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Seismic Behavior of Different configuration of Multi-Storey RC Buildings on Sloping Ground: A Review

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Abstract-Analysis and design of building on sloping ground for seismic loading is very necessary these days, because construction of buildings on plain ground leads to less availability of plain areas. It is also necessary to construct an economic and more durable structure on sloping ground. This paper provides idea about the seismic response of structures on inclined ground and plain ground. The dynamic and static response of the structure on slope surface and flat surface has been reviewed. The seismic effect on different configuration of structures such as set back building and step back buildings are studied. The majority of the investigations concluded that the structures laying on inclining ground has higher base shear and displacement compare to the building on plain ground. The shorter column effect is more in sloping ground structures under seismic effect. This paper provides an overview of critical issues for research on the sloping ground buildings and compares the analysis and results of sloping ground and plain ground buildings and also provides different methods of resistance of building against earthquake.

Keywords- Set-Step back building, Step back and Set back buildings, Shear wall and Bracing.

1. INTRODUCTION

Due to the shortage of plain ground, the R C Buildings such as residential buildings, hospitals, colleges and other commercial buildings are constructed on sloping ground. So that the construction of R C buildings on hilly areas is the only possible choice to the increasing accommodate demand of commercial and residential activities. Compare to the plain ground the earthquake effect is more in the sloping ground, so study of the seismic loading on R C building rested on sloping ground is necessary to understand effect caused on building during the earthquake. Shaking of the Earth surface is caused due to sudden arrival of vitality in the Earth's lithosphere that generates seismic waves that causes the earthquake. The seismic effect of an area is analyzed on the basis of frequency, type and size of earthquakes experienced over a period of time in a region under consideration. Where the rate of seismic activity fairly constants that zone is called seismic zone. Based on seismic activity different zone are classified. Earthquakes themselves do not cause casualties, the building collapse during severe earthquakes cause loss of human lives. The irregular buildings such as step back and set back, require more focus in the analysis and design under the action of seismic forces **[22].** During earthquakes, buildings near the edge of the slope are seriously damaged. Earthquake effect is controlled by providing shear wall and bracing system, these increase stiffness of building and reduce shear force demands on columns and beams in building **[1-22]**.

1.1. *Necessity to design the building on sloping ground*

Due to the rise in population these days, there is a huge growth in the construction industry. Presently, new techniques are adapted to developed construction industry and activities. New innovative techniques are constantly adopted in the construction industry. Due to the increase in construction, there is no abundant plain ground so the structures are constructed on the sloping ground.

2. STRUCTURE AND ANALYTICAL MODEL

There are two types of buildings mainly constructed on flat and inclined ground such as step back building and set back building. Figure 1, figure 2 and figure 3 represents the step back structure on flat ground, step back structure on inclined ground and set back structure on flat ground respectively. Figure 4 represents set-back structure on inclined ground. It has been observed that, most of the authors used the STAAD PRO, ETABS and SAP 2000 software for modeling and analysis of structures and they concluded that step back and set back are most preferred structures on inclined ground **[1-10]**.

