A DETAILED ANALYSIS OF MULTISTORY STRUCTURE CONSTRUCTED ON SLOPING GROUND BY STAAD

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ABSTRACT: In hilly areas, the buildings are built on sloping grounds. When the hilly areas come to under seismic zones, these buildings area highly vulnerable to earthquakes. The present study deals with analysis of multistoried building (G+4) on sloped ground. The study comprising of analysis of multistoried building (G+4) by considering gravity loads and seismic loads (response spectrum method used) and also includes slope stability analysis. The modeling has done by providing different elevations at foundation level and analysis of building has carried out by using finite element software such as Staad. Staad is a sophisticated and flexible to use, special purpose analysis such as gravity loads, earthquake analysis, P-δ analysis etc., and the programmers are integrated in the software in a well manner for the analysis of multistoried building. The material properties of concrete and steel has assigned according to the IS standards. The analysis has been carried out in the software. The reactions at the base of the building are taken from the software separately. The same reactions are further used for the analysis of slope to get the factor of safety by using different software for different varying sloping angles (0 to 300). From the study, it observed that there is decrease in the factor of safety with increasing sloping angle and also noted that there is increase in the reactions with increase in sloping angle in both the cases i.e. gravity as well as seismic conditions.
Keywords: Earthquake, Sloping Ground, , Stability of Slopes, Staad Software

I. INTRODUCTION

Now days, rapid construction is taking place in hilly areas due to scarcity of plain ground. As a result the hilly areas have marked effect on the buildings in terms of style, material and method of construction leading to popularity of structures in hilly regions. Due to sloping profile, the various levels of such structures step back towards the hill slope and may also have setback also at the same time. These structures become highly uneven and asymmetric, due to variation in mass and stiffness distributions on different vertical axis at each floor. Such construction in earthquake prone areas makes them to attract greater shear forces and torsion compared to normal construction.The process in which behaviour of soil affects the motion of the structure and motion of the structure affects the behaviour of soil is termed as soil-structure interaction (SSI). Buildings were analysed for different soil conditions using STAAD Pro software idealized by equivalent springs. It was found that as time period increases, response reduction factor decreases but was found to be the same after certain time period.

India having a great arc of mountains consisting of the Himalayas defines the northern Indian subcontinent. These were formed by the on-going tectonic collision of the Indian and Eurasian plates where housing densities of approximately 62159.2 per Sq. Km are around as per 2011 Indian census. Hence there is a requirement to research to be done on the seismic safety factor and designing of these structures on terrain plane. Calculation of ground terrain is fundamental to many traditional Geographical Information Systems (GIS) applications. Slope is an important component in scientific, military and civilian analyses. Various methods exist for calculating slope. Manual slope generation, based upon contour line information, is a long established and generally acceptable method.

II. LITERATURE REVIEW

In this review, characteristics of the structures due to the variation of the slope angle are explained. Then 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.

Y. Singh &PhaniGade (2011):This paper presents some observations about seismic behaviour of hill buildings during the Sikkim earthquake of September 18, 2011. An analytical study is also performed to investigate the peculiar seismic behaviour of hill buildings.Dynamic response of hill buildings is compared with that of regular buildings on flat ground in terms fundamental period of vibration, pattern of inter-storey drift, column shear, and plastic hinge formation pattern. The seismic behaviour of two typical configurations of hill buildings is investigated using linear and non-linear time history analysis. It is observed that hill buildings have significantly different dynamic characteristics than buildings on flat ground. The storeys immediately above the road level, in case of down-hill buildings, are particularly vulnerable to earthquake action. The analytical findings are corroborated by the damage pattern observed during Sikkim earthquake.

Singh et al. (2012): The present study carried out an analytical study using linear and nonlinear time history analysis. They considered 9 story RC frame building (Step back) with 45 degrees to the horizontal located on steep slope. The number of storeys was 3 and 9 and 7 bays along the slope and 3 across the slope. They took 5 set of ground motions i.e., 1999 Chi-Chi, 1979 Imperial Valley, 1994 Northridge , 1971 San Fernando , 1995 Kobe from strong motion database of pacific Earthquake Engineering Research Centre (PEER). They observed that almost all the storey shear is resisted by the short column. The effect of torsional irregularity is represented by the ratio of maximum to average inter storey drifts (Δmax/Δavg) in a storey. They observed the step back buildings are subjected to considerable amount of torsional effects under cross slope excitations.

