"STUDY OF SEISMIC BEHAVIOUR OF MULTI-STORIED R.C.C. BUILDINGS RESTING ON SLOPING GROUND AND BRACING SYSTEM"

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ABSTRACT

The buildings situated on hill slopes in earthquake prone areas are generally irregular, torsionally coupled and hence, susceptible to serve damage when affected by earthquake ground motion. Such buildings have mass and stiffness varying along the vertical and horizontal planes, result the center of mass and center of rigidity do not coincide on various floors. The dynamic analysis is carried out using response spectrum method. The dynamic response that is fundamental time period, storey displacement and base shear action induced in columns has been studied for buildings of different heights. These results show that the performance of step back and set back building frames are more suitable in comparison with step back building frames. But after considering bracings to the step back building frames, a better performance can be observed when compared with step back and set back building frames. Three dimensional space frame analysis is carried out for four different configurations of buildings ranging from eight, ten and twelve storey resting on sloping ground. Building models are analyzed by ETABS software to study the effect of time period, storey displacement and base shear.

Keywords *: Earthquake, Sloping Ground, Response spectrum method, step back frames, step back and set back frames, step back with bracings, ETABS software.*

1. INTRODUCTION

The study of earthquakes and the structure of the earth, by both naturally and artificially generated seismic waves. From the seismic history of our country, it is observed that majority of the devastating earthquakes have been occurred in northern and north-eastern states of India.

In the last decade, all these regions have gone under rapid changes due to economic development. Being the frontier states rapid urbanization is going on these boundary of country, states with growing real estate development. Due to this, population density in hill region has increased enormously and all types of construction practices are followed.

All short of building materials that is adobe, burnt bricks, stone masonry, dressed stone, bamboo, timber and reinforcement concrete etc. are used depending upon the locally available material.

The adobe burnt brick, stone masonry and dressed stone masonry buildings are generally made over level ground in hilly regions. Since level land in hilly region is very limited, therefore there is a pressing demand to construct buildings on hill slope.

Hence construction of multistory R.C. frames buildings on hill slope is the only feasible choice to accommodate increasing demand for residential and commercial activities.

Three major earthquakes of magnitude greater than 8, Kangra (1905) have occurred in this hilly track in the last century. The hilly seismic region of our country ranges from Jammu Kashmir, Himachal Pradesh, North Uttar Pradesh, North Bihar, Sikkim, North Bengal, Assam, Meghalaya, Nagaland, Auranachal Pradesh, Manipur, and Tripura and Mizoram.

It is observed from the past earthquakes, buildings in hilly regions have experienced high degree of damage leading of collapsed though they have been designed for safety of the occupants against natural hazards. Hence while adopting practice of multi-storey buildings in these hilly and seismically active areas, utmost care should be taken making these buildings earthquake resistant.

1.1 Objective of the Present Study

It is observed from the past earthquakes, buildings in hilly regions have experienced high degree of demand leading to collapse though they have been designed for safety of the occupants against natural hazards. Hence, while adopting practice of multi-storey buildings in these hilly and seismically active areas, utmost care should be taken, making these buildings earthquake resistant. In these areas buildings with step back configuration frames may sometimes give worst results so bracing system is used for these buildings and comparing the results with other configuration.

The objectives of this work are as follows:

- The dynamic analysis is carried out using response spectrum method to the step back and step back, step back building frames and regular building on plain ground.
- To carry out modeling and response spectrum analysis of seismic behaviour of multi-Storied R.C.C. buildings resting on sloping ground and considering bracing system by analytically and compared the same using ETABS software.
- Three dimensional space frame analysis is carried out for four different configurations of buildings ranging from eight, ten and twelve storey resting on sloping ground under the action of seismic load by using Etabs software.
- Dynamic response of these buildings, in terms of base shear, fundamental time period and displacement are find out and compared within the considered configuration as well as with other configurations.
- To calculate the design lateral forces on sloping ground buildings using response spectrum analysis and to compare the results of different configurations of structures.