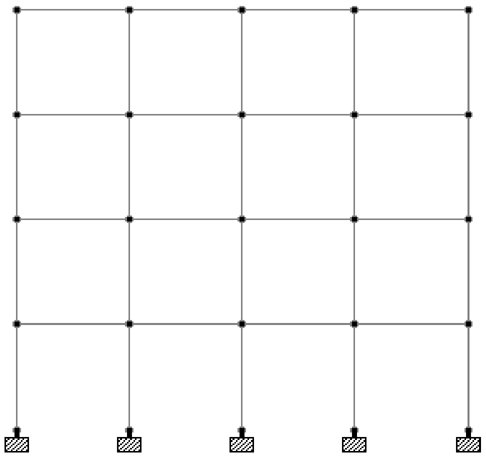

Figure 1-Step Back Structure on flat ground

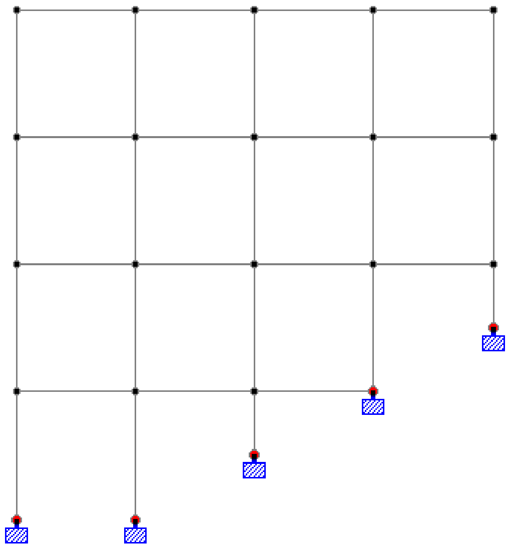

Figure 2-Step Back Structure on inclined ground

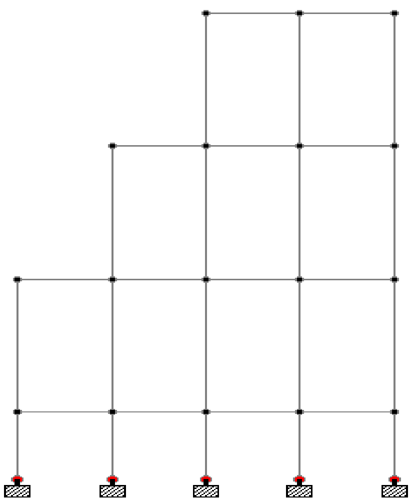

Figure 3-Set Back Structure on flat ground

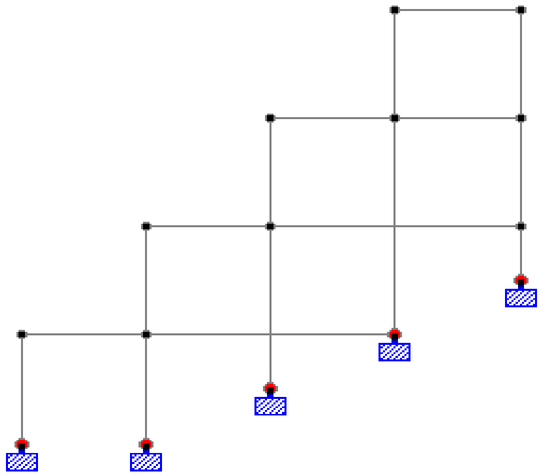

Figure 4-Set Back Structure on inclined ground

Daggupati Rajeswari et al. studied the behavior of different configuration of buildings such as step back and setback back building, with the plan dimensions of 40 x 40 m. Buildings of nine storey's on inclined ground were considered with fixed length of short column in every model **[1].**

Sujit kumar et al. predicted the behavior of inclined ground building under seismic forces, taking into account inclinations of 7.5^0 and 15^0. Different seismic zones were considered. Here G+ 4 storeys are taken for analysis and the results are compared for the same properties and loadings and concluded that increase in the inclination of the ground, increases bending moment within structure, while the axial force in the columns remains nearly the same **[2].**

Paresh G. Mistry et al studied on seismic analysis of building on sloping ground considering bidirectional earthquake and also carried out the study on plain ground. All structural modeled considered in zone-V and analyzed in SAP-2000 software. The dimensions of a beam are 300 mm x 450 mm and the size of the column is 450 mm x 450 mm. The slab with thickness 0.125 m was considered. The external wall thickness is 0.230 m and internal wall thickness is 0.115 m. The slabs are loaded with floor finish of 1.5 kN/m^2 and live load of 3 kN/m^2 and storey height is 3m. The grade of steel used was Fe-415 **[3].**

Roser J. Robert et al calculated the storey displacement for structures on inclined ground and had been assessed in +X and – X direction and additionally in +Z and – Z direction by considering five-storey residential building of 15×15 m with the storey height of 3.33m **[4].**

Glory Joseph, et al. conducted a study of soil - structure interaction on framed structure response by taking into consideration of 5, 10, 20 and 40-storey frames with fixed and flexible conditions. The vibration period was more significant when considering soil as an elastic continuum model than as a dynamical spring model and the impact of soil structure interaction on base shear was witnessed to be significant in frames over 10 storey's **[5].**

Priyanka, et al. (2014) considered the effect of lateral deflection on symmetric and asymmetric structures for 4 m and 5 m spacing of columns with fixed support for different soil conditions. Models in STAAD Pro V8i have been analyzed and found that with respect to soft soil, the lateral deflection for symmetric structures was greater for 5 m spacing column along the width **[6].**

Bhagwat and Patil carried out dynamic response of G+12 multi-storeyed RCC building by considering Koyna and Bhuj earthquake and analysis was done by time history and response spectrum methods. Seismic effects of such building are modeled with ETABS software. Two time histories have been utilized to create various adequate criteria **[7].**

Zaid Mohammad et al considered the vertical irregular structures on normal and inclining ground by considering the seismic load. Every model has same geometrical and material properties and lay on a similar sloping angle of ground which was 26˚.Storey height was taken as 3 meters and foundation is 1.5m in each one of the structures. The thickness of the slab at all floors in every model was considered as 125 mm **[8].**

