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

K Divya, A Srikanth, T Sreedhar Babu

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 90^0 (i.e. 0^0, 10^0, 20^0, 30^0, 40^0, 45^0, 50^0, 60^0, 70^0, 80^0, 90^0) to the building in Global direction, resting on the gentle sloped surface by considering the plain ground to Sloped ground up to 14^0 slope. i.e. 0^0, 2^0, 4^0, 6^0, 8^0, 10^0, 12^0 and 14^0. 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,

K Divya, M.Tech in Structural Engineering/ Department of Civil Engineering/ JNTU Kakinada, Vasireddy Venkatadri Institute of Technology, Guntur, Andhra Pradesh/ India
A Srikanth, Assistant Professor, Department of Civil Engineering /JNTU Kakinada, Vasireddy Venkatadri Institute of Technology, Guntur, Andhra Pradesh
Dr. T Sreedhar Babu , Professor & HOD, Department of Civil Engineering /JNTU Kakinada, Vasireddy Venkatadri Institute of Technology, Guntur, Andhra Pradesh

implemented in the major building codes, assume that a building should survive at a 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.

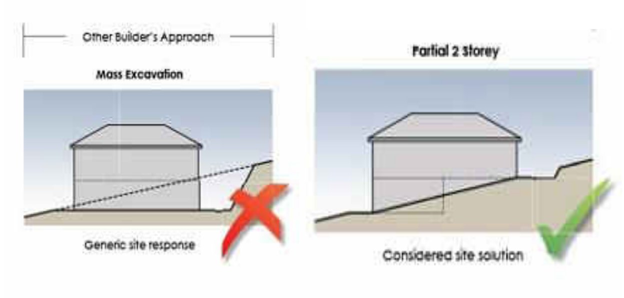

Fig. 1 Solution for building resting on Sloped ground

II. LITERATURE REVIEW

As per this survey, Due to rapid urbanization, lack of plain region leads to requirement for construction on Sloped ground. In these modern days, most of the structures are involved with architectural, aesthetic importance and it is highly impossible to plan with regular shapes. These irregularities are responsible for structural collapse under the action of dynamic loads. Hence, immense research is required for achieving ultimate performance even with a poor configuration. This review gives a brief view of recent contribution in various response parameters.

Akhil R (2017) made a comparative study to better understand of regular and irregular structure response to incoherent ground motion. The modeling of regular and irregular building for zone V of G+10 is analyzed .The main aim of his work is comparative study about the stiffness of the regular and irregular configuration. A geometric irregularity introduces discontinuities in distribution of mass, stiffness and strength along vertical direction needs to work in these regarding area. Author made an attempt to reach on more accurate conclusion to reduce their effect on structure. Among these regular and irregular, he identifies the best configuration from his analysis. It was concluded that response spectrum analysis allows clear understanding of contributions of different modes of vibration. Comparing the results, it was concluded that base shear and displacement are maximum in regular building.

Kusuma B (2017) studied 50 storied RC framed structure with different irregularities like re-entrant corner, mass irregularities, diaphragm irregularities, stiffness irregularities, vertical geometrical irregularities under seismic conditions by using response method from IS 1893 (part 1) : 2002. It was concluded that regular structure performs better under the action of seismic excitation than irregular structure. Compared to other irregular (mass and vertical geometrical) structures lateral displacement is increased when the irregularities present. Stiffness is reduced in irregular structure like vertical irregularities, re-entrant corner and stiffness irregular structure.

Buildings are asymmetric in plan or in elevation based on the distribution of mass and stiffness along each storey 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., 7.5^0 and 15^0 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 15^0 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). 15^0 sloped frame experience maximum story displacement due to low stiffness of short columns, while 25^0 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^o, 10^o, 20^o, 30^o, 40^o, 50^o. 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 20^0 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 pain 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., 0^0, 10^0, 15^0, 20^0, 25^0 and 30^0 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 0^0, 10^0,15^0, 20^0 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 0^0, 7^0 and 14^0. 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.

