reference to the suitability of a buildings configuration on sloping ground.

Keywords: Ground Motion, Linear Time History Analysis, Frequency Content, Finite Element Code.

I. INTRODUCTION

Structures on slopes differ from those on plains because they are irregular horizontally as well as vertically. The scarcity of plain ground in hilly areas compels construction activity on sloping ground resulting in various important buildings such as reinforced concrete frames hospitals, colleges, hotels and offices resting on hilly slopes. Due to varied configurations of buildings in hilly areas, those buildings become highly irregular and symmetric, due to variation in mass and stiffness distribution on different vertical axis at each floor. Such construction is seismically prone areas makes them exposed to greater shear and torsions as compare to conventional construction. Further due to site conditions, buildings on hill slopes are characterized by unequal columns heights within a story, which results in drastic variation in stiffness of columns of the same of story. The short, stiff column on uphill side attract much higher lateral forces and are prone to damages. As per IS 1893(part I); 2002, different vertical irregular configurations of buildings have been defined which are stiffness irregularity, mass irregularity, vertical irregularity.

II. RESEARCH SIGNIFICANCE

Dynamic response of a sloped building depends on Frequency content of the earthquake as it affects its performance when it is subjected to ground motion. In this research work experimental and numerical study is done by varying sloping angle. The scope of this study is summarized as follows:

- The experimental study is undertaken with a two storied sloped frame model mounted rigidly to a shake table, capable of producing sinusoidal acceleration to study the dynamic response of sloped frame due to change of slope inclination by keeping the total height of frame constant.
- Finite element method is used as a numerical tool to solve the governing differential equation for un-damped free vibration to find the natural frequency of model.
- New mark method is used for numerical evaluation of dynamic response of the frame model.
- Linear time history analysis is performed using structural analysis tool i.e., STAADPro.by introducing compatible time history as per spectra of IS 1893 (Part 1):2002 for 5 % damping at rocky soil.

III. LITERATURE REVIEW

- **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.

- **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.

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

- **Sanjaya Kumar Patro & Susanta Banerjee (2010) -** studied Dynamic characteristics of hill buildings are somewhat different than the buildings on flat ground. Tensional 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.

- **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. Pushover analysis was performed taking different lateral load cases in all three directions to identify the seismic demands.

- **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.

- **Babuet al. (2012)** performed pushover analysis of various symmetric and asymmetric structures constructed on plain as well as on sloping ground. They conducted analysis using structures with different configurations which are plan symmetry and asymmetry having different bay sizes.

- **Prashant and Jagadish (2013)** studied the seismic response of one way slope RC building with a soft storey. They have focused their work to the buildings with infill wall and without infill wall i.e., bare frame Sreerama and Ramancharla (2013) observed that Dynamic characteristics of the buildings on flat ground differ to that of buildings on slope ground as the geometrical configurations of the building differ horizontally as well as vertically.

IV. PROJECT MODELLING

The general software STAAD Pro. hasbeen used for the modeling. It is more user friendly and versatile program that offers a wide scope of features like static and dynamic analysis, nonlinear dynamic analysis and nonlinear static pushover analysis, response spectrum analysis, time history analysis etc. STAAD Pro. This chapter deals with experimental works performed on free vibration and forced vibration on sloped frame model. The results obtained from the experimental analysis are compared with the finite element coding executed in MATLAB platform. The work performed is categorized into three sections which are as follows:-

- Laboratory Equipment's
- Fabrication and Arrangement
- Free and Forced Vibration Analysis This project modeling study deals with experimental work, numerical work, and Software. Detailing of project modeling is given as follows:

Experiment Modeling

Details of laboratory equipments;

1. Three mild steel
2. Four threaded rods
3. Nut and washers
4. Wooden logs and planks
5. Shake table
6. Vibration analyzer
7. Control panel
8. Accelerometer
9. Personnel computer

Numerical Modeling

1. Finite element method
2. New mark direct integration approach

STAAD Modeling's

1. Frame modeling in staad
2. Structural element

V. SCOPE AND CONCLUSION

Earthquake is caused when it is subjected to the ground motion and due to which structure on hill slopes suffer damaged and to take care of such effects it is important to know the properties of earthquake and assumed its possible response which can occur on buildings. In this work, such analysis has been done experimentally with validation in structures analysis tool and finite element modeling to know the dynamic response of sloped buildings.
Following conclusions can be drawn for the three sloped frame model from the results obtained in analysis:

- 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.
- The base shear of all the buildings are nearly the same with little variations but their distribution on columns of ground story is such that the short column attracts the majority (75% approx.) of the shear force which leads to plastic hinge formation on the short column and are vulnerable to damage. Proper design criteria should be applied to avoid formation of plastic hinge.

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