Arun Kumar Y M et al performed work on the geology of step back and setback structures development. The ground profile inclination is considered to be 27 degree. Total number of storey was 10, each storey's height is 3.5 m. X dir's length is 45 m and along Y dir length was 30 m. Each unit's plan measurement was 4.5x5 m, while the slab thickness taken as 0.15 m. The live load is taken on the floor as 3kN / m^2 and the live load on the roof is 1.5kN / m^2. Seismic zone considered to be 5, factor-5, Importance factor-1 response reduction. The size of beams and columns were considered to be 0.23x0.5 m and 0.6x0.6m respectively **[9].**

3. METHODS OF ANALYSIS OF A STRUCTURE

By considering the properties of materials as an isotropic, homogeneous and elastic in nature, the models are analysed. Floor diaphragms are taken as concrete. M25 and M30 concrete were used and P-delta effect, shrinkage and creep effect were not considered. Axial deformation and tensional effect of columns were considered according to 1893:2002. The seismic investigation of the models have been done in the Staad Pro and ETABS v 9.0 programming by using dynamic and static method and to evaluate the seismic behaviour for various R.C building on inclining ground under the lateral load conditions according to IS 1893:2002 **[1,3,4,6,7,21,22].** A few papers investigated the Time History analysis and Response Spectrum investigation on structures in SAP-2000 programming **[2, 5, 9]** by considering zone 2**[1],** and zone5 **[2, 3, 4].**

4. RESULTS AND DISCUSSIONS

4.1. *Short Column Effect*

It can be found in a structure on inclined grounds that, short columns compared with long columns within one storey endured the additional damage because of the fluctuating heights of the column. A tall column and short column move evenly by same amount, which is of the same cross area, where the poor resistance of short column is seen to be addition damage at the time of ground movements. In any case, short column attracts in more seismic force when compared with the long column. The short column may encounter significant failure through a seismic effect on inclined ground **[1-20].**

4.2. *Base Shear*

Base shear is the maximum lateral forces predicted at the base of the structure which will occur at the base of a structure due to seismic ground movement. In some papers, they observed that the base shear increments by 20 %, if earthquake is applied to some point contrasted with right edge. It has been observed that the estimations of base shear are higher for time history analysis compared with response spectrum analysis. Base shear was increased by 12% and 14% in step back building compare to set back building on plain ground and in step back building moment increases by 5% in plain ground and 63% in sloping ground compared to the set back building.[2]. The base shear for the structures rested on level surface is 7.45% more than that of the building rested on inclined surface and also observed that compared to the setback buildings torsional moments were more in step-back buildings and also 45% of base shear value decreases in set-step back buildings compared to step-back buildings. Set back structures have more storey drift and displacement compared to the step back structures **[1-10].**

4.3. *Axial force*

Axial Force is the maximum force acting along the centre of the columns. In Bhuj earthquake time history, Axial force is almost same in all three types of building but moment increases by 66 % and 16 % in step back building compared to setback building. In Chamoli earthquake time history, axial force increased by 65 % and 16 % and moment increased by 87 % and 16 % in step back building compared to setback building respectively. In response spectrum analysis, axial force is almost same in all three types of building but moment increases by 63 % and 5 % in step back building compare to setback building. **[1-15].**

4.4. ***Storey displacement***

Storey drift is characterized as a proportion of inter storey displacement of floors and measured from bottom to top of the building. The degree to which a building twists or influences is known as storey drift. A structure may drift into the neighbouring building, or the structure might be protected however the walls and roof (non-structural columns) may get a failure if the level of drift is too high because of the twisting of the building making the walls be ripped far from their parts **[1-20].**

It has been demonstrated that the maximum possible top - storey displacement obtained from the equivalent static analysis decreased significantly by 51.37 percent, 57.09 percent, 53.83 percent and 10.54 percent respectively for soft clay (SC), dense sand (DS), hard clay (HC) and rock (RCK) respectively in respect of the step back structures without irregularity **[1-20].**

5. CONCLUSION

- Step back and setback structures are more vulnerable during the earthquake.
- At ground level, the extreme corner short column is most damaged due to seismic effect.
- For Step Back structures, the base shear is higher for plain ground and lower for sloping ground compared to setback structures.
- For Step Back structures, the lateral displacement of the top floor is the most extreme, compared to the setback structures on inclined soil.
- Set back structures on the inclined ground usually attract fewer forces compared to step - back structures.
- Compare to flat ground, storey displacement, storey drift and overturning moment are more in inclined ground.
- Due to plan, mass and geometrical irregularity, there is more displacement, drift and overturning moments observed in sloping ground building. And also more stiffness and base shear was observed in plain ground buildings.

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