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Analysis of Structural Response for Regular Buildings on Dynamic Input on Sloped Ground With Different Soil Structures

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ABSTRACT: Earthquake creates considerable damage to structure, its behavior is not predictable and it is very dangerous. If the structure is subjected to seismic forces and if the structure is on sloped ground, then the response of structure creates more damage to structure as well as human life. Due to sloped ground some columns may be short and some columns may be long, hence there is always uneven force distribution within structure. At some locations shear forces, bending moments, torsion having more magnitude than structure on flat ground. In northern India about 130 million years ago due to tectonic actions Himalayan mountainous range formed. In this region soil diversity can be observed

In this paper, G+5 regular building with different slopes are analyzed with the help of numerical analysis. Different soil structures in Central western Himalayan forest will be considered. Forest type having clayey soil or loam is considered and final consolidation settlement is used for finding out subgrade modulus. Structural response will be obtained by performing linear time history analysis in STAAD Pro. Comparison will be made for buildings on slopes with spring stiffness and same buildings without spring stiffness

KEYWORDS: Building on different slopes; soil structure; regular buildings; numerical analysis

I. INTRODUCTION

Earthquake creates considerable damage to structure, its behavior is not predictable and it is very dangerous. When a structure is subjected to earthquake forces it cause loss to human lives due to the damage cause to the structures that leads to the collapse of the building. Major destruction of the low and high rise buildings in the recent earthquakes leads to the need of investigation. When the earthquake occurs at a sloped building which is rested on hill and having some inclination to the ground, the chances of damage increases much more due to increased lateral forces on short columns. It may leads to the formation of plastic hinges.

In northern India about 130 million years ago due to tectonic actions Himalayan mountainous range is formed. In this region soil diversity can be observed. Due to erosion of soil there is different soil structures. Mostly soils are clayey in nature, which can be created differential settlement and with combination with earthquake it may create more hazard to human life. Now a day, due to the scarcity of the plain terrain there is a need of the construction of the buildings on the sloping ground.

Many researcher has already worked on dynamic analysis of buildings on sloped ground by comparing with buildings on flat ground. In the region like Central western himalaya, soil structure is different. Mostly soil layers are clayey in nature. There is always possibility of long term settlement i.e. Consolidation settlement. Hence there is need to consider this settlement in the structural analysis. This may give worst effect in addition with dynamic input.

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II. METHODOLOGY

A. Introduction to Consolidation of Soil

In the present study, long term deflection of clayey soil is considered and respective stiffnesses will be applied to support system.

Consolidation is the compression of soil mass due to expulsion of water from the voids under steady static and long term pressure. It is a slow long term process and it is experienced in clays or loam soils.

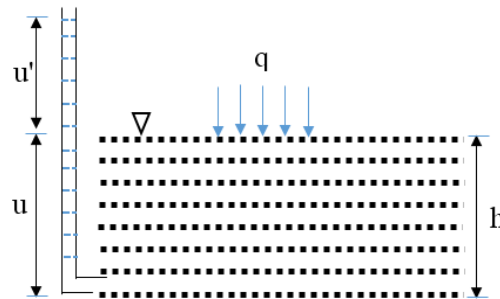


Fig. 2.1 Soil model

When a steady constant load 'q' is applied on soil, immediately after applying load, $u' = q$ and effective pressure $\sigma' = 0$. Hence following equation can consider,

$$u' + \sigma' = q \quad (2.1)$$

Where u is the hydrostatic pressure or static pore water pressure, u' is the hydrodynamic pressure or Excess pore water pressure and σ' is the effective pressure.

After long duration when soil is not fully consolidated, some excess pore water pressure released, $u' < q$ and $\sigma' > 0$.

At the time of consolidation excess pore water pressure removed $u' = 0$ and $\sigma' = q$.

B. Formulation of Consolidation

The graph below represents logarithmic variation of effective stress and void ratio. In the consolidation process void ratio decreases from initial void ratio e_0 to final void ratio e_f , for initial effective stress σ_0' to final effective stress σ_f' respectively.