J.F. Rave-Arango& C.A. Blandón-Uribe, (2012) the analysis of the effects that earth pressure can produce under seismic conditions on the behaviour of such structures located on slopes were addressed. Finite element models considering various support conditions, solution schemes, structure heights, soil types and ways to account for soil pressure, were implemented. First, compared with its movement away from the slope, when the structure drifts towards the backfill the deformation of the building in the lower levels is reduced due to the restriction imposed by the slope, which in turn decreases shear and overturning moment at these levels.

Second, when contrasting estimates obtained as is currently done for routine design projects of this type with results from a more complex, detailed and realistic model, it was noted that, even for a similar base shear, drift, shear and moment envelopes for the refined model were higher from the top of the backfill to the roof.

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Babu et al. (2012): The present study performed pushover analysis of various symmetric and asymmetric structures constructed on plain as well as on sloping ground. They conducted analysis using structures with different configurations which are plan symmetry and asymmetry having different bay sizes. They considered a 4 storey building in which one storey is above ground level and it is constructed at a slope of 30 degree. They observed that the short column subjected to worst level of severity and lie beyond collapse prevention (CP) from pushover analysis.

Hemal J shah et. Al, (2014) presented a comparative study of plain ground and sloping ground of 23 degree and 27 degree slope are considered with same loading condition sand properties for 5 storey and 10 storey in medium soil and seismic zone is taken as zone V structure dynamic analysis has been done using SAP 2000 and it is observed that the building on 23 degree slope has lowest time period so it is more rigid building and gives higher earthquake forces.

Sujit Kumar, Dr.Vivek Garg, Dr. Abhay Sharma (2014):The seismic analysis of a G+4 storey RCC building on varying slope angles i.e., 7.5 Degree and 15 Degree were studied and compared with the same on the flat ground. The analysis is carried out to evaluate the effect of sloping ground on structural forces. 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.

The critical horizontal forces and bending moment in footing increases with increase in ground slope. However, critical values of vertical reaction in footing remain almost same for different ground slopes.The critical bending moment in the column increases significantly for sloping ground (15 degree) compared to plane ground.

Arun Kumar Y M And Nishil Alva (2015): This paper investigates the seismic behaviour of multi storey buildings on sloping ground considering soil-structure interaction. A ten storey reinforced concrete structure with and without elevation irregularities are analysed for different soil conditions using finite element software SAP2000 and results are compared with respect to top storey displacement, time period and base shear.For models considered for analysis, effect of soil below foundation decreased the time period of the whole system with corresponding increase in frequency. Hence of all the models considered for analysis, model which is the most suitable configuration preferred for a particular sloping ground considered in the study.

III. METHODOLOGY

This research paper deals with comparative study of behaviour of structures building frames with three geometrical configurations and different slope of ground. This study is attempted in following steps:

1. Selection of building geometry, 4 bays and G+4 of 2D frame.
2. Selection of sloping angle of ground (0°, 10°, 15°, 20°, 25° and 30°).
3. Modelling of building frames using STAAD-Pro v8i software.

LOADING CONSIDERATION:

A) DEAD LOAD:-

Self-Weight = 0.125X25 = 3.125 kN/m^2 Floor Finish Load = 1kN/m^2

Total Floor Load = 4.125 kN/m^2 Masonry Wall Load = 3.1X0.1X20 = 6.2 kN/m

Parapet Wall Load = 1.25X20X0.2 = 5 kN/m

B) LIVE LOAD = 3 kN/m^2

C) SEISMIC LOAD

Seismic Parameter	Data/Value
Earthquake Zone	IV
Response Reduction Factor	3
Importance Factor	1
Damping	5%
Soil Type	Medium Soil

MATERIALS PROPERTIES CONSIDERED IN THE MODELLING

MATERIAL PROPERTIES	VALUES
DENSITY OF R.C.C	25 kN/m^3
DENSITY OF MASONRY	20 25 kN/m^3
YOUNG'S MODULUS (EC)	2.17X10^4 N/mm^2

POISSONS RATIO	0.17
COMPRESSIVE STRENGHT	25 N/mm^2
STEEL	Fe415

SIZES OF STRUCTURAL ELEMENTS

SR. NO	STRUCTURAL MEMBER	SIZE
1	COLUMN ON GROUND	600MMX600MM
2	COLUMNS ON 1ST TO 4TH FLOOR	300MMX600MM
3	BEAMS ON TYPICAL FLOORS	230MMX500MM
4	THICKNESS OF TYPICAL SLAB	150MM
5	EXTERIOR AND INTERNAL WALL THICKNESS	230 MM

