

Comparative Analysis of RC Framed Structures under the Effect of Sloping Ground with Setback Configurations under Seismic Conditions” - A Review

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Abstract — Since the population of world increases drastically from last few decades, due to this there is scarcity of land. In such conditions, most of the population have been located in hilly areas. Utmost of hilly regions in northern India where seismic actions are common, buildings are mandatory to be erected on sloping ground due to insufficiency of plain land. And in hilly regions, due to sloping land most of the structures has been constructed with step back and set back configurations. Such building having these configurations in hilly areas are much more susceptible to seismic environment. These building are generally irregular or torsionally coupled and hence liable to severe damage when affected by earthquake ground motion. The main purpose of this study is to perceive the behaviour of such buildings with different configurations like step back and setback under sloping or levelled ground which helps structural engineer to understand its sustainability, its behaviour, its response against lateral and is to review further technologies for seismic damage which help to prevent or control the seismic damage.

Keywords: Set Back Building, Step Back Building, Sloping Ground, Seismic Analysis, Levelled Ground, Etabs

I. INTRODUCTION

The insufficiency of plain ground in hilly areas has led to construction on sloping ground. The behaviour of building during earthquake depends on the mass and stiffness in both horizontal and vertical planes of the buildings. Most of the buildings constructed on hill slopes are irregular and asymmetric due to step back and set back type construction. Such buildings are disposed to have special structural and constructional difficulties such as shear, torsion and unequal column heights within a storey, which consequences in drastic distinction in stiffness of columns of the same storey. The short column attracts much higher lateral forces and is prone to damage. In order to highlight the differences in behaviour, which may further be influenced by the characteristics of the locally available foundation material, a parametric study has been conducted on five different buildings i.e step back and step back-set back buildings using SAP 2000. Indian Standard building codes including IS:1893 (Part 1):2002 and IS:1893 (Part 1):2016 propose detailed dynamic analysis of these type of buildings on different soil (hard, medium and soft soil) types. To asses' acceptability of the design it is important to predict the force and deformation demands imposed on structures and their elements by severe ground motions by means of static pushover analysis.

The monetary growth & rapid suburbanization in hilly region has enhanced the real estate expansion. Due to this, population density in the hilly region has amplified

immensely. Therefore; there is prevalent & tenacious demand for the construction of multi - storey buildings on hill slope in and around the cities. Since level land in hilly regions is very inadequate, there is a insistent demand to build buildings on hill slope. Hence construction of multi-storey R.C. Frame buildings on hill slope is the only practicable choice to lodge growing demand of residential & commercial activities. It is observed from the past earthquakes, buildings in hilly regions have proficient high degree of demand leading to fall though they have been designed for safety of the occupants against natural hazards. Hence, while implementing practice of multi -storey buildings in these hilly & seismically vigorous areas, extreme care should be taken, constructing these buildings earthquake resistant.

II. OBJECTIVES OF THE STUDY

Structural stability is a beneficial parameter which is accountable to co-relate the seismic elastic response of RC structures. The objective of the present study is to evaluate the previous researches carried out determine the sloping effect on various R.C. frame with set-back & step back configuration. Effects of such limitations are also measured to recognize their outcome on seismic performance of building frames. An attempt is also made to understand the effectiveness and utility of this study and its effect on the structure.

III. LITERATURE REVIEW

There were various studies which have been conducted on the static and dynamic analysis of such structures with different types of soil effects and sloping configurations. The studies also suggests about the difficulties arise for the seismic design of such building where such situation occurs. Few of the data from previous studies have been discussed here along with the methodology adopted and conclusions. Many research investigations have been carried out regarding the use of set back and step back system in the multi-storey structures. In this review, characteristics of the structures due to variation of the slope angle are explained. The effect of the irregular configurations on vulnerability due to seismic forces is discussed. There are very few researchers who explained the effect of change of sloping angle.

B.G. Birajdar¹, S.S. Nalawade SEISMIC ANALYSIS OF BUILDINGS RESTING ON SLOPING GROUND", 13th World Conference on Earthquake Engineering, Vancouver, B.C., Canada, August 1-6, 2004, Paper No. 1472 took the materials isotropic, homogeneous in nature. Floor diaphragms are taken as rigid.M25 concrete was used and P-delta effects creep & shrinkage effects were not considered. Axial deformation was considered for columns.

Torsional effect was considered as per IS-1893:2002. Seismic analysis was performed by Response Spectra Method as per IS 1893:2002. Ordinary moment resisting frame was taken for all these types of buildings in seismic zone III. Response reduction factor and importance factor was taken as 3 and 1 respectively. 5% of damping was considered.