1.2 Limitations of the Study

- The only RC framed buildings are considered for the analysis.
- The buildings considered (8-12 storey buildings) without basement, shear wall.
- The contribution of infill walls are considered as non-integral with RC frames.
- The out of plane action of masonry walls are neglected in the analysis.
- The effect of the supporting foundation medium on the motion of structure gives soil structure interaction but this effects may not considered in the seismic analysis for structures supported on rock or rock like materials.
- The Flexibility of floor diaphragms are neglected and considered as rigid diaphragm.
- The base of the column is assumed to be fixed in the analysis.
- Secondary effect P- shrinkage and creep are not considered.

The contribution of infill wall to the stiffness was not considered. Loading due to infill wall was taken into account.

2. LITRATURE SURVEY

2.1 Background

Himalayan-Nagalushai region, Indo-Gangetic Plain, Western India, Kutch and Kathiawar regions are geologically unstable parts of the country and some devastating earthquakes of the world have occurred there. A major part of the peninsular India has also been visited by strong earthquakes but these were relatively few in number occurring at much larger time interval at any site and had considerably lesser intensity. The buildings on hill differ from other buildings. The various floors of such building steps back towards the hill slope and at the same time buildings may have setbacks also. Buildings situated in hilly areas are much more vulnerable to seismic environment.

Hill buildings are different from those in plains; they are very irregular and unsymmetrical in horizontal and vertical planes, and torsionally coupled. Hence, they are susceptible to severe damage when affected by earthquake ground motion. Past earthquakes [e.g. Kangra (1905), Bihar-Nepal (1934 and 1980), Assam (1950), Tokachi Oki-Japan (1968), and Uttarkashi-India (1991)] have proved that buildings located near the edge of stretch of hills or sloping ground suffered severe damages. Such buildings have mass and stiffness varying along the vertical and horizontal planes, resulting the center of mass and center of rigidity do not coincide on various floors. This requires torsional analysis; in addition to lateral forces under the action of earthquakes.

2.2 Discussions on Literature Review

It was found that large numbers of research works were conducted on seismic behaviour of multi-storied R.C.C. buildings resting on sloping ground. Mostly among all available literature and experimental work was based on the seismic response of RC buildings with different configuration on sloping and plain ground.

The following literature surveys for "Study of Seismic Behaviour of Multi-Storied R.C.C. Buildings Resting on Sloping Ground and Considering Bracing System" have been covered.

2.2.1 Nagarjuna, Shivakumar B. Patil [Jul 2015][1]

The structures are generally constructed on level ground; however, due to scarcity of level grounds the construction activities have been started on sloping grounds. There are two types of configuration of building on sloping ground, the one is step back and the other is step back setback. In this study, G+ 10 storeys R.C.C building and the ground slope varying from 10^o to 40^o have been considered for the analysis. A comparison has been made with the building resting on level ground (setback). The modeling and analysis of the building has been done by using structure analysis tool ETABS, to study the effect of varying height of the column in bottom storey and the effect of shear wall at different position during the earthquake. The results have been compared with the results of the building with and without shear wall. The seismic analysis was done by linear static analysis and the response spectrum analyses have been carried out as per IS: 1893 (Part 1): 2002. The results were obtained in the form of top storey displacement, drift, base shear and time period. It is observed that short column is affected more during the earthquake. The analyses showed that for construction of the building on sloping ground the stepback setback building configuration is suitable, along with shear wall placed at the corner of the building.

2.2.2 Narayan Kalsulkar, Satish Rathod [Jun. 2015][2]

Generally, building frames are analyzed for gravity loads in vertical direction and lateral loads like earthquake load and wind load in lateral direction. The analysis of structure depends on idealization of geometry of structure and idealization of load system on the structure. The behavior of buildings during earthquake depends upon the distribution of mass and stiffness in both horizontal and vertical planes of the buildings. General behavior is shattered when the structure has irregularities. These kinds of irregularities are especially seen in hilly regions, where the structure rests on the sloping ground. In the present study, the response spectrum method is carried out on the type of structure that rests on the

sloping ground. Building frames which occurs in hilly regions are narrowed down to two basic formats such as step back frames and step back-set back frames and dynamic responses have been studied for various building configuration.