DESCRIPTION OF THE SOIL BASED STRUCTURE

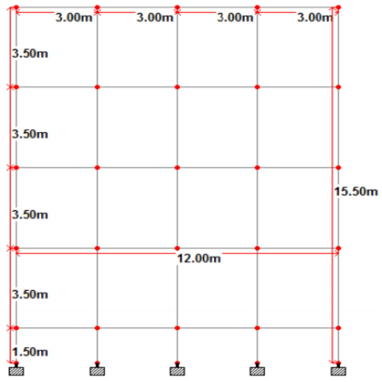
- A total of five four storeyed building frame models represented as M-1, M-2, M-3. M-4 and M-5 are considered in the present study. Model M-1 is generally a step back building i.e. without irregularity on sloping ground; whereas M-2, M-3, M-4 and M-5 are models with elevation irregularities on sloping ground.
- These models are modelled and analysed in STAAD Pro (Foundation) for different soils such as soft clay (SC), dense sand (DS), hard clay (HC), and rock (RCK). Properties of different soil considered are mentioned in Table.
- Direct method is adopted in the current study in which the response of the soil and structure is determined simultaneously by analysing the idealized soil- structure system in a single step.
- Soil stratum is idealized by elastic continuum theory in which physical representation of the infinite soil generates an elastic continuum model. The set of parameters adopted to represent the soil are young's modulus and Poisson's ratio.
- The soil is modelled using solid element. Foundation is designed using spread sheets and modelled using shell element. Soil is assumed to be linear, elastic and isotropic material.

Properties of Soil

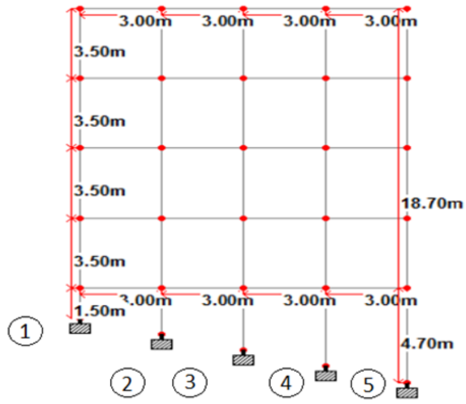
Soil Properties	Type of Soil			
	SC	DS	HC	RCK
Modulus of Elasticity (E)	25	50	100	14400
Poisson's Ratio (μ)	0.25	0.3	0.1	0.4
Density (kN/m^3)	17	21	20	26.5

SC-Soft Clay DS- Dense Sand HC- Hard Clay RCK- Rock

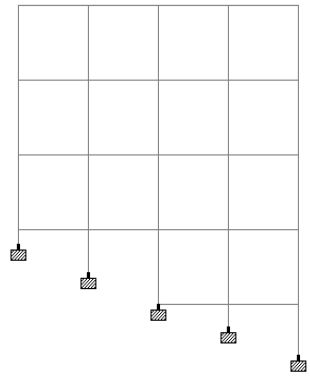
MODELING OF BUILDING



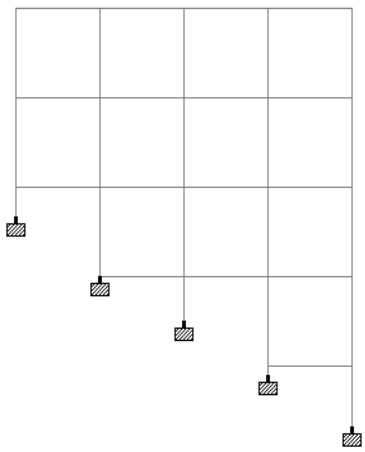
ELEVATION OF A SLOPING GROUND (0 DEGREE)



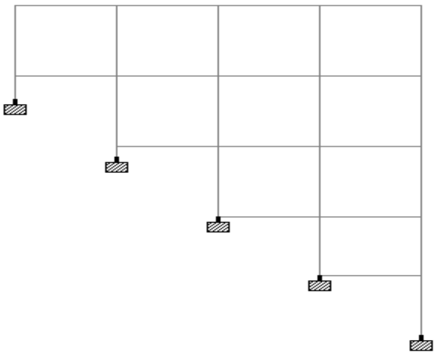
ELEVATION OF A SLOPING GROUND (15 DEGREE)



ELEVATION OF A SLOPING GROUND (20 DEGREE)



