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Seismic Analysis of RC Building on Sloping Ground with Shear Wall

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ABSTRACT - Now days, rapid construction is taking place in hilly areas due to scarcity of plain ground. The Buildings located in hilly areas are much more affected by seismic environment in comparison to the buildings that are located in flat regions. Structures on slopes differ from other buildings since they are irregular in both vertically and horizontally, and torsional coupled. Hence, they are susceptible to severe damage when subjected to seismic action. Due to sloping ground columns of ground storey have different height of columns. In this study, the analysis of G+7 storey building frame with and without shear wall at different slopes of ground as 10°, 15°, 30° and 45° are studied. Analysis have been done using structural analysis tool STAAD Pro v8i. Using the analysis results various parameter has been taken for the comparison. The maximum deflection, axial force, shear force, bending moment and base shear are critically analyzed to quantify the effects of various sloping ground.

Keywords: RCC Multistorey Building Frames, Sloping Ground 10^0, 15^0, 30^0 &45^0, Shear Wall, G+7, Seismic Zone-V, STAAD Pro

I. INTRODUCTION

A natural disaster is a major adverse incident resulting from natural processes of the Earth which includes floods, hurricanes, tornadoes, volcanic eruptions, earthquakes, tsunamis and other geologic processes. In which earthquake is the most terrible and unpredictable phenomenon of nature. Earthquake is the vibration of earth's surface caused by waves coming from a source of disturbance inside the earth As the waves radiate from the fault, they undergo geometric scattering and reduction due to loss of energy in the rocks. Since the interior of the earth consists of heterogeneous formations, the waves undergo multiple reflections, retraction, dispersion and reduction as they travel. The seismic waves arriving at a site on the surface of the earth are a result of complex superposition giving rise to irregular motion and shaking of ground surface wave coming from earthquake focus When a structure is subjected to seismic forces it does not cause loss to human lives directly but due to the damage cause to the structures that leads to the collapse of the building. Mass destruction of the low and high rise buildings in the recent earthquakes leads to the need of investigation especially in a developing country like India. Structure subjected to seismic/earthquake forces are always vulnerable to damage and if it occurs on a sloped building as on hills which is at some inclination to the ground the chances of damage increases much more. Structures on slopes vary from those on plains because they are asymmetrical horizontally as well as vertically.

OBJECTIVES

The objectives of the study on seismic analysis of RC building on the sloping ground. By considering the G+7 multistorey frame structure with and without shear wall at different slope case are taken for the same purpose. Modelling and analysis is done with the help of STAAD Pro v8i are as follows:

The main objectives of the study are as follows:

- To analyze G+7 multistorey building resting on sloping ground having slope of 10°, 15°, 30° and 45° with the horizontal situated in zone-V and on medium soil type, for bare frame, and shear wall using STAAD Pro v8i software.
- To analyze the variation of stability parameters such as shear force, bending moment, axial force and node displacement at different slopes.
- To compare the effect of earthquake forces for G+7 multistorey building frames without shear wall with G+7 multistorey building frames with shear wall along periphery, shear wall at corner, shear wall at core means shear wall at different position or location of multistorey building plan.
- To interpret the results from analysis of multistorey frame building and to identify the best location or position of the shear wall with respect to stability criterion.

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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. No research work is done based on experimental investigation of the structures on sloping ground.

Mujeeb Ul Hasan et al. (2017) [1]: "Effect of RC Shear Wall on Seismic Performance of Building Resting on Sloping Ground". The analysis of G+10 storey building frame with and without shear wall at different slopes of ground as 0° and 10° is studied. It is assumed that the columns are fixed at base and building is situated in seismic zone-IV. The different models are analyzed by means of Staad-pro software. The comparison of maximum values of storey displacements, storey drift, support reactions, forces in beams and columns has been carried out for useful interpretation of results. The use of shear wall in building frame reduces nodal displacements in the floors, storey drift and critical values of shear force, bending moment and torsion in structural members. They conclude that, shear wall is very effective to reduce the displacements, storey drift and torsion moments in building. Shear wall at centre is found to be more effective as compared to shear wall at corner.