2.2.3 A. S. Swathi et al. [May 2015][3]

In hilly areas buildings are built on sloping grounds. When the hilly areas come under the seismic zones, these buildings are highly vulnerable to earthquakes. This is due to the fact that the columns in the ground storey are of different heights in such a way that column in one end is a short column and column in other end is a long column. Along with this if the building has an open ground storey, the seismic vulnerability is further increases. This paper deals with the comparison of seismic performance of soft storey building on sloping grounds and soft storey building retrofitted with shear wall. The aim of the paper is to check if the seismic performance of the structure is improved when it is retrofitted with shear wall.

2.2.4 S. K. Deshmukh, Farooq. I. Chavan [Apr. 2015][4]

The aim of study is to analyze the RCC building sloping ground ,as such building are different from those in plains, they are irregular variation along the vertical and horizontal planes. The Experimental method used over here for seismic analysis is linear static method for seismic analysis of G+6 storey plain building as well as inclined building. In these case the analysis of structure is carried out computationally by using STAAD.Pro Initially plain they are very irregular and unsymmetrical in horizontal and vertical planes and subjected to torsion and twisting forces, this leads to, severe damage when subjected by Earthquake ground motion due to mass and stiffness building G+6 storey with plan dimension of 20m x 9m has been analyzed which is later on compared with analysis of similar building resting on sloping ground.

2.2.5 Prasad Ramesh Vaidya [Mar.2015][5]

This study investigates the seismic performance of shear wall building on sloping ground. The main objective is to understand the behaviour of the building on sloping ground for various positions of shear walls and to study the effectiveness of shear wall on sloping ground. The performance of building has been studied with the help of four mathematical models. Model one is of frame type structural system and other three models are of dual type (shear wall-frame interaction) structural system with three different positions of shear walls. Response spectrum analysis is carried out by using finite element software SAP 2000. The performance of building with respect to displacement, story drift and maximum forces in columns has been presented in this paper.

2.2.6 R. B. Khadiranaikar and Arif Masali [Sep. 2014][6]

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 behaviour of buildings resting on sloping ground has been presented. It is observed that the seismic behaviour 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.

2.2.7 G. Suresh, E. Arunakanth [Sep. 2014][7]

Three dimensional space frame analysis is carried out for two different configurations of buildings ranging from 8 to 10 storey resting on sloping and plain ground under the action of seismic load by using Etabs software. And also considering bracing system to step back building configuration. Dynamic response of these buildings, in terms of base shear, fundamental time period and displacement is presented, and compared within the considered configuration as well as with other configurations. At the end of suitable configuration of building to be used in hilly area is suggested.

2.2.8 Shivanand.B, H.S.Vidyadhara [Aug. 2014][8]

The buildings resting on hill areas have to be configured differently from flat ground. Hill buildings are different from those in plains; they are very irregular and unsymmetrical in horizontal and vertical planes, and torsionally coupled and hence susceptible to sever damage when affected by earthquake. The floors of such buildings have step back towards the hill slope and at the same time setback also. In this study 3D analytical model of 12 storied building have been generated for symmetric and asymmetric case. Building models are analyzed and designed by ETABS software to study the effect of influence of bracings, shear wall at different positions. Seismic analysis done by linear static (ESA), linear dynamic (RSA) and non-linear static Analysis (Pushover Analysis)

2.3 Summary of Literature Review

- The review of the study indicates that there are numerous research efforts found on seismic analysis of buildings resting on sloping ground.

- It was found that less numbers of research works were conducted on seismic behaviour of multi-Storied R.C.C. buildings resting on sloping ground and considering bracing system.
- This review reference paper aims to analyze the dynamic characteristics of these type of buildings with four different configuration such as
    - Step Back Buildings without Bracings.
    - Step Back Buildings with Bracings.
    - Step Back and Set Back Building without Bracings.
    - Regular Building on Plain Ground.

- It is observed from past earthquakes that the buildings on slopes serves more damage and collapse occurs.
- The study of earthquake resistant building on slopes becomes popular to prevent the loss of life, property during earthquake ground motion.

