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Comparative Analysis of multistorey RCC- building frame resting on sloping ground using STAAD Pro

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Abstract- In this study, the seismic analysis of three different sloping ground frame buildings—10 degree slope, 12 degree slope, and 15 degree slope frames of G+12 storeys—was performed for seismic zone V, Himachal Pradesh, and Uttarakhand using structural software called STAAD.Pro.V8i (Series 5). This study's goal is to perform equivalent static analyses (ESA) for three distinct sloping RCC frame buildings using comparable physical characteristics, such as built-up area, beam and column sizes, load calculations, seismic parameters, and material specifications. Here, the principal stress, shear force, bending moment, and node movement are compared. The most efficient building will be determined by summary criteria, but the least efficient building will also be revised or redesigned. The goal of the research project is to find a solution to the issue of maximum displaced building. More precisely, this project's goals are: In order to assess design parameters like Node Displacement, Bending moment, Shear force, axial force, and the torque principle tension in all frames. To accomplish the most cost-effective, responsive slope building possible, which means offering in the best possible location.

Keywords- STAAD Pro. V8i, G+12, Zone V, RCC, and structural analysis.

I. INTRODUCTION

The real estate industry has been boosted by the quickly expanding urbanization and economy in hilly areas, which is luring more people to live there. Therefore, the need for multistory building development has increased. Because the ground in hilly areas slopes, building construction there is entirely different from that of structures constructed on flat land. This is due to the fact that the ground in hilly areas slopes at an angle from the normal ground level, resulting in varying column heights within the same storey. As a result, the supports within the same storey maintain varying stiffness values.

Many conventional Geographical Information Systems (GIS) applications require the determination of ground slope as a basic step. Slope is a crucial factor in studies conducted by scientists, the military, and civilians.

There are numerous ways to calculate inclination. The technique of manually creating slopes based on contour line data has been around for a while and is generally regarded as acceptable. Future periods will see a significant increase in the number of multi-story building frames constructed on sloped terrain. It is crucial that these building frames on sloping ground be realistically analyzed and designed in this respect. STAAD-Pro v8i software is used today to create such multi-story building frames. This inspiration served as the impetus for this research on the impact of various sloping angles in multi-story building frames. (2D-Frames).

Earthquakes are among the most hazardous natural disasters. Seismic analysis of structures located in areas prone to strong earthquakes is crucial. According to historical earthquake data, RCC buildings that contain columns of varying heights within the same storey have more harm in the short column of that storey than the tall column of the same storey. Due to the slope of the ground, the short columns on the uphill side are more vulnerable to damage than the long columns on the downhill side and are prone to higher lateral forces.

This is due to the fact that the short column is more rigid than the tall column, drawing more powerful seismic forces. The "Short Column Effect" is the name given to this phenomenon. The short column experiences shear failure and the damage appears as X-shaped fractures. In hilly areas, structures have irregularities in their mass and stiffness along their longitudinal and transverse axes.

In this paper, the seismic behavior of RC buildings on sloping ground is analyzed; considering the G+12 storey frame geometries with shear wall and without shear wall at different slopes. The modeling and analysis is done with the help of STAAD Pro v8i. The objectives of the study are as follows:

- To analyze 3-D building with Dead load, live load, under seismic load on different slopes i.e. 10degree, 12degree and 15degree.
- To study the variation of shear force, bending moment, axial force and Node displacement at different slopes.
- To optimize the structure stability with different angles.

II. LITERATURE

In this review, characteristics of the structures due to variation of the slope angle are explained. 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. No research work is done based on experimental investigation of the structures on sloping ground.

S.P. Pawar et al. (2016) [1] – This study based on the seismic behavior of buildings resting on sloping ground with a shear walls. It is observed that the seismic behavior of buildings on sloping ground differ from other buildings. The various floors of such buildings step backs towards hill slope. Most of the studies agree that the buildings resting on sloping ground have higher displacement and base shear compared to buildings resting on plain ground and the shorter column attracts more forces and undergo damage when subjected to earthquake. Step back building could prove more vulnerable to seismic excitation. They conclude that, buildings on sloping ground have higher stiffness on shortest column. The base shear and displacement is more along the slope than in other transverse direction. The straight shape (or rectangular) shear walls configuration proves to be better among all configurations for resisting the lateral displacement.