Sripriya Arjun et al. (2015) [2]: "studies on Dynamic Characteristics of RC Buildings on hill slopes". 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 slopes angles i.e.. l6.7°. 21.8° , 26.57° and 30.96° using structural analysis tool STAAD Pro.by performing Response Spectrum analysis have been carried out as per IS:1893 (pant 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]: "studies the effect of sloping ground on structural performance of RCC building under seismic load". He studied the seismic analysis of a G+4 story RCC building on varying slope angles as 7.5^0 and 15^0 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. This study emphasizes the need for proper designing of structure resting on sloping ground.

M.Venkateswarlu et al. (2016) [4]: "Seismic analysis of RC framed building for different position of shear wall". Five different model of RC building, one with no shear wall and other four models with different position of shear wall which is subjected to earthquake load in zone-V has been studied. The parameter like lateral displacement, storey drift, and base shear was studied and suitable location of shear wall was determined among these models. The response of building with and without opening in shear wall is also studied. This study also incorporates how the bending moment, shear force for beam and axial Force for column vary with change in positioning of RC shear wall. Buildings are modelled and analyzed using standard package ETABS 2013.

III. MODELLING DESCRIPTION

In this present study we have considered a G+7 multistorey RC building frame resting on sloping ground of 10^0, 15^0, 30^0 & 45^0 respectively situated in seismic zone-V have been configured and modelled as a bare frame structure for comparison with same multistorey RC building frame which includes shear wall at three different positions of the same bare frame. The configuration of multistorey bare frame without shear wall and the multistorey building frame with shear wall are the same as mentioned in table No.3.1 except shear wall at different positions. STAAD Pro. Software is used for modelling of the G+7 multistorey building frame. For every structure a 3D model is developed.

A rectangular shape building considered for analyzing is symmetric in plan and elevation. The plan dimensions of the building to be modelled are 15 m × 15 m. It consists of five bays of 3m each in X and Y directions respectively.

Table No. 3.1: Details and dimension of the multistorey building frame model

Title	Specifications
Plan area size	15 m x 15 m
Height of building	21 m
Spacing in X direction	3m
Spacing in Y direction	3m
Beam sizes	250 mm × 400 mm
Column sizes	450 mm × 450 mm
Slab thickness	150 mm
Thickness of shear wall	200 mm
Live load	3 KN/m^2

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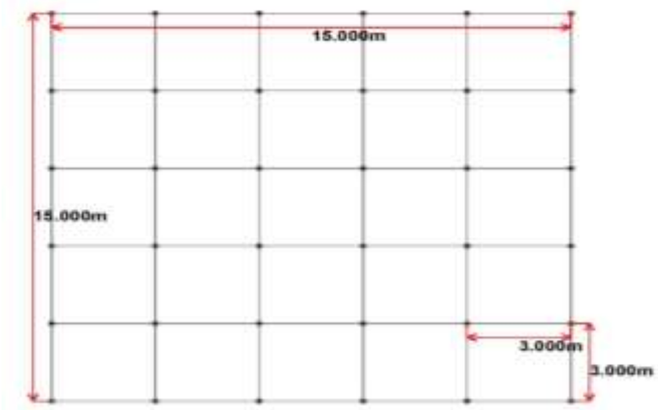
Floor finish	1 KN/m^2
Concrete Grade	M 20
Poisson ratio	0.17
Comprehensive strength	20000 KN/m^2
Steel	Fe 415

