Effect of Ground Slope on Dynamic Performance of G + 5 Building

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Abstract—In recent decades economic growth and urbanization has brought about development of massive amount of high-rise structures which has imparted lack of plain region for development of Structures, which initiates requirement for construction on slanted ground. The main objective of this study is seismic behavior of the G+5 building orientated with respect to the propagation of seismic wave up to 90° (i.e. 0°, 10°, 20°, 30°, 40°, 45°, 50°, 60°, 70°, 80°, 90°) to the building in Global direction, resting on the gentle sloped surface by considering the plain ground to Sloped ground up to 14° slope. i.e. 0°, 2°, 4°, 6°, 8°, 10°, 12° and 14°. The method of analysis carried out in this study is Response spectrum analysis in STAAD Pro. The seismic parameters such as Base shear, Natural frequency of building and top story drift values are computed for Zone V.

Index Terms—Base Shear, Natural Frequency of Building, Response Spectrum Analysis, Sloping Ground, Top Story Drift.

I. INTRODUCTION

The Peninsular country of India consists of great arc of mountains which consists of Himalayas in its northern part which was formed by collision of tectonic plates. India, owing its geography is prone to hazards which show a lot of seismic activity in the Collision Zone of the Indo Plate with the Asian Plate. Now days, rapid construction is taking place in hilly areas due to rapid urbanization and increase in economic growth and therefore increase in population density causes the scarcity of the plain terrain in this region. Hence there is an obligation of the construction of the buildings on the sloping ground. As a result the sloped areas have marked effect on the buildings in terms of style, material and method of construction leading to popularity of structures in hilly regions. It is difficult to prevent earthquakes; however the effect can be reduced by safe design and good construction work. Hence there is a need of study of seismic safety and the design of the structures on slopes.

During an earthquake, generally failure of structure starts at points of weakness. This weakness arises due to discontinuity in mass, stiffness and geometry of structure. The structures having these discontinuities are termed as Irregular structures. Irregular structures contribute a large portion of urban infrastructure development. Major structural collapses occur when a building is under the action of dynamic loads such as earthquake and wind loads. In these modern days, most of the structures are involved with architectural importance and it is highly impossible to design with regular shapes. These irregularities are responsible for structural collapse of buildings under the action of dynamic loads. Hence, extensive research is required for achieving ultimate performance even with a poor configuration. A building is said to be a regular when the building configurations are almost symmetrical about the axis and it is said to be the irregular when it lacks symmetry and discontinuity in geometry, mass or load resisting elements.

India has track record of catastrophic earthquakes, at various regions, which left behind loss of many lives and heavy destruction to property and economy. Investigation of buildings in sloped region is somewhat different than the buildings resting on leveled ground, since the column of the slope building rest at different levels on the slope. Such building have mass and stiffness varying along the vertical and horizontal planes resulting the center of mass and center of rigidity which do not coincide on various floors, hence they demand torsional analysis, in addition to lateral forces under the action of seismic activity. The unsymmetrical building requires great attention in the analysis and design under the action of seismic excitation. Past earthquakes results in which, buildings located near the edge of a stretch of hills or on sloping ground suffered severe damages. The shorter column attracts more forces than regular column and undergoes damage, when subjected to seismic loads. The other problems associated with hill buildings are slope instability, additional lateral earth pressure at various levels, different soil profile yielding and unequal settlement of foundation.

If short and long columns exist within the same storey level, then the short columns attract abundance time’s larger earthquake force and suffer rigorous damage as compared to long ones. Generally, Seismic performance expounds a structure’s competency to sustain its main structural functions, such as its safety and serviceability, at and after a particular earthquake exposure. A structure is considered as safe when it does not imperil the lives and salubrity of those in or around it by partially or thoroughly collapsing. A structure may be considered serviceable when it is able to consummate its operational functions for what purpose it was designed. Rudimentary concepts of the earthquake engineering,
implemented in the major building codes, assume that a building should survive at an uncommon, very rigorous earthquake excitation by sustaining consequential damage but without ecumenically collapsing. On the other hand, it should remain operational for more frequent, but less astringent seismic events.

Buildings are asymmetric in plan or in elevation based on the distribution of mass and stiffness along each story throughout the height of the buildings. Asymmetric building shows more vulnerable to earthquake damage. **Sharon Esther (2017)** generated different types of analytical models using STTAD. He made an attempt on vertical geometrical irregularities of 6 storeys, 8 storeys and 10 storeys with a range of 0 to 75 % irregularities with interval of 25%. For each case he studied member forces such as bending moment, shear force, displacement, and drift. From his study he concluded that i). Shear force and bending moment is maximum in 75% irregularity i.e., irregularity increases bending moment and shear force increases. ii). Drift also increases with irregularity of building increased if it exceeds 0.10 it leads to collapse. iii). The maximum displacement of 75 % increased by 75% irregularity and 65% with plus shape without irregularity.

