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Structural Behaviour of Building Resting on Sloping Ground Subjected to Dynamic Loading

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ABSTRACT: Framed structures constructed on hill slopes show different structural behavior than that on the plain ground. Since these buildings are unsymmetrical in nature, hence attract large amount of shear forces and torsional moments, ands how unequal distribution due to varying column lengths. Due to lack of space for horizontal expansions, the ultimate height of the structures is increasing day by day, ultimately causing change in their behavioral patterns. Remote areas especially hilly regions in the northern part of India. The selection of a building's configuration often dictated by architectural considerations is perhaps one of the most important aspects of the overall design. It may impose severe limitations on the structure in its role to provide seismic protection. These walls are usually long compared to their height, utilizing in-plane stiffness and acting as a vertically spanning beam to resist lateral forces. Shear walls, usually concrete or masonry; resist lateral forces as a vertical diaphragm through in-plane shear.

The buildings resting on sloping ground in earthquake prone regions are generally irregular, torsional coupled and hence, susceptible to severe damage when affected by earthquake ground motion. The behaviour of buildings during earthquake depends upon the distribution of mass and stiffness in both horizontal and vertical planes of the buildings. Such buildings have mass and stiffness varying along the vertical and horizontal planes, resulting the center of mass and center of rigidity do not coincide on various floors. The short, stiff columns which are on uphill side attracts much higher lateral forces and are lying face down to more damage. Hence, these structures are susceptible to severe damage when affected by earthquake ground motion. To improve the seismic performance of RCC buildings, incorporation of shear wall is one of the best alternatives as suggested by many researchers. According to all above situations this research is also based on G+16 building resting on sloping ground analyze by software E-taabs 2016with short column and shear wall.

I. INTRODUCTION

The development of today's generation in industrialization in developing countries like India, has led migration from rural to urban areas to a large extent which has caused scarcity of land space for horizontal development. Due to lack of space for horizontal expansions, the ultimate height of the structures is increasing day by day, ultimately causing change in their behavioural patterns. Remote areas, especially hilly regions in the northern part of India, which weren't that developed are also reshaping their developments in infrastructures. Consequently, it creates an elevated risk for such structures to be structurally evaluated under dynamic loads such as earthquakes. Also, the response of structures is influenced by many factors viz. Type of structure, materials, configuration of the structure, loads for which it has been designed, philosophy of design adopted, location and topography of the region where the structure is located.





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Figure:01 Typical view of building constructed on slope

The structures constructed on these sloping hills may represent different behavioral patterns. constructing building structures on inclined ground, setback strategy is used. The buildings resting on sloping ground in earthquake prone regions are generally irregular, torsional coupled and hence, susceptible to severe damage when affected by earthquake ground motion. The behaviour of buildings during earthquake depends upon the distribution of mass and stiffness in both horizontal and vertical planes of the buildings.

Such buildings have mass and stiffness varying along the vertical and horizontal planes, resulting the center of mass and center of rigidity do not coincide on various floors, hence they demand torsional analysis, in addition to lateral forces under the action of earthquakes.

II. LITERATURE REVIEW

Literature survey was conducted on the works carried out by earlier researchers whose efforts have been devoted to study comparative analysis for different height of structures. Two different types of slopes the summary and literature survey are discussed below.

Summary of Literature Review

Some of researchers doing their research on two different types of slopes, they are using SAATD PRO and SAP-2000 software for their analysis.

Some of researchers taking only frame structure for analysis on sloping ground with 8 to 10 story of buildings. On sloping grounds study have been done for less inclination such as 10^{0} ,7.5⁰, and 15^{0} degrees. But our research is based on 3 different types of slopes 20^{0} ,30⁰ and 40 degrees with G+15 story with and without shear wall, with and without column at outer periphery.

Gaps found in Literature Review

- 1. The study can be further carried out on the varying slopes or two directional sloped.
- 2. To study seismic response of multi-story building with soil structure interaction resting on sloping ground.
- 3. To study the seismic response of multi-story building with soil structure interaction resting on sloping ground with varying angles or slopes.
- 4. The base of column is assumed to be fixed or hinged in the analysis.
- 5. The contribution of infill walls is considered as non-integral with bare frame.
- 6. Analysis can be done with different soil condition.