Sripriya Arjun and Arathi S. (2015) [2] – In this study, behavior of G+3 storied sloped frame building having step back set back configuration is analyzed for sinusoidal ground motion with different slope angles i.e., 16.7°, 21.8°, 26.57° and 30.96° using structural analysis tool STAAD Pro. By performing Response Spectrum analysis as per IS: 1893 (part 1): 2002. The results were obtained in the form of top storey displacement and base shear. It is observed that short column is affected more during the earthquake. The analyses showed that for construction of the building on sloppy ground the step back setback building configuration is suitable. Sujit

Kumar et al. (2014) [3] – He studied the seismic analysis of a G+4 story RCC building on varying slope angles i.e., 7.50 and 150 is studied and compared with the same on the flat ground. The seismic forces are considered as per IS: 1893-2002. The structural analysis software STAAD Pro v8i is used to study the effect of sloping ground on building performance during earthquake. Seismic analysis has been done using Linear Static method. The analysis is carried out to evaluate the effect of sloping ground on structural forces.

The horizontal reaction, bending moment in footings and axial force, bending moment in columns are critically analyzed to quantify the effects of various sloping ground. 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. Thus, the section of these columns should be designed for modified forces due to the effect of sloping ground. The present study emphasizes the need for proper designing of structure resting on sloping ground.

Prasad Ramesh Vaidya (2014) [4] –This study investigates the seismic performance of shear wall building on sloping ground. The main objective is to understand the behavior of the building on sloping ground for various positions of shear walls and to study the effectiveness of shear wall on sloping ground. The performance of building has been studied with the help of four mathematical models. Model one is of frame type structural system and other three models are of dual type (shear wall-frame interaction) structural system with three different positions of shear walls. Response spectrum analysis is carried out by using finite element software SAP 2000. The performance of building with respect to displacement, story drift and maximum forces in columns has been presented in this study.

III. METHODOLOGY

The study is all about the analyzing the different sloping conditions of frames under equivalent seismic analysis by using STAAD Pro. The built-up area considered for three different shaped frames (i.e. 10 degree slope, 12 Degree slope & 15 Degree slope) .The frames is been abbreviated as during this study are as follows - Case 1 (10 degree slope), Case 2 (12 Degree slope) & Case 3 (15 Degree slope) .The size of column 0.35 X 0.35 m . The size of beams have size of 0.35 X 0.23 m. The Slab thickness of each frame cases is 150 mm. The material used in RCC frame cases is concrete of M30 Grade & steel of Fe415 Grade. This irregularity comes under the vertical geometrical irregularity as per IS1893:2002/ in zone 5, Damping ratio 0.05%.

Sloping ground building having different degrees are as follows:

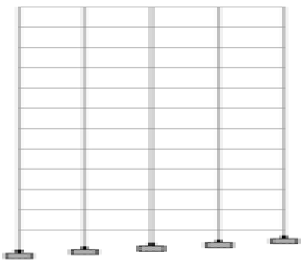

Fig 1. 10 Degree.

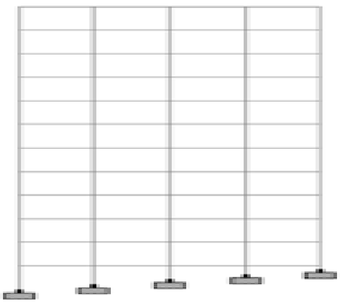

Fig 2. 12 Degree.

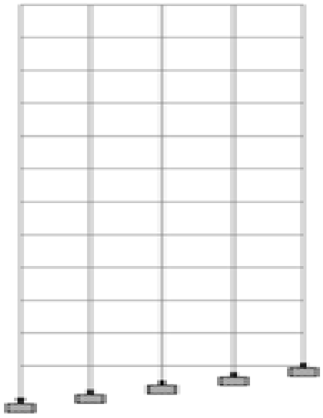

Fig 3. 15 Degree.

IV. RESULT AND ANALYSIS

1. Maximum Node displacement summary in Y-direction of Rcc building frame having sloping ground at 10 degree:

Node Displacement Summary

	Node	L/C	X (mm)	Y (mm)	Z (mm)	Resultant (mm)	rX (rad)	rY (rad)	rZ (rad)
Max X	321	24:GENERATE	**60.618**	-0.246	0.240	60.619	-0.000	0.000	-0.001
Min X	325	22:GENERATE	**-62.500**	-1.501	0.712	62.522	-0.000	-0.000	0.001
Max Y	191	1:EQ X	40.744	**1.472**	0.026	40.771	-0.000	0.000	-0.000
Min Y	193	7:GENERATE[	-1.606	**-8.547**	0.421	8.706	0.000	-0.000	0.000
Max Z	61	21:GENERATE	-2.336	-1.652	**62.928**	62.993	0.001	0.000	-0.000
Min Z	321	27:GENERATE	-1.533	-0.261	**-62.384**	62.403	-0.001	-0.000	-0.000
Max rX	346	25:GENERATE	-1.038	0.040	16.729	16.761	**0.002**	0.000	0.000
Min rX	346	23:GENERATE	0.645	-2.076	-16.647	16.788	**-0.002**	-0.000	0.000
Max rY	61	25:GENERATE	-1.871	-0.277	62.790	62.818	0.001	**0.000**	-0.000
Min rY	321	23:GENERATE	-2.001	-1.764	-62.250	62.307	-0.001	**-0.000**	-0.000
Max rZ	346	22:GENERATE	-15.562	-2.081	0.010	15.700	-0.000	-0.000	**0.002**
Min rZ	346	24:GENERATE	15.168	0.045	0.072	15.168	0.000	0.000	**-0.002**
Max Rst	321	21:GENERATE	-0.339	-5.749	62.917	**63.180**	0.000	0.000	-0.000