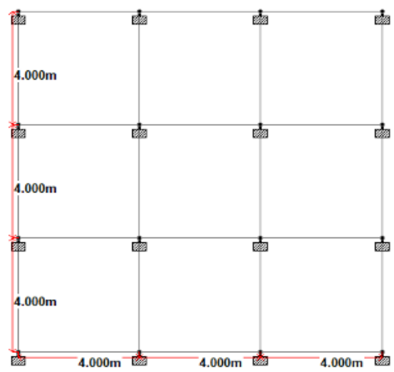

Fig.2. Plan Orientation @ 0^0

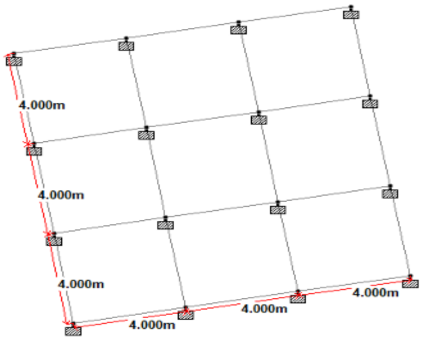

Fig.3. Plan Orientation @ 10^0

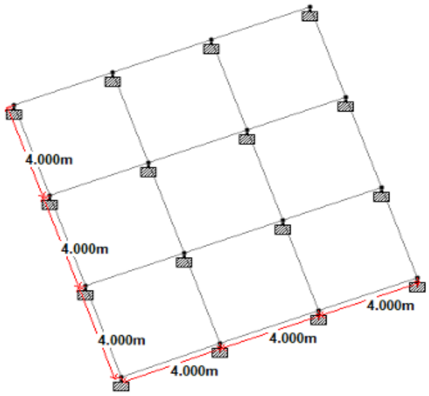

Fig.4. Plan Orientation @ 20^0

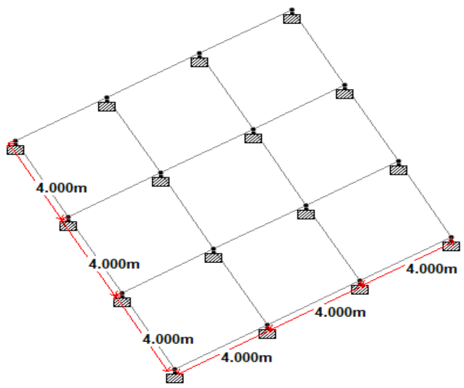

Fig.5. Plan Orientation @ 30^0

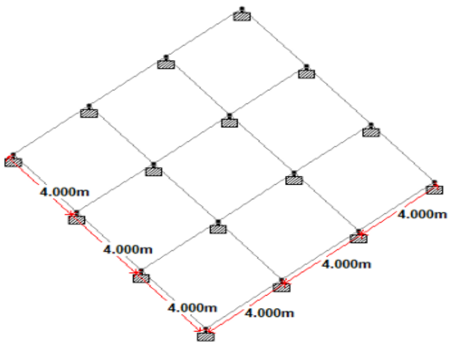

Fig.6. Plan Orientation @ 40^0

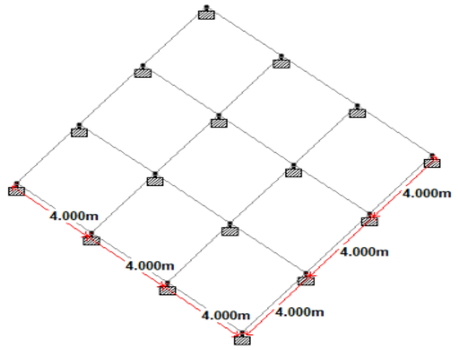

Fig.7. Plan Orientation @ 45^0

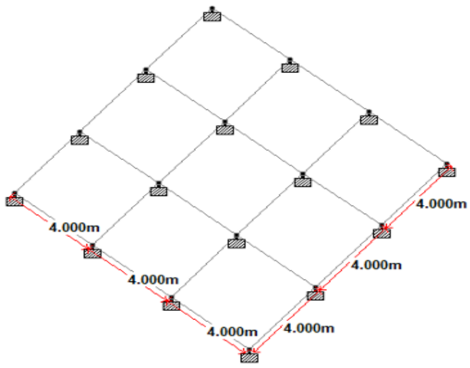

Fig.8. Plan Orientation @ 50^0

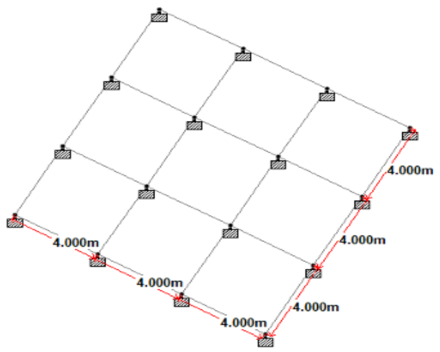