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OBJECTIVE

- 1. Find out the Behaviour of Building resting of different types of slopes such as 20,30 and 40 degrees.
- 2. Analyse the model with shear walls at internal areas of structure for 20-, 30- and 40-degree slopes (Base shear, and Story displacement).
- 3. Analyze the model with shear walls at outer periphery for 20,30 and 40 degrees of slopes (Base shear, and Story displacement).

Scope

After studying the literatures and the researches available on this research area, following necessities were realized

- 1. Rapid urbanization and growth in real estate sector has led to an increased demand of high-rise constructions in hilly regions as well.
- 2. Construction of structures on hilly regions will require execution guidelines, bringing this study in the area of active researches.
- 3. High rise structures demand maximum safety, since no much provision for structures on sloping grounds has been suggested by Indian standards, it has become a need to be evaluated for.
- 4. Based on the literature available different structures exhibits varied characteristics, hence it is of an elevated need to assess the structures under different circumstances.

III. METHODOLOGY AND MATERIAL PROPERTIES

Building structures are generally subjected to two types of loads, Static and Dynamic. Static loads are constant while dynamic loads vary with respect to time. In this study we have used ETAAB-2016 for modeling and analysis for G+15 story building with respect to shear walls at outer portion, column at center, with infill walls, and without infill walls.

Seismic Methods of Analysis

Once the structural model has been selected the next step is to perform analysis to determine the seismically induced forces in the structures were considered in accordance with the seismic code 1893-(2002). All the structures were considered to be located in zone IV of India, and were designed for special moment resistance. The importance factor has been considered as 1, and the soil strata supporting the structure are taken as medium soil. The dead and imposed loads acting on the structure were taken according to IS-875. The pressure due to earth soil exerted on the columns was neglected. The structure was analysed for seismic loads with Time history method of analysis.

The details of models have been described in tables below: The properties of materials, structural specifications and the loads contemplated in this study are described in the subsequent tables. ILNS- $20^{\circ} 30^{\circ} 40^{\circ}$ shows inclination at $20^{\circ} 30^{\circ}$ 40° for bare frame. ILSI- $20^{\circ} 30^{\circ} 40^{\circ}$ shows inclination at $20^{\circ} 30^{\circ} 40^{\circ}$ for shear wall in internal area. ILSE- $20^{\circ} 30^{\circ} 40^{\circ}$ shows inclination at $20^{\circ} 30^{\circ} 40^{\circ}$ for shear wall at external periphery.

Designation of the model	Inclination of the slope	Structural specifications
ILNS-20	20°	Bare Frame
ILNS-30	30°	Bare Frame
ILNS-40	40°	Bare Frame
ILSI-20	20°	Shear walls in the internal area
ILSI-30	30°	Shear walls in the internal area

Table 1: Structural Specifications

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ILSI-40	40°	Shear walls in the internal area
ILSE-20	20°	Shear walls on the external periphery
ILSE-30	30°	Shear walls on the external periphery
ILSE-40	40°	Shear walls on the external periphery

Table 2: Material Specification

1.	Grade of concrete	M30
2.	Grade of reinforcing steel	Fe 415
3.	Density of concrete	25 KN/m3
4.	Density of brick masonry	19 KN/m3
5.	Damping ratio	5%

Table 3: Building Geometry

1.	Plan Dimensions	18m X 18m
2.	Height of the structure	48 m
3.	Height of storey	3m
4.	Thickness of Slabs	150 mm
5.	Internal Wall thickness	150 mm
6.	External wall thickness	150 mm
7.	Depth of Foundations	Varied

Table 4: Structural Specifications

1.	Type of sections	R.C.C.
	Sizes of column sections in mm	
2.	Columns (C1)	300X600
	Sizes of beam sections in mm	
3.	Primary Beams	300 X 530

Table 5: Loading

1.	Floor load	3.75 KN/m ²
2.	Live load	3.0 KN/m ²
3.	External wall load	15 KN/m
4.	Internal wall load	15 KN/m
5.	Code for RCC	IS 456 (2000)
6.	Code for Earthquake analysis	IS 1893 (2002)
7.	Zone	IV (severe)
8.	Zone factor (Z)	0.24
9.	Importance factor	1.0





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10.	Moment resisting frame type	SMRF
11.	Response reduction factor	5.0
12.	Site soil type	Medium (II)

IV. MODELLING & ANALYSIS

The Lateral Earthquake Force as per IS 1893 (Part 1): 2016

As specified in the tables all structures are 46 m in height and having slope inclinations 20°, 30°, 40° for a different number of floors. All the seismic specifications were considered in accordance with the seismic code 1893-(2002).