**Sujit Kumar (2014)** a comparative study on analysis of a G+4 storey RCC building on varying slope angles i.e., 7.5° and 15° with the flat ground. He made an attempt on horizontal reaction and bending moment in footing of structure, bending moment in columns is compared for different ground slopes under different seismic loads. He concluded from his analysis that i). Critical horizontal forces and bending moment in footings significantly increases with increase of ground slope, however the vertical reactions in footing remains almost same. ii). Critical bending in column increases slightly in 15° slope compare with plain ground, hence it requires more steel to greater resistance.

**Himanshu Shrivastava (2015)** made a comparative study on G+10 unsymmetrical building frame with various sloping ground and different soil conditions in all seismic Zones. He analyzed 36 problems using STTAD Pro and axial force, shear, bending moment maximum displacement story displacements which are fundamentally examined to measure the impact of the sloping ground. He concluded that i). all responses are maximum in soft soils and in Zone V compared to other soil conditions as well as other Zones. ii). As slope increases the response in all parameters are also increased.

**A Joshua Daniel and S Sivakamasundari (2016)** made a comparative study of three setback buildings of Type A building is stepping back at every floor level on the slope, up to 4 storeys and has two storeys above road level. The Type B building is stepping and setting back at every floor level. The Type C buildings is stepping back at fourth floor level only and has two storeys above road level having weight and plan same as with the regular building resting on flat ground. He concluded that, i). From the cumulative modal mass participation ratio, the energy dissipation of regular building on flat ground is higher than the respective hill building. ii). Flexibility of regular building endures larger displacement than building resting on hill.

**B. V. Rajiv Vinayak (2016)** studied the behaviour of two storied sloped frame having step back configuration is analyzed for sinusoidal ground motion with different slope
angles i.e., 15°, 20° and 25° with an experimental set up and are validated by developing a Finite Element code executed in MATLAB platform and using structural analysis tool STAAD Pro. by performing a linear time history analysis. He concluded from his study that i). 15° sloped frame experience maximum story displacement due to low stiffness of short columns, while 25° frame experiences minimum story displacement ii). Time history response of the top floor acceleration is maximum at resonance condition (excitation frequency matches with fundamental frequency for all considered models iii) Base shear is nearly same with little variation but their distribution on columns such as short columns attracts more shear force which leads to formation of plastic hinges on short columns, which are more vulnerable to damage. He advised proper design criteria should be applied to avoid plastic hinge formation.

Miss. Pratiksha Thombre (2016) analyzed building on different sloping surfaces i.e., 0°, 10°, 20°, 30°, 40°, 50°. She considered 5 columns randomly throughout the plan in all the sloping conditions. She observed from analysis that, i). Column 1 Displacement is slightly more for plain ground than other slope angle building ii). Column 2 displacement is less for plain building and further it is gradually increased in slope angle building iii). Column 3 displacement is slightly more than other all observed columns and also gradually decrease with increase of slope angle iv). Column 4 & 5 are having the displacement are nearly same as the column 1 & 2. She concluded from her observations, the displacements value gets smaller as the sloping angle increases due to curtailment of column.

Paresh G. Mistry, Hemal J. Shah (2016) performed Response spectrum analysis and Time History analysis for Bhuj and chamoli earthquakes will be carried out for setback, set back with step back on sloped ground at 20° and regular building on plain ground. In Bhuj earthquake time history analysis, the base shear value is increased 12% and 14% in setback with stepback compared to plain and setback building. In chamoli earthquake, it was increased 5% and 18% in setback compared to plain and setback with stepback building. Both comparing response and time history, the value of base shear is higher in time history analysis.

Roser J. Robert and Ranjana M. Ghate (2016) made a comparison between the behaviour of G+4 storey building rested on sloped surface and on flat surface with same intensity of seismic load on both the buildings. They are mainly focused on storey displacement and base shear of buildings have been evaluated in +X and –X direction as well as in +Z and –Z direction. They conclude that i). The story displacement is 10% more in Flat surface in X direction and 30% more in sloped surface in Z direction. ii). Base shear is 7.45% more in Flat surface than sloped surface. iii). number of storey increases storey displacement decreases in both buildings iv) building rested on sloped surface is more vulnerable than building rested on flat surface during seismic effect.

Mr.Achin Jain (2017) analyzed G+ 4 storeys RCC building on varying slope angles i.e., 0°, 10°, 15°, 20°, 25° and 30° is compared with the flat ground with different soil condition. Equivalent static method is used. He concluded from his analysis, storey displacement and time period are decreases with increase of stiffness of soil along with increase of slope.