2. Maximum Node displacement summary in Y-direction of Rcc building frame having sloping ground at 12 degree

Node Displacement Summary

	Node	L/C	X (mm)	Y (mm)	Z (mm)	Resultant (mm)	rX (rad)	rY (rad)	rZ (rad)
Max X	321	24:GENERATE	**59.229**	-0.241	0.007	59.229	-0.000	0.000	-0.001
Min X	325	22:GENERATE	**-61.942**	-1.385	-0.007	61.958	-0.000	-0.000	0.001
Max Y	191	1:EQ X	40.154	**1.484**	0.010	40.181	0.000	0.000	-0.000
Min Y	193	7:GENERATE[	-2.394	**-8.768**	-0.012	9.089	-0.000	0.000	0.000
Max Z	61	25:GENERATE	-1.533	-0.274	**60.997**	61.017	0.001	0.000	-0.000
Min Z	321	23:GENERATE	-2.211	-1.764	**-61.017**	61.082	-0.001	-0.000	-0.000
Max rX	26	21:GENERATE	-1.055	-0.919	26.467	26.504	**0.002**	0.000	0.000
Min rX	286	23:GENERATE	-1.057	-0.908	-26.472	26.509	**-0.002**	-0.000	0.000
Max rY	61	21:GENERATE	-2.210	-1.775	60.995	61.061	0.001	**0.000**	-0.000
Min rY	321	27:GENERATE	-1.535	-0.269	-61.010	61.030	-0.001	**-0.000**	-0.000
Max rZ	30	22:GENERATE	-26.255	-0.603	0.007	26.262	-0.000	-0.000	**0.002**
Min rZ	26	20:GENERATE	25.094	-0.900	0.013	25.110	-0.000	0.000	**-0.002**
Max Rst	191	22:GENERATE	-61.923	-7.057	-0.025	**62.324**	-0.000	-0.000	0.000

3. Maximum Node displacement summary in Y-direction of Rcc building frame having sloping ground at 15 degree:

Node Displacement Summary

	Node	L/C	X (mm)	Y (mm)	Z (mm)	Resultant (mm)	rX (rad)	rY (rad)	rZ (rad)
Max X	61	24:Generated	**59.848**	-0.243	0.002	59.848	0.000	-0.000	-0.001
Min X	65	22:Generated	**-62.349**	-1.436	0.004	62.365	0.000	0.000	0.001
Max Y	191	1:eqx	40.521	**1.489**	-0.000	40.549	0.000	-0.000	-0.000
Min Y	193	7:Generated Ir	-2.219	**-8.907**	-0.000	9.180	-0.000	-0.000	0.000
Max Z	61	21:Generated	-2.195	-1.763	**61.866**	61.930	0.001	0.000	-0.000
Min Z	321	23:Generated	-2.195	-1.763	**-61.866**	61.930	-0.001	-0.000	-0.000
Max rX	26	21:Generated	-1.163	-0.906	27.245	27.285	**0.002**	0.000	0.000
Min rX	286	23:Generated	-1.163	-0.906	-27.245	27.285	**-0.002**	-0.000	0.000
Max rY	61	21:Generated	-2.195	-1.763	61.866	61.930	0.001	**0.000**	-0.000
Min rY	321	23:Generated	-2.195	-1.763	-61.866	61.930	-0.001	**-0.000**	-0.000
Max rZ	30	22:Generated	-26.767	-0.638	-0.000	26.775	-0.000	-0.000	**0.002**
Min rZ	26	20:Generated	25.653	-0.894	-0.000	25.668	-0.000	0.000	**-0.002**
Max Rst	191	22:Generated	-62.340	-7.077	0.000	**62.741**	-0.000	0.000	0.000

4. Maximum Axial force, Shear force, Torsion, Bending moment summary in Y-direction of Rcc building frame having sloping ground at 10 degree:

Beam End Force Summary

The signs of the forces at end B of each beam have been reversed. For example: this means that the Min Fx entry gives the largest tension value for an beam.