ELEVATION OF A SLOPING GROUND (30 DEGREE)



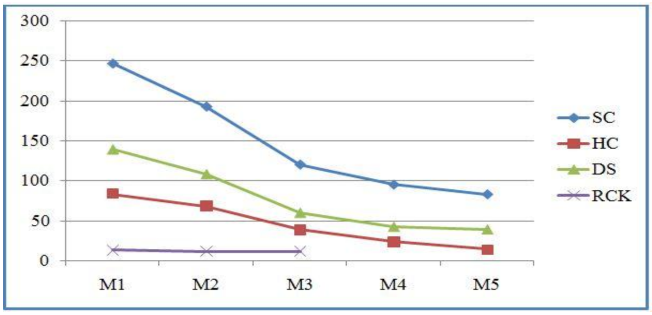
ELEVATION OF A SLOPING GROUND (40 DEGREE)

IV. RESULTS

STOREY DISPLACEMENT WITH RESPECT TO DIFFERENT TYPE OF SOIL:

MODEL NUMBER	TYPE OF SOIL			
	SC	HC	DS	RCK
M1	247.10	83.48	139.61	13.66
M2	193.04	68.28	108.47	12.06
M3	120.17	38.54	59.90	12.22
M4	94.87	23.69	42.34	10.32
M5	82.66	14.42	39.06	9.76

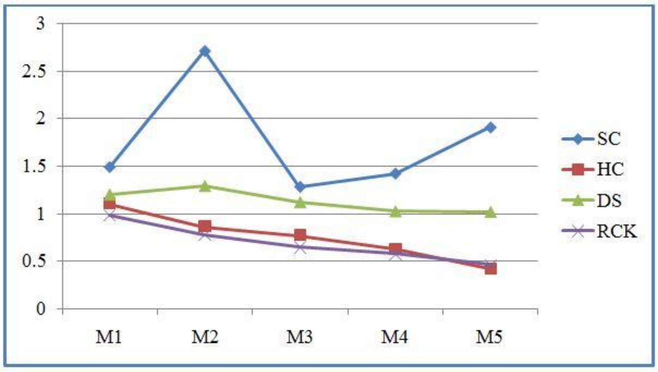
STORY DISPLACEMENT FOR DIFFERENT TYPES OF SOIL



TIME PERIOD FOR DIFFERENT MODELS UNDER DIFFERENT SOIL CONDITIONS:

MODEL NUMBER	TYPE OF SOIL			
	SC	HC	DS	RCK
M1	1.493	1.105	1.201	0.982
M2	2.714	0.869	1.292	0.78
M3	1.285	0.777	1.120	0.653
M4	1.425	0.632	1.024	0.578
M5	1.910	0.426	1.017	0.467

TIME PERIOD FOR DIFFERENT MODELS



V. CONCLUSIONS & FUTURE SCOPE

CONCLUSIONS

Analysis of structural frame for earthquake forces is a common problem formulation now aday's due to presence of several software tools and programs. Reinforced concretestructural frames are common form of constructions resting on plains and sloping ground in India. There structureswere subjected to different types of forces during their lifetime, such forces like dead load, live loads and dynamic forces like the wind and earthquake load.

Results from seismic evaluation performed on six RC buildings with six different ground slopes (0^0, 10^0, 15^0, 20^0, 25^0 and 30^0) were carried out by using static method. Thedisplacement of the top storey and the footing reaction, axial force, shear and moment action carried in columns and beams have been followed to analyze the influence of inclined ground on structural performance of building frame. The static analysis was done with the help of STAAD Pro. Software using the seismic parameters as per the IS: 1893-2002 for the zone (IV) and the post processing result were obtained. The sloping ground buildings possess relatively maximum reactions which may give to critical situations than the flat ground. It is found that there will be maximum reactions at 300 slope. From the analysis it can be concluded that there will be increase in reactions on the sloping ground, when the slope is subjected to the gravity as well as earthquake loading. The factor of safety of slope has varied in greater range, i.e in the beginning from 50 to 250 there will be decrease in factor of safety under both gravity loading (5.748 to 1.082) and for seismic loading (5.634 to 1.067). After 250 to 300 it is found that the factor of safety is less than 1. So it can be concluded that the factor of safety which less than 1 leads to failure of slopes.

FUTURE SCOPE

Research work can be carried out in this specific study area and it can help in designing the multistoried structures in hilly terrain considering, the various aspects with different soil spectrum, different seismic zones and varying angle of slope.

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