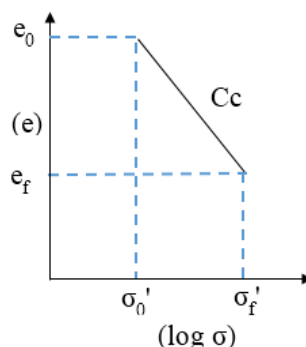


Fig. 2.2 Coefficient of Compressibility

Coefficient of Compression Index (C_c) is formulated as below,

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$$Cc = \frac{e_0 - e_f}{\log_{10} \left(\frac{\sigma_{f'}}{\sigma_{0'}} \right)} \quad (2.2)$$

$$Cc = \frac{\Delta e}{\log_{10} \left(\frac{\sigma_{f'}}{\sigma_{0'}} \right)} \quad (2.3)$$

$$\Delta e = Cc \log_{10} \left(\frac{\sigma_{f'}}{\sigma_{0'}} \right) \quad (2.4)$$

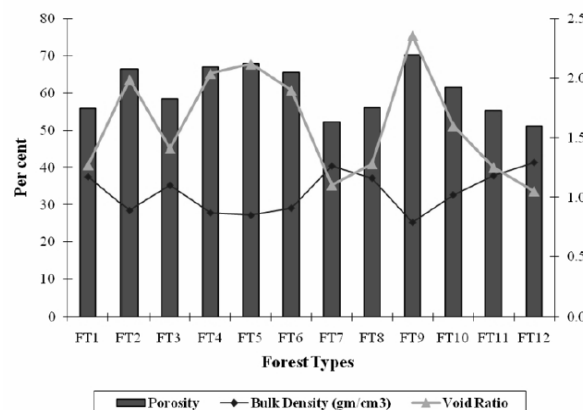
Where, $Cc = 0.009 (W_L - 10)$ for natural undisturbed soil

For laterally confined soil, final settlement is formulated as below

$$\Delta H = \frac{H_0 Cc \log_{10} \left(\frac{\sigma_{f'}}{\sigma_{0'}} \right)}{1 + e_0} \quad (2.5)$$

C. Case Study

For the study of consolidation, Himalayan region is considered due to clayey soil or loam is present at most of location. Research paper by C.M. Sharma et.al.^[5] is referred for the present study. There are five forest types (FT1 to FT5), which has loam soil texture. Hence these soil data are considered for study.



Graph 2.1 Soil texture data

Above graph represents relation between different forest types and void ratio, bulk density and porosity. For the forest types FT1 to FT5 Final settlements are shown below.

Forest Types	Soil	Consolidation settlement	Spring Stiffness
FT1	Loam	25 mm	2256kN/m ² /m
FT2	Loam	21 mm	2652 kN/m ² /m
FT3	Loam	21 mm	2620 kN/m ² /m
FT4	Loam	22 mm	2502 kN/m ² /m
FT5	Loam	19 mm	2857 kN/m ² /m

Table 2.1

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For calculation of consolidation settlement footing size of 3m X 3m and depth of footing is 2m below ground surface is considered. Column reaction of 500kN is considered.

D. Structural Modelling

RCC medium rise building of G+5storeyes with floor height 3 m subjected to earthquake loading in V has been considered. In this regard STAAD Pro V8i software has been considered as tool to perform. Effect of sloping effect of the ground on behavior of structural frames is analyzed by considering minimum stiffness of support. Displacements have been calculated for top floor.

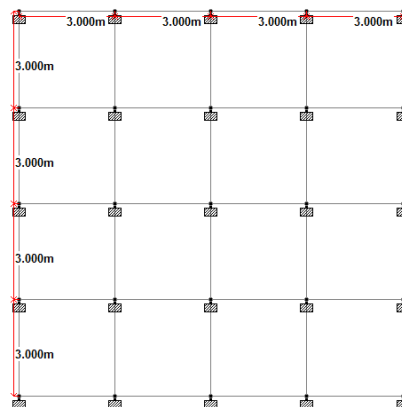
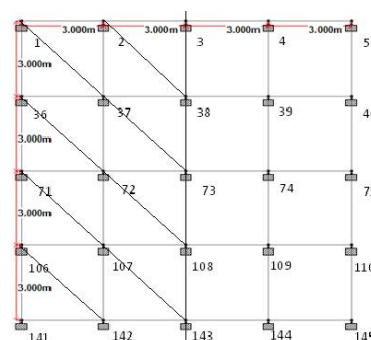


Fig. 2.3 Plan of building

The plan for the above building shown in figure has been considered to carry out the study the dimension of the building are 12m x 12m. A regular G+5 building is considered for analysis such that its center of mass and center of rigidity coincides. Hence torsional forces are neglected from analysis. 10 different models having slopes varying from 0 to 45 degrees have modelled in STAAD Pro.

