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

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Abstract—

From the past few decades the population of the world has been rising hastily, due to this there is scarcity of land. To overcome this drawback, structures of different configurations such as Step-back and Step back-set back has been adopted on hilly regions. Most of hilly regions in northern India where seismic activities are common, buildings are required to be constructed on sloping ground due to scarcity of plain land. Buildings situated in hilly areas are much more vulnerable to seismic environment. The buildings situated on hill slopes in earthquake prone areas are generally irregular, torsionally coupled and hence susceptible to severe damage when affected by earthquake ground motion. The aim of this study is to observe the behaviour of such buildings with step back and setback configurations under different ground conditions i.e sloping ground and levelled ground and find its sustainability and is to review technologies for seismic control.

Keywords *– Set back Building, Step Back Building, Sloping Ground, Seismic Analysis, Levelled Ground, Etabs.*

1. Introduction -

The scarcity 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. Majority of buildings constructed on hill slopes are irregular and asymmetric due to step back and set back type construction. Such buildings are prone to have special structural and constructional problems such as shear, torsion and unequal column heights within a storey, which results in drastic variation 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. Current building codes including IS:1893 (Part 1):2002 and IS:1893 (Part 1):2016 suggest 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 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. Therefore; there is popular & pressing demand for the construction of multi - storey buildings on hill slope in and around the cities. The adobe burnt brick, stone masonry & dressed stone masonry buildings are generally made over level ground in hilly regions. Since level land in hilly regions is very limited, there is a pressing demand to construct buildings on hill slope. 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. 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 & seismically active areas, utmost care should be taken, making these buildings earthquake resistant.

2. OBJECTIVES OF THE STUDY

Structural stability is a useful parameter which is responsible 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 parameters are also studied to identify their effect 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.

3. 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. Torsion-al 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 45º 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 slopping 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 sloppy 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.

4. Conclusion –

From the above literatures of set back and step back system on the sloping ground, it is find out that the shorter column attracts more forces and undergoes damage, when subjected to earthquakes. The other problems associated with hill buildings are, additional lateral earth pressure at various levels, slope instability, different soil profile yielding unequal settlement of foundation. Analysis of buildings in hill region is somewhat different than the buildings on levelled ground, since the column of the hill building rests at different levels on the slope. Such buildings have mass and stiffness varying along the vertical and horizontal planes resulting the centre of mass and centre of rigidity do not coincide on various floors, hence they demand 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 observed vigilantly in the Earthquake prone areas.

5. References -

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