Figure No. 3.1: Plan of the multistorey building frame



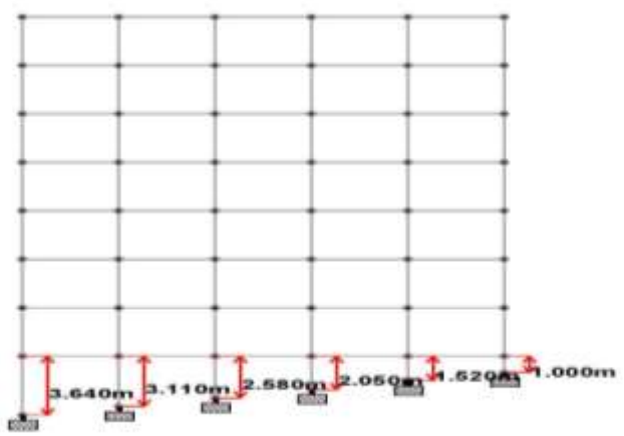


Figure No. 3.2: Elevation of the G+7 building building frame

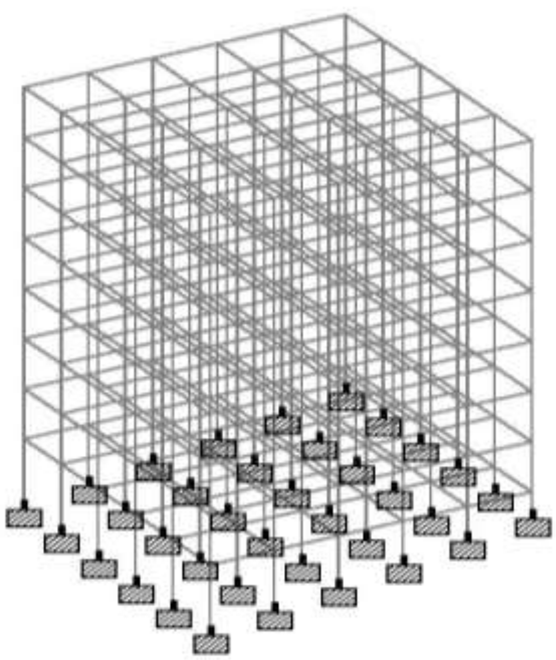


Figure No. 3.3: 3D view of G+7 multistorey building frame

IV. METHODOLOGY

This present study deals with the behavior analysis of multistorey buildings on sloping ground considering different inclination of 10°, 15°, 30° and 45° under earthquake forces at zone-V. The comparison of different model on the Slopping ground with shear wall and without shear wall is done. Here G+ 7 multistorey are taken and same live load is applied in all the buildings for its behavior and comparison is done. The framed buildings are subjected to vibrations because of earthquake and therefore seismic analysis is essential for these building frames. The fixed base system is adopted to analyze all building frames in seismic zone V by means of STAAD Pro. Software. Following steps have been adopted in this study.

Step l: Selection of G+7 building frame.

Step 2: Selection of different ground slopes as 10°, 15°,30° and 45°.

Step 3: Defining the position of the shear wall at corner, core and periphery.

Step 4: Selection of seismic zone-V.

Step 5: Formation of load combinations.

Step 6: Modelling of building frame using STAAD Pro software. Model I for bare frame means which has no shear wall, at four different ground slopes. Model II, Model III and Model IV with shear wall at different positions along with same ground slopes. Four model for each four Model cases.

Step 7: Analysis of all the cases which are considered in the study

Step 8: Comparative study of results in terms of maximum moment, shear force, and maximum displacement, etc.

V. ANALYSIS AND RESULT

All the building frames on sloping ground with shear wall and without shear wall are analyzed with the help of STAAD Pro software. All the models are analyzed in the seismic zone V. Using the analysis results various graphs are plotted and compared for all the models with different parameters. For comparison following are the main parameters.

- Maximum Node Displacement
- Maximum Shear Force
- Maximum Bending Moment
- Maximum Axial Force
- Base shear
- There are total 16 cases modelled and analyzed.