For analysis of structure, stiffness due to consolidation (Soft support) is considered in three cases, as shown below.

Case 1 – Half supports of structure at downward side of slope are considered as soft support, and remaining supports are considered as fixed support



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As per analysis of structure where supports are considered as fixed support, reaction at each end node is known. By considering worst reaction in hatched portion, stiffness is considered for analysis of case 1.

Case 2 – Half supports of structure at upward side of slope are considered as soft support, and remaining supports are considered as fixed support.

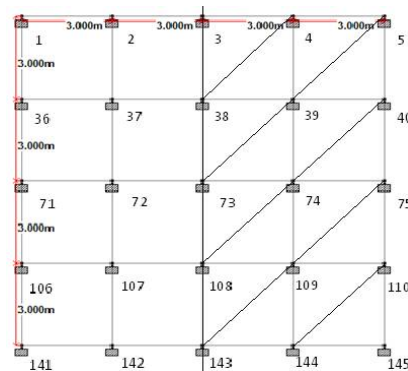


Fig. 2.5 Case2

As per analysis of structure where supports are considered as fixed support, reaction at each end node is known. By considering worst reaction in hatched portion, stiffness is considered for analysis of case 2.

Case 3 –Diagonally half supports of structure at downward side of slope are considered as soft support, and remaining supports are considered as fixed support

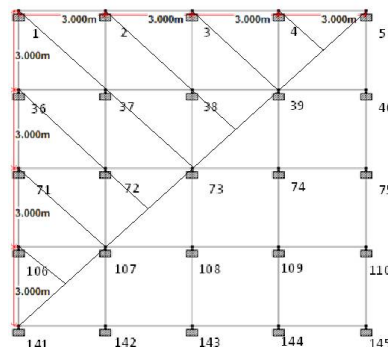


Fig. 2.6 Case3

As per analysis of structure where supports are considered as fixed support, reaction at each end node is known. By considering worst reaction in hatched portion, stiffness is considered for analysis of case 3.

Loading consideration Dead Load (DL) and Live load (LL) have been taken. Time history analysis (EL Centro Earthquake) is done and dynamic loading is applied in +X and -X direction with magnitude of 1.5 Following data is assumed for analysis

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Storey Height-

3.0 m

Column Size-

0.4 m x 0.4 m

Beam size-

0.3 m x 0.3 m

Live load-

4kN/m²

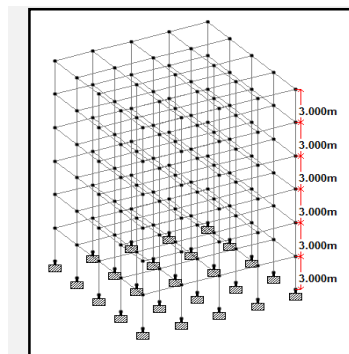


Fig. 2.7(0 degrees slope)

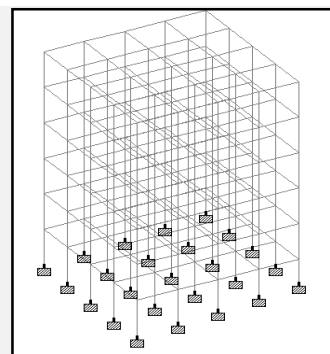


Fig. 2.8(5 degrees slope)

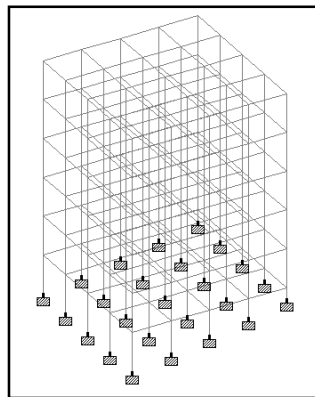


Fig 2.9(10 degrees slope)

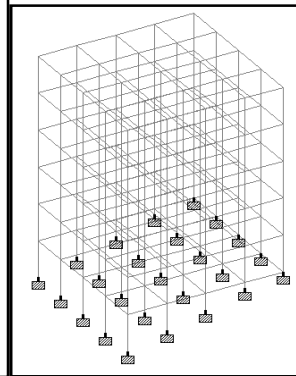


Fig.2.10(15 degrees slope)

