Seismic Performance of the Building Resting on Sloping Ground with Shear Wall

Mr. Mohammed Waaez Ahmed
M.E. Student, Sanmati Engineering College, Washim.
waaez.ahmed10@gmail.com

Prof. M Salman Shaikh,
Asst. Professor in
Civil Engineering Department
Sanmati Engineering College, Washim.

Abstract

The behavior of buildings on sloping ground differs from those on flat ground. Buildings in hilly areas that are prone to earthquakes are often irregular and not symmetrical, making them vulnerable to serious damage during an earthquake. Therefore, it is crucial to consider the effects of earthquakes and design buildings that can resist them for safety reasons. Shear walls are commonly used to resist lateral loads in multistory concrete buildings for better seismic performance. They provide significant strength and stiffness in their orientation direction, reducing the building's lateral movement. This study aims to analyze the seismic performance of buildings on sloping ground with and without shear walls using linear time history analysis in structural engineering software SAP2000.

Keywords: *Seismic Performance, Shear wall, Critical column, Linear time History Analysis.*

1. Introduction:

The economic growth and rapid urbanization in hilly regions have led to a surge in real estate development. This has resulted in a sharp increase in population density in the area, sparking a strong demand for the construction of multi-storey buildings on hill slopes in and around cities. Traditionally, adobe burnt brick, stone masonry, and dressed stone masonry buildings are erected on level ground in hilly regions. However, the limited availability of level land in hilly areas has created a pressing need to build on hill slopes. Therefore, constructing multi-storey Reinforced Concrete Frame buildings on hill slopes is the most viable option to meet the rising demand for residential and commercial spaces.

Buildings situated on hill slopes in earthquake-prone areas are typically irregular and torsionally coupled, leaving them vulnerable to severe damage during earthquakes. These structures exhibit varying mass and stiffness along the vertical and horizontal planes, leading to a misalignment between the center of mass and the center of rigidity across different floors. As a result, they require torsional analysis and need to account for lateral forces during earthquakes. The asymmetric nature of these buildings demands meticulous attention in analysis and design. Analyzing hill buildings differs from analyzing buildings on level ground because the columns of hill buildings rest at different levels on the slope. Consequently, the shorter columns bear more forces and are more susceptible to damage during earthquakes.

Shear Wall:

Shear walls are one of the most commonly used lateral load-resisting systems. They have high in-plane stiffness and strength, allowing them to resist large horizontal loads and support gravity loads. Well-designed and detailed reinforced concrete shear walls can provide the required lateral stiffness, strength, and ductility for resisting seismic loads in a building. Reinforced concrete walls with boundary elements have substantially higher bending strength and horizontal shear force-carrying capacity.

Shear walls are easy to construct because reinforcement detailing is relatively straightforward and easily implemented on-site. They must possess the ability to dissipate energy imparted to them by earthquakes through hysteretic behavior.For buildings on a hill slope, the height of columns below the plinth level is not the same, which can affect the building's performance during an earthquake. To improve the seismic performance of buildings, shear walls play a very important role. Therefore, there is a need to study the shape and positioning of shear walls to understand their impact on the seismic performance of buildings situated on a hill slope.

Khadiranaikar and Masali (2014) reviewed literature related to studies on the seismic behavior of buildings resting on a hill slope. They found that buildings on a hill slope experience higher displacement and base shear compared to buildings on plain ground. Additionally, short columns attract more forces and undergo more damage when subjected to earthquake forces. The presence of infill walls and shear walls influence the behavior of the structure by reducing storey displacement and drifts considerably, but it may increase the base shear. Therefore, special attention should be given in design to reduce base shear. The study also concluded that a greater number of bays are better under seismic conditions, as the number of bays increases, the time period and top storey displacement decreases in hill slope buildings.

S.M. Nagargoje and K.S. Sable (2012) studied the seismic performance of multi-storied buildings resting on sloping ground. They performed three-dimensional space frame analysis for different building configurations such as Step back, Step back-Setback, Setback. The seismic analysis of all buildings was carried out using the Seismic coefficient method and the dynamic response of these buildings in terms of base shear and top floor displacement was presented and compared within the considered configurations as well as with other configurations. A suitable configuration of a building to be used in a hilly area was suggested at the end.

B.G. Birajdar, S.S. Nalawade (2005) carried out seismic analysis of buildings resting on sloping ground. They performed 3-D analysis including torsional effect using the response spectrum method. The dynamic response properties such as fundamental time period, top storey displacement, and the base shear action induced in columns were studied with reference to the suitability of a building configuration on sloping ground. It was observed that the Step back-Setback configuration has favorable seismic performance.

Robert Tremblay and Laure Poncet (2004) studied the seismic performance of concentrically braced steel frames in multi-story buildings with mass irregularity. A reference regular structure was also considered for comparison. The design of each structure was performed according to the proposed 2005 National Building Code of Canada NBCC provisions using two analysis methods: The equivalent static force procedure and the response spectrum analysis method. Although severe, the mass irregularity conditions considered in this study were found to have a limited negative impact on the seismic performance of the structures designed with the static analysis method.