5.1 Maximum node displacement

The maximum node displacement is shown in the table No. 5.1 and Figure No. 5.1

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Table No. 5.1: Maximum node displacement for different ground slopes

Model No.	Different Cases	Node displacement for different ground slopes (in mm)			
		10 degree	15 degree	30 degree	45 degree
I	Bare frame (No shear wall)	35.895	39.542	41.880	43.647
II	shear wall at corner	14.213	17.036	19.155	21.195
III	shear wall at core	14.902	19.197	22.308	26.667
IV	shear wall at periphery	9.057	12.652	14.648	17.440

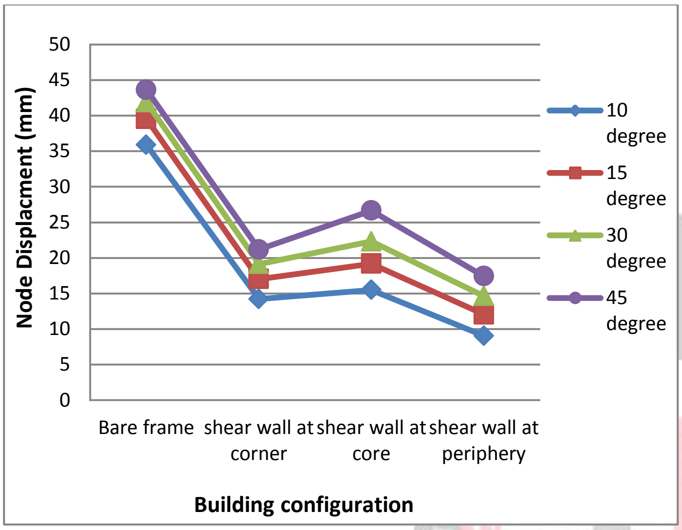

Figure No. 5.1: Maximum node displacement for different ground slopes

- From the results it is observed that maximum node displacement is found in the bare frame with 45° slope and minimum in building with shear wall at periphery having 10° slope.
- We can observe that, node displacement is increased with the inclination of the slopes.
- It is said that shear wall at the periphery is the best location to reduce the node displacement.

5.2 Maximum shear force

The maximum shear force is shown in the table No.5.2.1 and Figure No. 5.2.1.

Table No. 5.2.1: Maximum shear force for different ground slopes

Model No	Different Cases	Shear force for different ground slopes (in KN)			
		10 degree	15 degree	30 degree	45 degree
I	Bare frame (No shear wall)	252.93	402.332	690.892	801.026
II	Shear wall at corner	100.50	248.200	343.620	398.946
III	Shear wall at core	151.425	268.755	389.240	601.341
IV	Shear wall at periphery	108.193	189.139	264.479	374.732

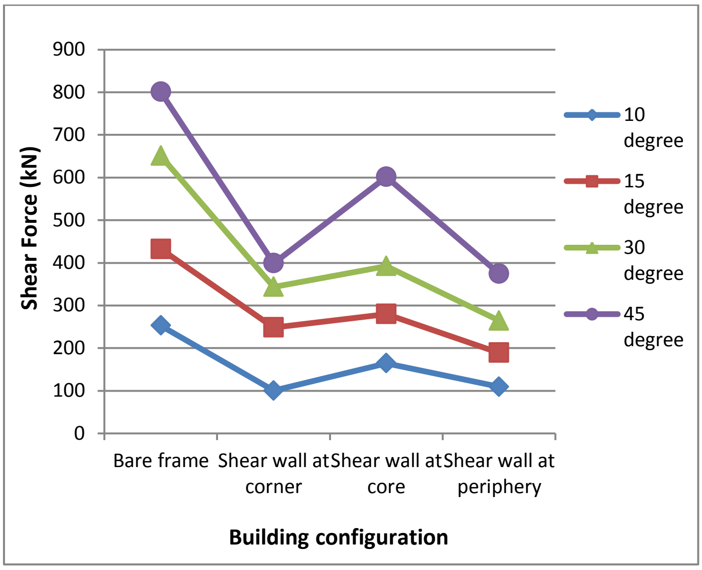

Figure No. 5.2.1 Maximum Shear force for different ground slopes

- From the results it is observed that Maximum shear force is found in bare frame and minimum in building with shear wall at corner.
- Maximum shear force found on 45° slope means shear force increases with the inclination of the slope.
- We can see that. Shear force is reduced in the building with shear wall that means shear wall resists the load acting on the building.