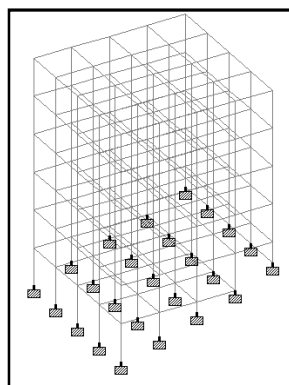


Fig.2.11(20 degrees slope)

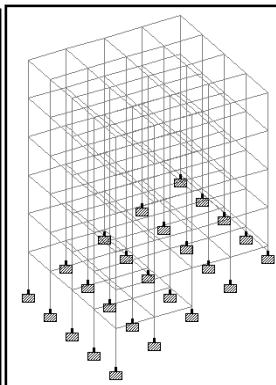


Fig.2.12(25 degrees slope)

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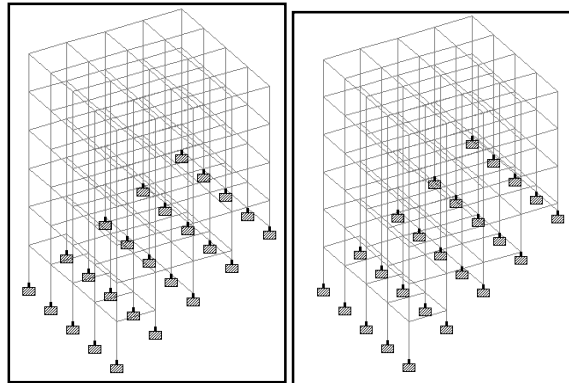


Fig.2.13 (30 degrees slope) Fig.2.14 (35 degrees slope)

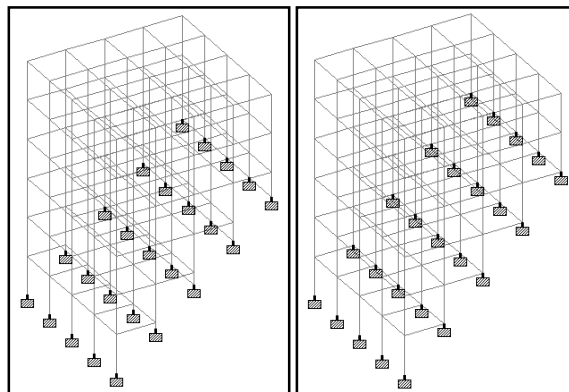


Fig.2.15 (40 degrees slope) Fig.2.16 (45 degrees slope)

III. RESULTS AND CONCLUSIONS

3.1 Results:

Due to consolidation of soil and sloped ground, responses of structure are compared and represented as below for 0 degree and 10 degree slope.

A. For 0 degree slope

	Natural Time (T) Sec.	Mass Participation Factor (At mode 30)	Max. Story Displacement (mm)	Max Base Shear (kN)	Maximum Bending Moment (kNm)
Fixed Support	0.53	98.292	12.3	314	30.6
Case 1	0.669	99.362	13.6	264	50
Case 2	0.669	99.362	13.6	264	78.7
Case 3	0.654	99.07	14.4	237	50.5

Table. 3.1 Results for 0 degree slope

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B. For 10 degree slope

	Natural Time (T) Sec.	Mass Participation Factor (At mode 30)	Max. Story Displacement (mm)	Max Base Shear (kN)	Maximum Bending Moment (kNm)
Fixed Support	0.494	92.68	7.79	300	42.88
Case 1	0.6	94.55	12.3	283	116
Case 2	0.57	94.7	13.1	275	100
Case 3	0.584	94.15	12.8	278	146.3

Table. 3.2 Results for 10 degree slope

3.2 Observations

- Natural time period of structure is dependent on mass, structural stiffness and stiffness of support. By considering soft supports, natural time period increases.
- Mass participation factor (MPF) is dependent on support conditions also.
- Maximum storey deflection is observed in soft supports than fixed end supports.
- Maximum base shear is observed in fixed supports than soft supports.
- Maximum bending moments are observed in cases where soft supports are considered.

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