Pandey A.D et.al(2011) “Seismic Soil -Structure Interaction of Buildings on Hill Slopes”, Vol 2 No 2, International Journal of Civil and Structural Engineering :Static pushover analysis and response spectrum analysis(RSA) have been conducted on five buildings for different configuration with varying soil conditions. These buildings were analysed for different soil conditions (hard, medium and soft) by equivalent springs. The displacement from both pushover analysis and RSA was considered and response correction factor was obtained. Displacement obtained from pushover analysis was greater than displacement from that of RSA. The value of T increases with the decrease in the correction factor.

Y.Singh et.al(2012) - Seismic Behavior of Buildings Located on Slopes-An Analytical Study and Some Observations from Sikkim Earthquake of September 18,2011”, 15WCEE LISBOA 2012 : Dynamic analysis of hill structure of different configuration of sloping angle 45° was compared with regular structure on a plain ground with respect to, inter story drift ,fundamental period of vibration, plastic hinge formation and column shear. Linear and non-linear time history analysis was carried out. Hill buildings have different dynamic characters compared to structures on plain ground. Due to vertical and horizontal irregularity on a sloping ground torsional irregularity was observed due to shifting of centre of stiffness and centre of mass with floor level. Story shear was higher on hill slope which resulted in shear failure.

S.M.Nagargoje and K.S.Sable Seismic performance of multi-storeyed building on sloping ground", Elixir International Journal, 7 December 2012 analysed the seismic behaviour of these building located in seismic zone III by Seismic Coefficient Method as per IS 1893:2002. Response reduction factor and importance factor was taken as 5 and 1 respectively. Minimum six modes were analysed for each type of building.

Prasad Ramesh Vaidya (2014) [4] “Seismic analysis of building with shear wall on sloping ground” *International Journal of Civil and Structural Engineering Research* ISSN 2348-7607 (Online), 2(2), pp: (53-60), (2014). –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 study.

Sujit Kumar et al. (2014) [3] “The effect of sloping ground on structural performance of RCC building under seismic load” *International Journal of Science, Engineering and Technology*, 2(6), (2014). – He studied the seismic analysis of a G+4 story RCC building on varying slope angles i.e., 7.50 and 150 is studied and compared with the same on the flat ground. The seismic forces are considered as per IS: 1893-2002. The structural analysis software STAAD Pro v8i is used to study the effect of sloping ground on building performance during earthquake. Seismic analysis has been done using Linear Static method. The analysis is carried out to evaluate the effect of sloping ground on structural forces. The horizontal reaction, bending moment in footings and axial force, bending moment in columns are critically analyzed to quantify the effects of various sloping ground. It has been observed that the footing columns of shorter height attract more forces, because of a considerable increase in their stiffness, which in turn increases the horizontal force (i.e. shear) and bending moment significantly. Thus, the section of these columns should be designed for modified forces due to the effect of sloping ground. The present study emphasizes the need for proper designing of structure resting on sloping ground.

Sripriya Arjun and Arathi S. (2015) “Dynamic Characteristics of RC Buildings on Hill slopes” *International Journal of Science and Research (IJSR)* ISSN (Online): 2319-7064 Index Copernicus Value 6.14, pp. 1116-1119, (2015). – In this study, behaviour of G+3 storied sloped frame building having step back set back configuration is analyzed for sinusoidal ground motion with different slope angles i.e., 16.7°, 21.8°, 26.57° and 30.96° using structural analysis tool STAAD Pro. by performing Response Spectrum analysis as per IS:1893 (part 1): 2002. The results were obtained in the form of top storey displacement and base shear. It is observed that short column is affected more during the earthquake. The analyses showed that for construction of the building on slopy ground the step back setback building configuration is suitable.

S.P. Pawar et al. (2016) [1] “Effect of positioning of RC shear wall of different shapes on seismic performance of building resistance on sloping ground” *International Journal of Civil Engineering and Technology (IJCIET)*, 7(3), pp. 373–384, (2016). – This study based on the seismic behaviour of buildings resting on sloping ground with a shear walls. 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. Most of the studies agree that the buildings resting on sloping ground have 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. They conclude that, buildings on sloping ground have higher stiffness on shortest column. The base shear and displacement is more along the slope than in other transverse direction. The straight shape (or rectangular) shear walls configuration proves to be better among all configurations for resisting the lateral displacement.