				Axial	Shear		Torsion	Bending	
	Beam	Node	L/C	Fx (kN)	Fy (kN)	Fz (kN)	Mx (kNm)	My (kNm)	Mz (kNm)
Max Fx	793	338	7:GENERATEI	**1.26E+3**	0.848	0.181	0.000	-0.111	-0.174
Min Fx	786	331	2:EQ Z	**-264.242**	-28.996	-22.081	-0.790	28.420	-22.838
Max Fy	784	329	24:GENERATE	783.592	**125.865**	-0.370	0.153	0.255	86.250
Min Fy	784	329	22:GENERATE	200.234	**-126.573**	0.052	-0.160	-0.204	-89.385
Max Fz	782	327	23:GENERATE	644.715	53.659	**98.201**	1.979	-64.556	28.686
Min Fz	784	329	21:GENERATE	654.469	54.143	**-98.083**	-1.973	64.581	28.752
Max Mx	783	328	23:GENERATE	632.396	-0.059	97.370	**2.002**	-64.571	-1.869
Min Mx	783	328	25:GENERATE	379.131	-0.804	-97.291	**-2.001**	64.591	-1.320
Max My	173	87	23:GENERATE	591.048	-1.697	49.876	0.036	**74.675**	2.683
Min My	173	82	23:GENERATE	604.037	-1.697	49.876	0.036	**-74.954**	-2.408
Max Mz	784	329	24:GENERATE	783.592	125.865	-0.370	0.153	0.255	**86.250**
Min Mz	784	329	22:GENERATE	200.234	-126.573	0.052	-0.160	-0.204	**-89.385**

5. Maximum Axial force, Shear force, Torsion, Bending moment summary in Y-direction of Rcc building frame having sloping ground at 12 degree

Beam End Force Summary

The signs of the forces at end B of each beam have been reversed. For example: this means that the Min Fx entry gives the largest tension value for an beam.

				Axial	Shear		Torsion	Bending	
	Beam	Node	L/C	Fx (kN)	Fy (kN)	Fz (kN)	Mx (kNm)	My (kNm)	Mz (kNm)
Max Fx	793	338	7:Generated Ir	**1.33E+3**	2.181	-0.000	-0.000	0.000	0.645
Min Fx	786	331	2:eqz	**-266.618**	-32.742	-13.081	-0.676	18.390	-20.277
Max Fy	785	330	25:Generated	651.020	**207.431**	-120.443	0.833	65.804	64.682
Min Fy	781	326	21:Generated	121.469	**-212.396**	-117.976	1.048	66.590	-70.315
Max Fz	783	328	23:Generated	651.733	-3.503	**145.958**	2.738	-65.330	-4.117
Min Fz	783	328	21:Generated	651.733	-3.503	**-145.958**	-2.738	65.330	-4.117
Max Mx	781	326	22:Generated	133.801	-153.241	-21.636	**3.361**	5.567	-81.937
Min Mx	785	330	22:Generated	133.801	-153.241	21.636	**-3.361**	-5.567	-81.937
Max My	386	209	21:Generated	704.141	1.833	-50.121	-0.040	**75.842**	2.467
Min My	170	79	23:Generated	704.141	1.833	50.121	0.040	**-75.842**	2.467
Max Mz	783	328	24:Generated	799.159	190.309	-0.000	0.000	0.000	**84.789**
Min Mz	783	328	22:Generated	243.614	-195.915	0.000	-0.000	-0.000	**-91.375**

6. Maximum Axial force, Shear force, Torsion, Bending moment summary in Y-direction of Rcc building frame having sloping ground at 15 degree:

Beam End Force Summary

The signs of the forces at end B of each beam have been reversed. For example: this means that the Min Fx entry gives the largest tension value for an beam.