Rahul Manojsingh Pawar (2017) 24 buildings of G +10, G+15, G+20 of setback, step back with set back on plain ground , sloped ground of 0°, 10°,15°, 20° are analyzed by Tie history method and Response spectrum method using STAAD Pro. He concluded from his analysis, i). Buildings resting on sloping ground have less base shear than buildings on Plain ground. ii). Base shear increases with increase of Slope angle iii). Lateral displacement is more in building resting on sloped ground than buildings on Plain ground. iv). Shear force and moments are more value on sloping ground than plain ground while critical Axial force on column is more on plain ground than Sloping ground. v). The performance of set- step back building during seismic excitation is more vulnerable than other building configurations.

Rajkumar Vishwakarma (2017) made a comparative study on analysis of seismic behaviour of tall structures G+10 building with different soil types and different slope of ground as 0°, 7° and 14°. Under the Earthquake effect as per IS 1893(part I) -2002 static analysis. He concluded that from his analysis, Shear force, bending moment and displacement are increased with increase of slope from soft to hard soils.

III. STRUCTURAL MODELING
A RCC medium rise building of G+ 5 Building with floor height 3 m subjected to earthquake loading in Zone V has been considered. In this regard STAAD Pro V8i software has been considered as tool to perform. Effect of Ground slope on Dynamic performance is analyzed.
Effect of Ground Slope on Dynamic performance of G +5 Building

Fig.3. Plan Orientation @ 10°

Fig.7. Plan Orientation @ 45°

Fig.4. Plan Orientation @ 20°

Fig.8. Plan Orientation @ 50°

Fig.5. Plan Orientation @ 30°

Fig.9. Plan Orientation @ 60°

Fig.6. Plan Orientation @ 40°

Fig.10. Plan Orientation @ 70°
Fig. 11. Plan Orientation @ 80°

Fig. 12. Plan Orientation @ 90°

Fig. 13. Elevation view @ ground slope 0°

Fig. 14. Elevation view @ ground slope 2°

Fig. 15. Elevation view @ ground slope 4°

Fig. 16. Elevation view @ ground slope 6°
Effect of Ground Slope on Dynamic performance of G +5 Building

Fig.17. Elevation view@ ground slope $8^\circ$

Fig.19. Elevation view@ ground slope $12^\circ$

Fig.18. Elevation view@ ground slope $10^\circ$

Fig.20. Elevation view@ ground slope $14^\circ$
Table. 1 Sectional Properties

<table>
<thead>
<tr>
<th>Member</th>
<th>Shape</th>
<th>Size (B x D) in m</th>
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</thead>
<tbody>
<tr>
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<td>Rectangular</td>
<td>0.3 x 0.6</td>
</tr>
<tr>
<td>Column</td>
<td>Circular</td>
<td>0.6</td>
</tr>
</tbody>
</table>

IV. ANALYSIS & RESULTS
Response spectrum analysis was performed & results were presented.

![Fig.21. Base Shear values](image)

![Fig.22. Natural Frequency of Building](image)

![Fig.23. Top Story drift in X direction](image)

![Fig.23. Top Story drift in Z direction](image)

V. RESULTS & DISCUSSIONS
Regular building resting on slope 0°, 2°, 4°, 6°, 8°, 10°, 12° and 14° analyzed by Response Spectrum Analysis. Along with slope building orientation of 0°, 10°, 20°, 30°, 40°, 50°, 60°, 70°, 80°, 90° along with the Global X Direction are analyzed on Regular G+5 Building. The following conclusions are drawn from this study based on the results of this research are

A. Base Shear values
- At 0° slope, the higher base shear value is obtained at 45° angle of orientation of building w.r.t Global X direction.
- At 2° & 4° slopes, the higher base shear values are obtained at 40° angle of orientation of building w.r.t Global X direction.
- At 6°, 8°, 10°, 12° & 14° slopes, the higher base shear values are obtained at 20° angle of orientation of building w.r.t Global X direction.

B. Natural Frequency of Building
- At 0° slope, the higher natural frequency of building is obtained at 45° angle of orientation of building w.r.t Global X direction.
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- At $2^\circ$ & $4^\circ$ slope, the higher natural frequency of building is obtained at $20^\circ$ angle of orientation of building w.r.t Global X direction.
- At $6^\circ$, $8^\circ$, $10^\circ$, $12^\circ$, & $14^\circ$ slope, the higher natural frequency of building is obtained at $0^\circ$ angle of orientation of building w.r.t Global X direction.

C. Top Story Drift Values

At all slopes, the higher top story drift value are obtained both X and Z directions at $0^\circ$ & $90^\circ$ respective angle of orientation of building w.r.t Global X direction.

VI. CONCLUSION

A. Base Shear

Along slope Direction, Increases with increase of Slope
In Perpendicular Direction, Decreases with increase of Slope.

B. Natural Frequency Of Building

Both Along the Slope & Perpendicular to Slope increases with Increase of Slope.

C. Top Story Drift Value

Along the slope direction increases in X direction & In perpendicular direction increases in Z direction with increase of slope.

REFERENCES