Fig.9. Plan Orientation @ 60^0

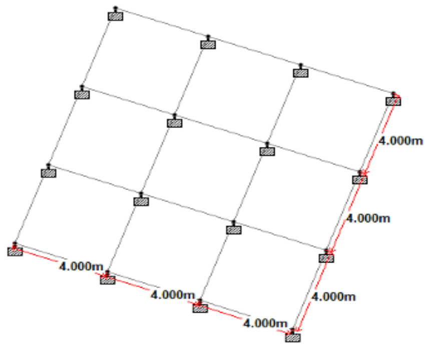

Fig.10. Plan Orientation @ 70^0

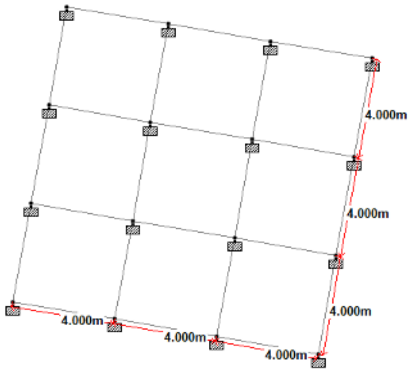

Fig.11. Plan Orientation @ 80^0

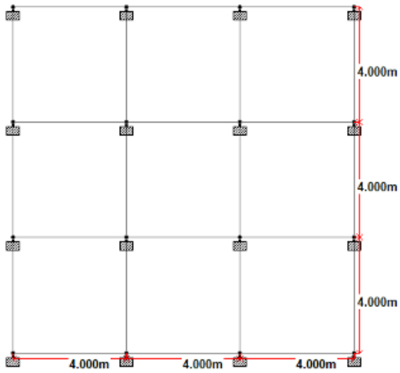

Fig.12. Plan Orientation @ 90^0

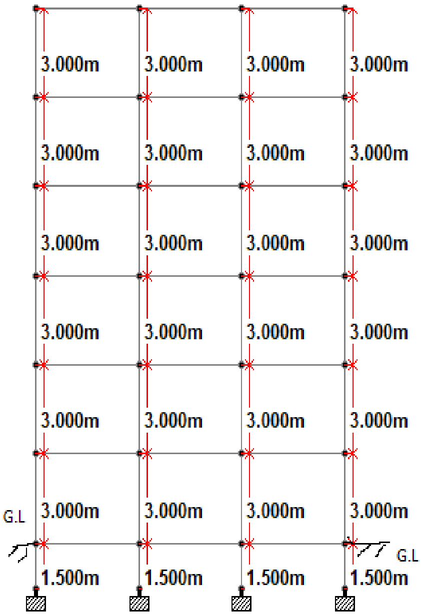

Fig.13.Elevation view @ ground slope 0^0

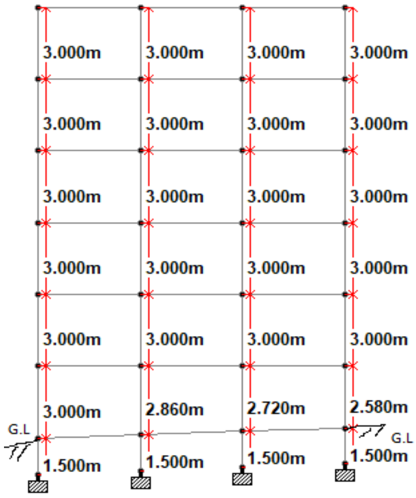

Fig.14.Elevation view @ ground slope 2^0

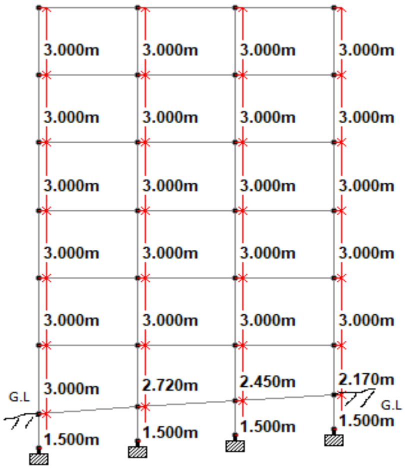

Fig.15. Elevation view@ ground slope 4^0

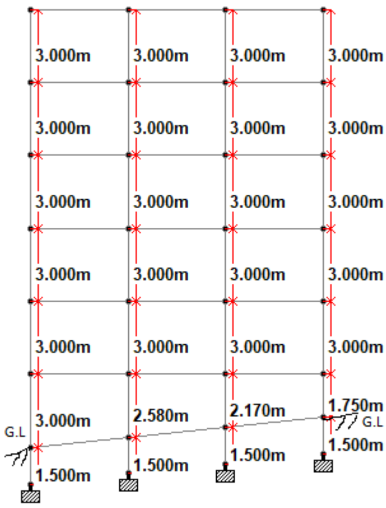