				Axial	Shear		Torsion	Bending	
	Beam	Node	L/C	Fx (kN)	Fy (kN)	Fz (kN)	Mx (kNm)	My (kNm)	Mz (kNm)
Max Fx	793	338	7:GENERATEI	**1.33E+3**	5.792	-0.033	-0.001	0.017	2.249
Min Fx	783	328	12:GENERATE	**-1.06E+3**	-182.310	0.217	0.010	0.027	-9.735
Max Fy	783	328	22:GENERATE	-250.487	**255.453**	-0.254	-0.007	-0.026	7.204
Min Fy	783	328	24:GENERATE	-779.483	**-237.850**	0.271	0.010	0.031	-8.728
Max Fz	783	328	23:GENERATE	-643.719	11.274	**157.610**	-3.342	6.971	-0.920
Min Fz	783	328	25:GENERATE	-386.251	6.329	**-157.594**	3.346	-6.966	-0.603
Max Mx	785	330	22:GENERATE	-137.652	187.625	34.456	**6.929**	-6.287	-6.504
Min Mx	781	326	22:GENERATE	-137.823	186.285	-34.572	**-6.884**	6.126	-6.566
Max My	386	209	21:GENERATE	709.996	1.710	-50.246	-0.045	**76.202**	2.365
Min My	170	79	23:GENERATE	710.054	1.714	50.263	0.045	**-76.229**	2.375
Max Mz	170	79	20:GENERATE	706.147	50.776	1.403	0.003	-1.907	**77.080**
Min Mz	386	214	20:GENERATE	693.096	50.775	-1.388	-0.007	-2.276	**-75.251**

7. Maximum plate centre principal stress summary of RCC building frame having sloping ground at 10 degree:

Plate Centre Principal Stress Summary

			Principal		Von Mis		Tresca	
	Plate	L/C	Top (N/mm²)	Bottom (N/mm²)	Top (N/mm²)	Bottom (N/mm²)	Top (N/mm²)	Bottom (N/mm²)
Max (t)	816	22:GENERATE	**0.503**	-0.008	0.466	0.076	0.503	0.080
Max (b)	808	24:GENERATE	-0.065	**0.119**	0.459	0.106	0.487	0.119
Max VM (t)	808	22:GENERATE	0.502	-0.042	**0.473**	0.109	0.502	0.124
Max VM (b)	811	23:GENERATE	0.255	0.226	0.383	**0.344**	0.441	0.396
Tresca (t)	816	22:GENERATE	0.503	-0.008	0.466	0.076	**0.503**	0.080
Tresca (b)	811	23:GENERATE	0.255	0.226	0.383	0.344	0.441	**0.396**

8. Maximum plate centre principal stress summary of RCC building frame having sloping ground at 12 degree:

Plate Centre Principal Stress Summary

			Principal		Von Mis		Tresca	
	Plate	L/C	Top (N/mm²)	Bottom (N/mm²)	Top (N/mm²)	Bottom (N/mm²)	Top (N/mm²)	Bottom (N/mm²)
Max (t)	804	21:Generated	**0.656**	0.374	0.641	0.460	0.656	0.513
Max (b)	816	25:Generated	-0.013	**0.127**	0.635	0.443	0.641	0.492
Max VM (t)	804	21:Generated	0.656	0.374	**0.641**	0.460	0.656	0.513
Max VM (b)	811	23:Generated	0.378	0.362	0.564	**0.540**	0.648	0.621
Tresca (t)	812	23:Generated	0.425	0.296	0.587	0.427	**0.670**	0.489
Tresca (b)	811	23:Generated	0.378	0.362	0.564	0.540	0.648	**0.621**

9. Maximum plate centre principal stress summary of RCC building frame having sloping ground at 15 degree

Plate Centre Principal Stress Summary

			Principal		Von Mis		Tresca	
	Plate	L/C	Top (N/mm²)	Bottom (N/mm²)	Top (N/mm²)	Bottom (N/mm²)	Top (N/mm²)	Bottom (N/mm²)
Max (t)	816	27:GENERATE	**0.521**	0.370	0.538	0.505	0.554	0.575
Max (b)	816	21:GENERATE	0.047	**0.198**	0.549	0.476	0.571	0.543
Max VM (t)	812	21:GENERATE	0.315	0.311	**0.657**	0.611	0.755	0.704
Max VM (b)	817	23:GENERATE	0.447	0.687	0.474	**0.739**	0.498	0.782
Tresca (t)	812	21:GENERATE	0.315	0.311	0.657	0.611	**0.755**	0.704
Tresca (b)	817	23:GENERATE	0.447	0.687	0.474	0.739	0.498	**0.782**

V. CONCLUSION

Based on different configurations of the building on sloping ground the following conclusions are drawn. It is observed that maximum displacement is found in case of 12 degree slope .Hence we can say that, risk increases with the inclination of the slope.

In this study we found that, on increasing the slope of ground most of the parameter are increasing accordingly. Maximum axial force obtained at 12 degree and 15 degree both whereas Torsion force is maximum at 15 degree slope.

It is observed that, maximum shear force and maximum bending moment increase significantly for sloping ground at 15° slope. It is observed that, axial force increases in the buildings with increasing slope. Maximum principal stress in plate centre at top is found on 12 degree slope, whereas Von mesca and tresca forces on top are obtained at 15degree.

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