Figure:02 Typical view of ILNS-20

The Lateral Wind Force (Fz) As Per IS 875 (Part 3): 2015

According to the provisions of Bureau of Indian Standards for wind loads, IS 875 (Part 3):2015 dynamic analysis for wind load is suggested for closed buildings with height to minimum lateral dimension ratio of more than 5 or fundamental frequency of the building less than 1 Hz. It is suggested to check for wind induced oscillations and a magnification factor called gust response factor needs to be included in the dynamic effects of the wind. The structures considered here has a height of 42m and minimum lateral width dimension as 18m, which is less than 5. Still as the structure as considered for a high wind flow area. The authors intentionally analyzed the structure for wind forces for the sake of research work. All the parameters were calculated according to IS-875 part-III (2015).

Exposure and Pressure Coeffic	cients	Wind Coefficients		
 Exposure from Extents or 	f Rigid Diaphragms	Wind Speed, Vb (m/s)	50.	
Exposure from Area Obje	ects	Terrain Category	3	~
Include Frame Object	s ts (Open Structure)	Importance Factor	1.15	
Wind Exposure Parameters		Risk Coefficient (k1 Factor)	1.07	
Wind Direction Angle		Topography (k3 Factor)	1.09	
Windward Coeff, Cp Leeward Coeff, Cp				
Windward Coeff, Cp Leeward Coeff, Cp Modify/Show Expo	sure Widths			
Windward Coeff, Cp Leeward Coeff, Cp Modify/Show Expo	sure Widths			
Modify/Show Expo Exposure Height	sure Widths		_	
Windward Coeff, Cp Leeward Coeff, Cp Modify/Show Expo Exposure Height Program Calculated User Specified	sure Widths	ОК		

Figure 03: Wind Parameter Definition





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V. RESULTS

One of the most significant parameters for measuring the influence of seismic forces on the structure is base shear. it can be seen that the structures resting on steep slopes attracts lower amount of inertia force in the X-direction.





All the structures analysed were studied for the maximum displacements they reflected. The respective displacements have been described in the subsequent figures. From the results it was seen that as the angle of slope moved towards steep the displacements also increased to a considerable extent. Secondly it was seen that, the structures with shear walls on its exterior periphery due to their elevated rigid nature reflected very less displacements. The structures with shear walls on the interior part of the structure reflected higher displacement values than the previously described configuration but were again less than the structures with no shear walls.





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Figure 06: Storey Displacement in mm (20°)



Figure 07: Storey Displacement in mm (30°)



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VI. CONCLUSIONS

- 1. Base Shear decreases as the slope inclination goes on increasing.
- 2. ILSE structures compared to ILSI and ILNS attracts minimum inertia forces.
- 3. Unexpectedly providing shear walls inside the periphery of the structure near the core increases time period hence becomes an unsuitable location of placing shear walls in the structures with sloping bases.
- 4. The structure with ILSE configuration represents lowest values of time period exhibiting the best suit for considerably better performance of such structures.
- 5. Mode-3 as well as mode-4 amongst the seismic modes exhibits the most critical movement of the structure which may prove to be fatal.
- 6. The external columns on the extreme upstream and downstream of the slope must be provided with an additional area to be torsion resistant.
- 7. It was seen from the results that as the inclination of the ground went from 20 to 30, the structures attracted lesser inertia forces, whereas when the inclination went on 40, the magnitude of the inertia forces was almost same to that attracted by the structure resting on 30 slopes.
- 8. Secondly, the ILSI structures were subjected to larger forces at its base when the structures were resting on 30- and 40-degree slopes, whereas ILNS attracted larger shears in case of 20-degree inclination.
- 9. The time period was largely influenced by the degree of slope in an inversed manner, the time period went down as the slope inclination went higher.
- 10. The structure proved to behave in a flexible manner when the shear walls were provided in the internal area (ILSI) whereas the structures with external shear walls (ILSE) proved to behave as a rigid frame.
- 11. The maximum displacements recorded in the structures were for the structures resting on 40-degree slopes, followed by structures on 20-degree slopes and was optimum for the structures resting on 30 degrees.

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