Short column of RC frame building serves damage because of attracting more forces during earthquake.

3. METHODOLOGY OF WORK

- **Problem Statement**

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 multi-storey buildings on hill slope in and around the cities.

It is observed from the past earthquakes, buildings in hilly regions have experienced high degree of demand leading to collapse though they have been designed for safety of the occupants against natural hazards. Hence, while adopting practice of multi-storey buildings in these hilly and seismically active areas, utmost care should be taken, making these buildings earthquake resistant.

Most of the constructions in hilly regions are constrained by local topography which results in the adoption of either a step back or step back and set back configuration. Due to this the structure is irregular by virtue of varying column heights leading to torsion and increased shear during seismic ground motion. The dynamic analysis is carried out using response spectrum method to the step back and step back and set back building frames. The dynamic response that is fundamental time period, storey displacement and drift, and base shear action induced in columns have been studied for buildings of different heights. These results show that the performance of step back and set back building frames are more suitable in comparison with step back building frames. But after considering bracings to the step back building frames, a better performance can be observed when compared with step back and set back building frames.

4 RESULTS AND DISCUSSIONS

In all, twelve buildings have been analyzed for seismic load. The seismic force was applied in X direction and Y direction independently. Important results are presented in terms of base shear, time period and top storey displacement. Results are compared according to building configuration frames such as step back without bracings, step back with bracings, step back and set back without bracing and regular building on plain ground frames under seismic loading.

4.1 Analysis of Results of R.C.Frames Building Configurations (2D) for 8 Storey by using Etabs 2015

4.1.1 Comparison of time period between step back without bracings, step back with bracings, step back and set back without bracing and regular building on plain ground frames of 8 storey building:

Time Period of Building Configurations for 8 Storey

Mode No.	Time Period in Seconds			
	Step Back without Bracings	Step Back with Bracings	Step-Set Back	Regular building
1	2.13	2.11	1.21	2.706
2	0.719	0.599	0.562	2.546
3	0.393	0.372	0.308	2.043
4	0.286	0.278	0.235	0.933
5	0.237	0.25	0.2	0.837
6	0.213	0.207	0.182	0.651
7	0.184	0.185	0.169	0.546
8	0.139	0.152	0.143	0.489

- **Result Conclusion:** from the above graph time period for step back without bracings and with bracings frames and regular building on plain ground are more than step-set back frames.

4.1.2 Comparison of storey shear between step back without bracings, step back with bracings, step back and set back without bracing and regular building on plain ground frames of 8 storey building:

Storey Shear of Building Configurations for 8 Storey

Number of Storey	Storey Shear in kN with respect to X-direction			
	Step Back without Bracings	Step Back with Bracings	Step-Set Back	Regular building
1	18.5925	134.4767	77.61	640.74
2	47.2681	231.0342	182.588	637.155

3	99.7293	359.549	332.028	622.699
4	181.4638	495.965	495.087	590.219
5	296.9171	635.2836	713.0672	532.476
6	448.1019	737.0458	1029.9723	442.253
7	631.3263	779.9709	1538.2347	312.332
8	285.3291	352.0129	589.58	135.494

- **Result Conclusion:** from the above graph storey shear for first stories step back without bracings and step-set frames are less than step back with bracings frames and regular building on plain ground.

5. CONCLUSION

To develop model by following basis

- **Model Description**
  - The height and length of building in a particular pattern are in multiple of blocks (in vertical and horizontal direction), the size of block is being maintained at 7 m x 5 m x 3.5 m.
  - The height of all floors is 3.5m
  - The depth of footing below ground level is taken as 1.8 m where, the hard stratum is available.
  - The slope of ground is 27 degree with horizontal, which is neither too steep or nor too flat.
  - Basically model consists of two bays with four groups of building configurations.
  - The dynamic analysis is carried out using response spectrum method to the step back and step back and step back building frames.
  - Three dimensional space frame analysis is carried out for four different configurations of buildings ranging from eight, ten and twelve storey resting on sloping ground under the action of seismic load by using Etabs software.

    In these way to analysis of these system.

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