Fig.16. Elevation view@ ground slope 6^0

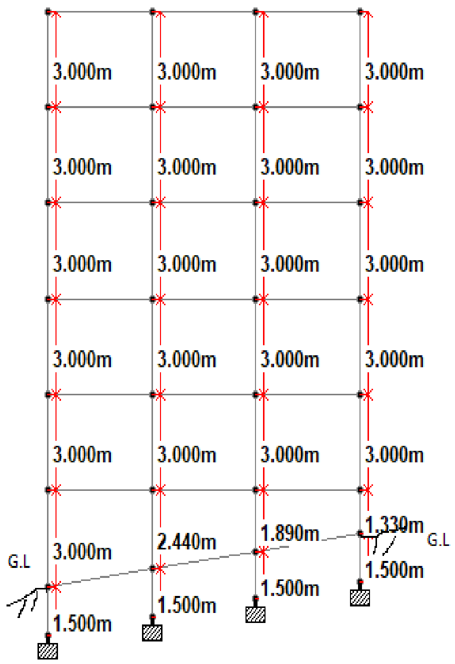

Fig.17. Elevation view@ ground slope 8^0

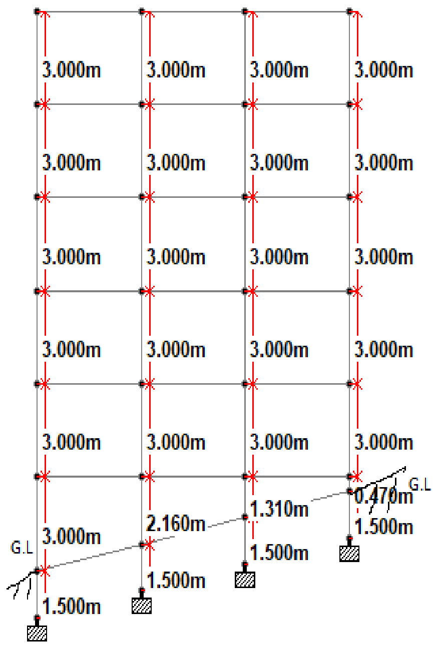

Fig.19. Elevation view@ ground slope 12^0

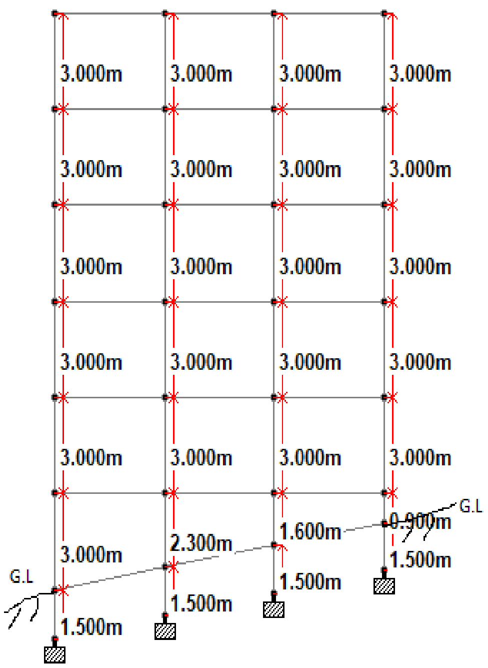

Fig.18. Elevation view@ ground slope 10^0

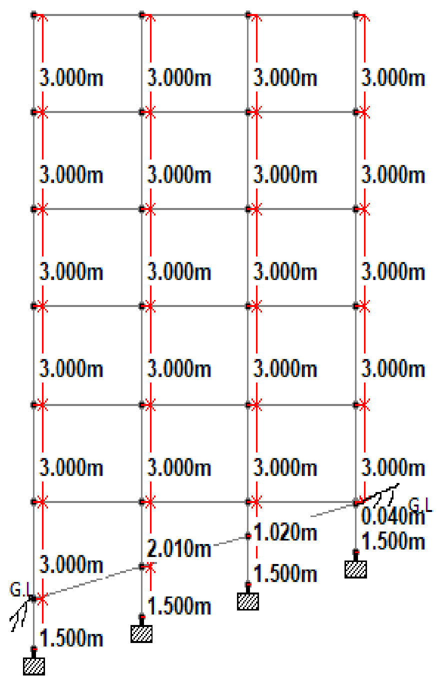

Fig.20. Elevation view@ ground slope 14^0

Table. 1 Sectional Properties

Member	Shape	Size (B x D) in m
Beam	Rectangular	0.3 x 0.6
Column	Circular	0.6

IV. ANALYSIS & RESULTS

Response spectrum analysis was performed & results were presented.