Sahil Abbas Zaidi et. al. - Study on the effects of seismic soil-structure interaction of concrete buildings resting on hill slopes Volume 43, Part 2, 2021, Pages 2250-2254

<https://doi.org/10.1016/j.matpr.2020.12.532> - Due to the irregularity and asymmetry of the hill buildings, the centre of mass and the centre of stiffness of the buildings do not coincide and the buildings are subjected to greater shear and torsion. The present study is undertaken to observe the soil-structure interaction effect on a 4 storey RC building resting on hill slopes. The considered building rests on three different slopes. The ground slope is varied as 0° , 15° and 27° . The considered buildings have been modelled and analysed in SAP2000 software. The considered building models are subjected to earthquake forces. A nonlinear static pushover analysis is performed on the considered building models. The results obtained from the analysis in terms of base shear and displacement at the performance point are then compared within the considered configurations of the building. It is observed that the response of the structure reduces to a much significant amount when the effect of soil-structure interaction is considered. Hence, it is concluded that the effect of soil-structure interaction must be considered while designing a building. By doing so, the structure can be designed for a much lower capacity resulting in an economical design.

Sukh Sagar Shukla and Yogesh Aggarwal, - Modelling of RCC Framed Structure on Sloping Ground using ANN and Random Tree techniques Proceedings-AIR2022, River Publishers (ISSN: 2794-2333) 2023 - Framed buildings built on hill slopes exhibit structural behaviour that differs from those built on flat ground. Because these structures are unsymmetrical in nature, they draw a high quantity of shear pressures and torsional moments, and their distribution is uneven owing to different column lengths. Because analysing complex structures takes a significant amount of time and effort. The aim of this paper is to create a model to predict seismic analysis parameters using machine learning methods and evaluate the outcomes of various techniques utilised.

Bush RC, Varsha Rani et. al. - Seismic Performance Evaluation and Comparative Study of Reinforced Concrete Building on a Sloped Terrain with Regular Building by Considering the Effect of URM Infill Walls 2024, 14, 33 - <https://doi.org/10.3390/buildings 14010033> - This paper focuses on the seismic vulnerabilities of multi-storey buildings in hilly regions like Sikkim and Uttarakhand, where rapid construction is driven by population growth and tourism. The study particularly evaluates step-back buildings on hilly slopes, comparing their vulnerability to standard buildings on flat terrain. Using non-linear analysis to assess structural aspects like displacement and storey drift ratio, the research examines the performance of these buildings in both uphill and downhill orientations against typical three-storey and six-storey structures, respectively. The findings indicate that step-back buildings, especially those without infill walls, are more susceptible to seismic damage. For instance, on the uphill side, a step-back building shows a mean drift ratio 15.11% greater in the X direction and 4.57% greater in the Y direction compared to a three-storey regular building (3SR). This vulnerability is exacerbated when infill walls are absent, with mean drift ratios in step-back buildings being 74.75% and 33% higher in the X and Y directions, respectively. Moreover, at a seismic acceleration of 0.36 g, the mean displacement of a step-back building is 83% greater in the X

direction and 51% greater in the Y direction than those with infill walls (SBIN), underscoring the significant role of infill walls in enhancing earthquake resilience. The study also highlights that short columns in step-back buildings are particularly prone to severe damage, especially just above the uppermost foundation level. While infill walls offer substantial mitigation of damage at the Design Basis Earthquake (DBE) level, at the Maximum Considered Earthquake (MCE) level, step-back buildings still endure severe damage compared to regular buildings with infill walls. Consequently, the research establishes that step-back buildings demonstrate greater vulnerability at DBE levels without infill walls and are more susceptible to damage than flat terrain buildings at MCE levels, emphasizing the need for careful design and reinforcement strategies in earthquake-prone hilly areas.

IV. CONCLUSION

From the above literatures of set back and step back system on the sloping ground, it is found out that the shorter column attracts more forces and undergoes damage, when subjected to earthquakes. The further difficulties related with hill buildings are, supplementary lateral earth pressure at various levels, slope instability, different soil profile resilient inadequate settlement of foundation. Analysis of buildings in hill region is somewhat unlike than the buildings on flattened ground, since the column of the hill building respites at different levels on the slope. Such buildings have mass and stiffness fluctuating along the vertical and horizontal planes ensuing the centre of mass and centre of rigidity do not concur on various floors, hence they mandate torsion-al analysis, in addition to lateral forces under the action of earthquakes. From the above points, it is concluded that the performance of such structure needs to be perceived alertly in the Earthquake prone areas.

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