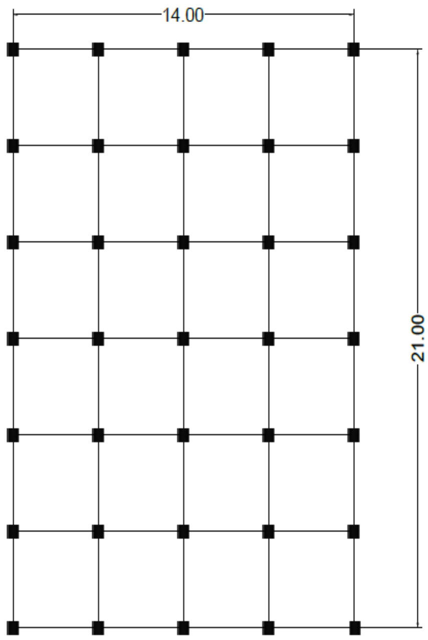
Objective:

The study aims to achieve the following objectives:
1. Investigate the seismic performance of a building located on sloping ground without shear walls.
2. Examine the seismic performance of a building situated on sloping ground with shear walls at all corners and only at two corners of the long column.

3.

scription of the Building:

The model consists of a G+4 storey RCC building with four bays in the X-direction and six bays in the Y-direction; each bay has a width of 3.5m. The storey height for each floor and the plinth height are set at 3m and 1.5m, respectively. The longitudinal and transverse beam sizes are 0.30m x 0.5m. The column size is 0.45m x 0.45m, and the slab thickness is 0.120m. A parapet wall, 1m in height, is considered. The shear wall thickness is 0.150m. The models are analyzed on sloping ground with slopes of 20° and 30° in the horizontal direction. The frames considered in the present study on sloping ground are depicted in Fig. 1 and Fig. 2. The concrete grade used is M20, and the steel grade is Fe



415.

Fig.1. Plan of the building showing column positions

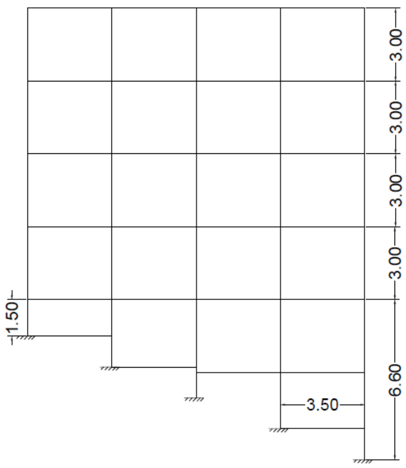


Fig. 2. Elevation of building on 20⁰ slope

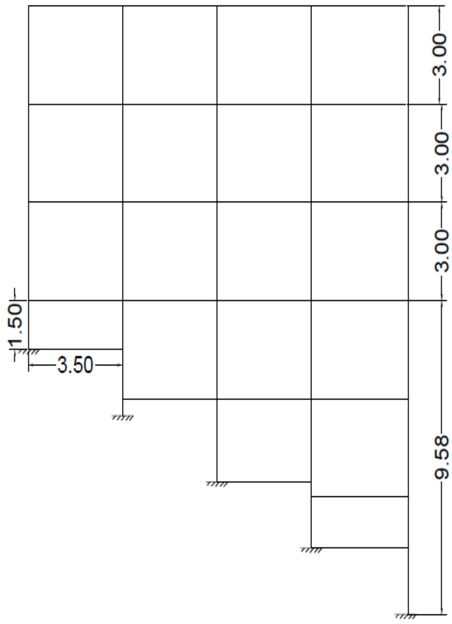


Fig. 3. Elevation of building on 30⁰ slope

3. Loads:

1)Dead Loads:

- Superimposed dead load (floor finishes or waterproofing) for all floors = 1.875 kN/m2
- External wall load (230mm thick) = 13.8 kN/m
- Internal wall load (115 mm thick) = 6.9 kN/m
- Parapet load = 2.3 kN/m

2)Live Loads:

- Live load on floor = 4 kN/m2
- Live load on roof = 1.5 kN/m2

3)Earthquake Load:

Imperial Valley Earthquake record is applied in the X-Direction.

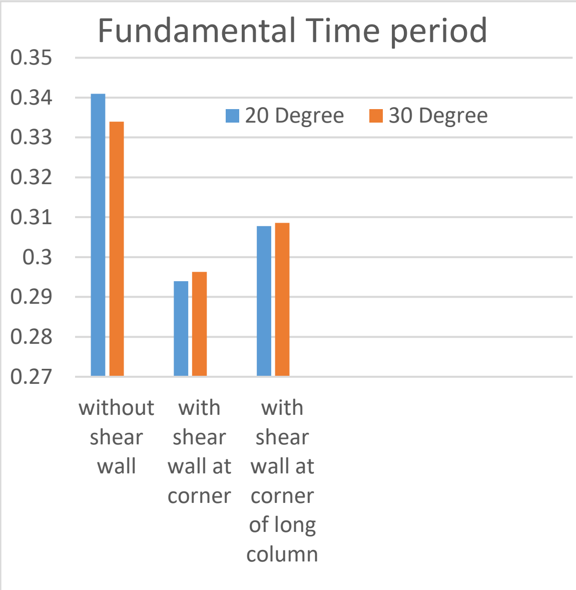
4)Method of Analysis:

Dynamic analysis of the building is done using finite element software SAP-2000. 3D analysis has been carried out by the time history method for this study. The dynamic response of these buildings in terms of base shear, fundamental time period, and storey drift is presented and compared within the considered configuration of shear wall as well as with the model without shear wall on sloping ground. In the end, the efficient position of the shear wall configuration to be used is suggested. Damping was considered for all modes of vibration at five percent.

Results and Discussion:

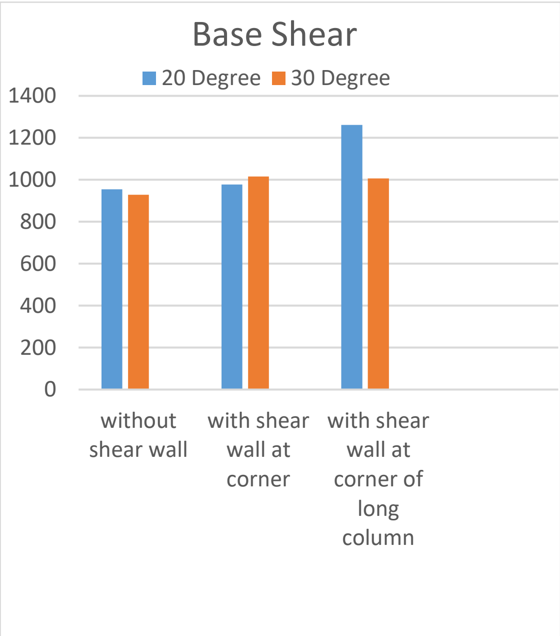
5.1 Fundamental Time Period:

Fundamental time period of the building is reduced after the provision of shear wall as shown in the graph below.



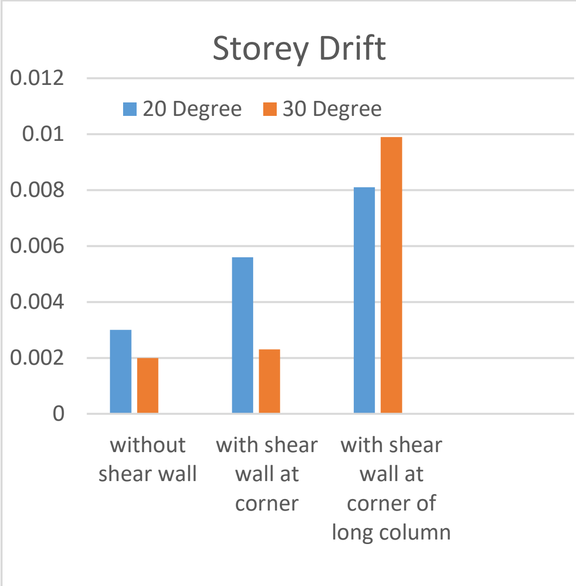
5.2 Base Shear:

Base shear of the building is increased after the provision of shear wall.



5.3 Storey Drift:

Storey Drift of the bottom storey is increased with the shear wall inclusion as well as slope of the ground as shown in graph below.



6. Conclusions:

The base shear of the building increases with the incorporation of shear walls. The storey drift of the bottom storey of the building also increases with the provision of shear walls. The fundamental time period is reduced by the provision of shear walls, resulting in a significant improvement in the seismic performance of the building on sloping ground. The shear walls at all four corners prove to be better for resisting lateral forces during an earthquake when compared with shear walls at only two corners of the long column.

References:

[1] SandipDoijad and SurekhaBhalchandra, (2015) "Seismic performance of RC buildings resting on plain and sloping ground with different configurations of shear walls", *journal of civil engineering and environmental technology*, ISSN: 2349-8404, volume-2, KrishiSanskriti Publications.

[2] Khadiranaikar R. B. and ArifMasai(2014), "Seismic Analysis of Buildings
Resting on Sloping Ground-A Review", *Journal of*

Volume: 08 Issue: 07 | July - 2024 SJIF Rating: 8.448 ISSN: 2582-3930

Advances in Structural Engineering, Springer.

[3] Nagargoje. S.M. and Sable. K.S. (2012) "Seismic performance of multistoried building on sloping ground", *Elixir international Journal*, ISSN-2229-712X.

[4] Birajdar B. G. and Nalawade S. S. (2004),"Seismic Analysis of Buildings resting on sloping ground", *13th world conference on Earthquake Engineering, Vancouver, B.C. Canada.*

[5] Robert Tremblay and Laure Poncet (2005), "Seismic Performance of Concentrically Braced Steel Frames in Multistory Buildings with Mass Irregularity" *Journal of structural engineering*, ASCE