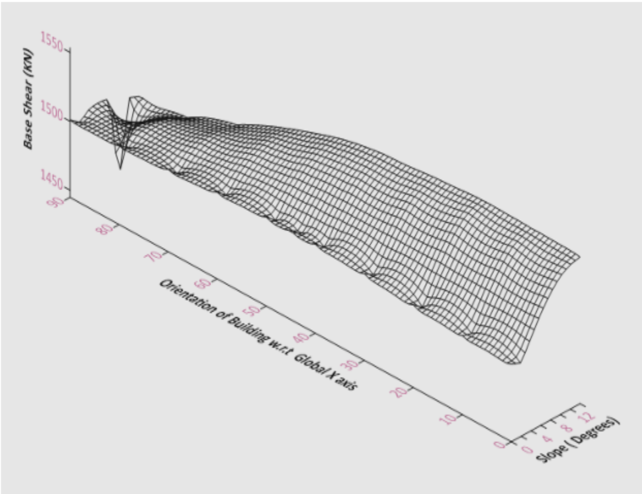

Fig.21. Base Shear values

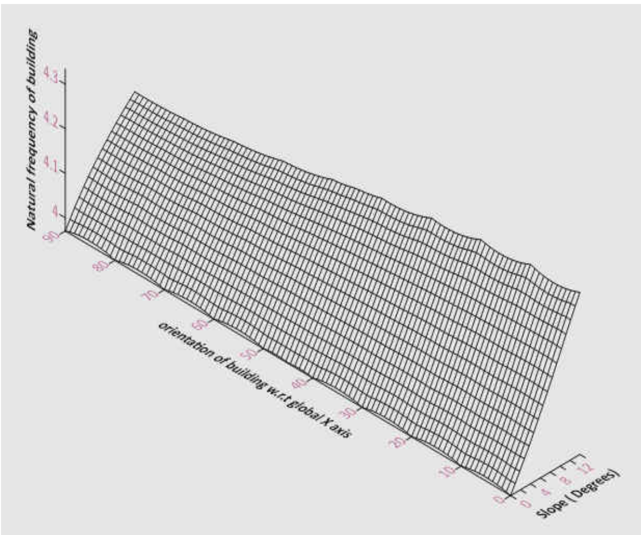

Fig.22. Natural Frequency of Building

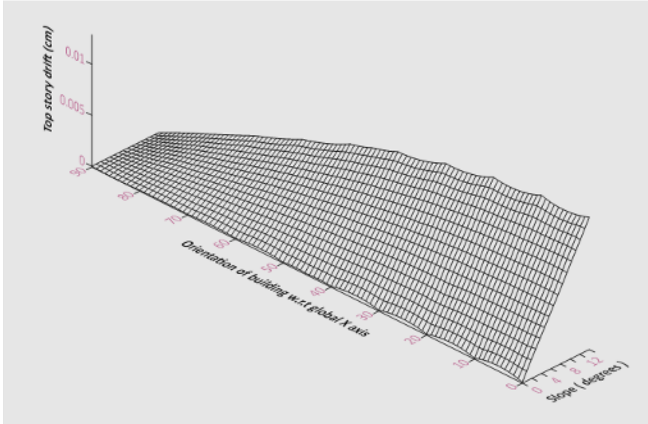

Fig.23. Top Story drift in X direction

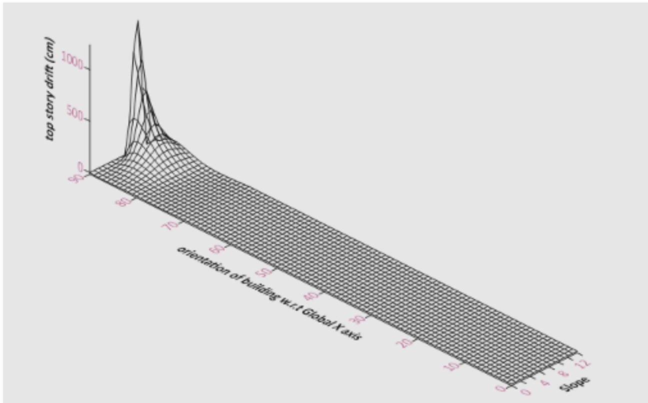

Fig.23. Top Story drift in Z direction

V. RESULTS & DISCUSSIONS

Regular building resting on slope 0^0, 2^0, 4^0, 6^0, 8^0, 10^0, 12^0 and 14^0 analyzed by Response Spectrum Analysis. Along with slope building orientation of 0^0, 10^0, 20^0, 30^0, 40^0, 50^0, 60^0, 70^0, 80^0, 90^0 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 0^0 slope, the higher base shear value is obtained at 45^0 angle of orientation of building w.r.t Global X direction.
- At 2^0 & 4^0 slopes, the higher base shear values are obtained at 40^0 angle of orientation of building w.r.t Global X direction.
- At 6^0, 8^0, 10^0, 12^0 & 14^0 slopes, the higher base shear values are obtained at 20^0 angle of orientation of building w.r.t Global X direction.

B. *Natural Frequency of Building*

- At 0^0 slope, the higher natural frequency of building is obtained at 45^0 angle of orientation of building w.r.t Global X direction.

- At 2^0 & 4^0slope, the higher natural frequency of building is obtained at 20^0 angle of orientation of building w.r.t Global X direction.
- At 6^0, 8^0, 10^0, 12^0, & 14^0slope, the higher natural frequency of building is obtained at 0^0 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 0^0 & 90^0 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

[1] *R, Akhil.* **Seismic analysis of regular and irregular buildings with vertical irregularity using staad.pro**. *volume: 04 , no. issue: 06 (june -2017)*

[2] *B, Kusuma.* **Seismic analysis of a high-rise rc framed structure with irregularities**. *international research journal of engineering and technology (irjet) volume: 04 , issue: 07 (july -2017).*

[3] *Esther, Sharon.* **A comparative study on vertical geometric irregular frame-wall structure under lateral loading**. *imperial journal of interdisciplinary research (ijir) vol-3, issue-4 (2017).*