5.3 Maximum bending moment

The maximum bending moment are shown in the table No. 5.3.1 and Figure No. 5.3.1.

Table No. 5.3.1: Maximum bending moment for different ground slopes

Model No.	Different Cases	Bending moment for different ground slopes (in KNm)			
		10 degree	15 degree	30 degree	45 degree
I	Bare frame (No shear wall)	154.952	294.854	457.756	569
II	Shear wall at corner	78.573	127.884	207.983	247.93
III	Shear wall at core	103.322	174.24	295.158	469.006
IV	Shear wall at periphery	87.564	124.567	232.136	345.028

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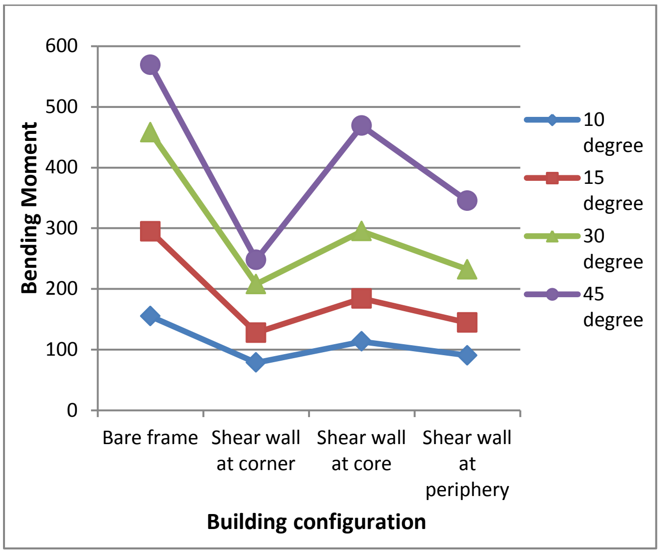

Figure No. 5.3.1: Maximum bending moment for different ground slopes

- From the results it is observed that maximum bending moment is found in bare frame and minimum in building with shear wall at comer.
- Maximum bending moment is found on 45° slope, means bending moment increases with the inclination of the slope.
- We can see that, shear wall reduce the moment acting on the building

5.4 Maximum axial force

The maximum axial force are shown in the table No. 5.4.1 and Figure No. 5.4.1.

Table No. 5.4.1: Maximum axial force for different ground slopes

Model No	Different Cases	Axial force for different Ground slopes(in KN)			
		10 degree	15 degree	30 degree	45 degree
I	Bare frame (No shear wall)	1387.793	1487.783	1564.502	1386.825
II	Shear wall at corner	2048.310	2053.493	2058.627	2186.825
III	Shear wall at core	2618.449	2501.143	2317.927	2483.528
IV	Shear wall at periphery	2244.96	2252.707	2260.454	2284.370