[4] *Kumar, Sujit.* **Effect of sloping ground on structural performance of rcc building under seismic load.** *international journal of science, engineering and technology volume 2 , no. issue 6 (august 2014).*

[5] *Shrivastava, Himanshu.* **Seismic analysis of different sloping ground considering different soil conditions**. *international journal of engineering sciences & research technology volume 4, no. issue 12 (december 2015).*

[6] *Sivakamasundari, A Joshua Daniel And S.* **Seismic vulnerability of building on hill slope.** *international journal of earth sciences and engineering volume 09, no. issue 5 (october 2016): p.p.1892-1899.*

[7] *Vinayak, B. V. Rajiv.* **Experimental and numerical studies on dynamic analysis of sloped buildings**. *international jounal of innovative technologies vol.04, no. issue.14 (october-2016): 2461-2466.*

[8] *Thombre, Pratiksha.* **Seismic analysis of building resting on sloping ground**. *journal of emerging technologies and innovative research (jetir) volume 3, no. issue 6 (june 2016).*

[9] *Mistry, Paresh G.,Hemal J. Shah.* **Seismic analysis of building on sloping ground considering bi-directional earthquake**. *international journal of scientific development and research (ijsdr) volume 1, no. issue 4 (april 2016).*

[10] *Ghate, Roser J. Robert And Ranjana M.* **Seismic analysis of multistoried rcc building on sloping ground**. *international journal for research in emerging science and technology volume-3, issue-12 (dec-2016).*

[11] *Jain, Achin.* **Analysis of building constructed on sloping ground for different types of soil**. *international journal for technological research in engineering volume 4, no. issue 12 (august-2017).*

[12] *Pawar, Rahul Manojsingh.* **Analysis of set back step-back building resting on sloping ground.** *journal of emerging technologies and innovative research (jetir) volume 4 , no. issue 06 (june 2017).*

[13] *Vishwakarma, Rajkumar.* **Analysis of a rcc frame tall structure using staad pro on different seismic zones considering ground slopes**. *international research journal of engineering and technology (irjet) volume: 04 , no. issue: 03 (mar -2017).*

[14] **IS 1893 (part 1) : 2002**. *Indian Standard Criteria for Earthquake Resistant Design of Structures, Burea of Indian Standard*