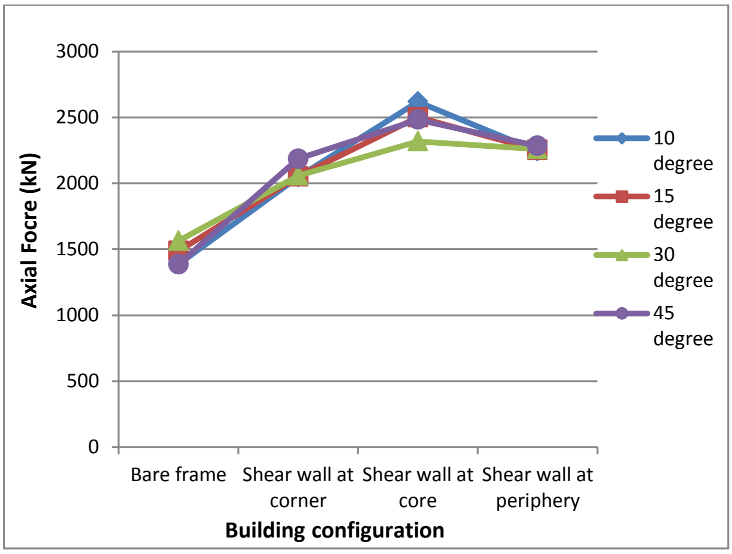

Figure No. 5.4.1: Maximum axial force for different ground slopes

- From the results it is observed that maximum axial force is found in building with shear wall at core and minimum in bare frame.
- Maximum axial force is found on 10° slope and minimum on 45° ground slope.

5.5 Base shear

The base shear are shown in the table No. 5.5.1 and Figure No. 5.5.1.

Table No. 5.5.1: Base shear for different ground slopes

Model No.	Different cases	Base shear for different ground slopes (in KN)			
		10 degree	15 degree	30 degree	45 degree
I	Bare frame(No shear wall)	1378.41	1389.97	1410.67	1465.92
II	Shear wall at corner	1573.09	1624.09	1663.07	1744.19
III	Shear wall at core	1475.25	1511.11	1541.08	1609.32
IV	Shear wall at periphery	1578.09	1622.95	1661.93	1743.05

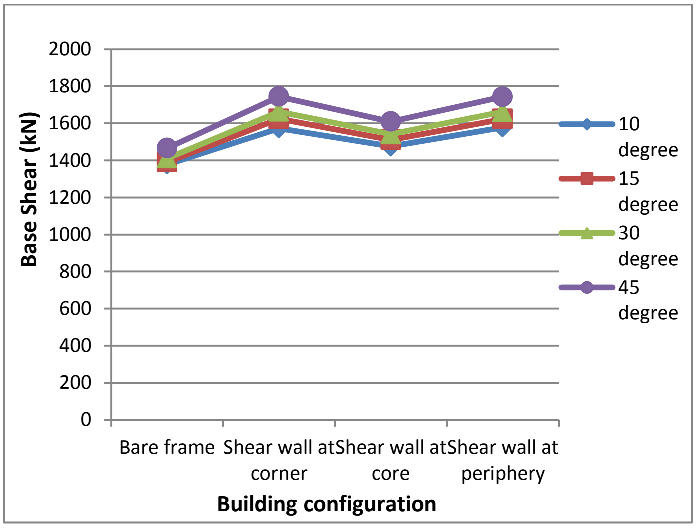

Figure No. 5.5.1: Base shear for different ground slopes

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- From the results it is observed that maximum base shear is found in building with shear wall at corner & periphery and minimum in bare frame.
- Base Shear is found maximum on 45° slope and minimum on 10° ground slope, it means base shear increases with the inclination of the slope.
- We can say that, base shear is increase in the building with shear wall, due to increase the dead load of the shear wall.

VI. CONCLUSION

In this study, the analysis of G+7 multistorey RC building on different slopping ground are modeled by STAAD Pro v8i. software and we have got the following conclusions.

1) There is significant improvement has been found in seismic performance of building on sloping ground by providing shear walls with different configurations since lateral displacement and member force reduce considerably in building due to provision of shear walls.
2) On analysis based on designed structure with various positional configuration of shear wall with respect to seismic load acting as calculated from STAAD.Pro software shows that, shear wall is best suited with respect to corner positions of the structure for the lateral resisting system.
3) The straight shape (or rectangular) shear walls configuration proves to be better among all configurations for resisting the lateral displacement.
4) It has been found that as the slope increases, displacement also increases.
5) It has been found that shear force and bending moment also increases with the inclination of the slope.
6) It has been found that axial force increases in the buildings with shear wall
7) It has been found that the value of maximum base shear increases in structure with shear wall as compared to structure without shear
8) It is evident that shear walls which are provided from the foundation to the rooftop, are one of the excellent mean for providing earthquake resistant to multistory reinforced buildings.

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