# Effect of irregular building resting on sloping ground with soil structure interaction

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***Abstract*—Structures located on inclined terrain were evaluated in relation to seismic loads, taking into account the influence of soil-structure interaction (SSI). The response of the structure is primarily influenced by the forces arising from soil-structure interaction, which affect the integrity of the structure. In this research G +20 irregular building is analyzed for the seismic behavior examining the irregular building resting on sloping ground under varying slope angles i.e.$15^0$, $20^0$, $25^0$ and different type of soil strata like soft, medium, hard. The time history analysis is a computational simulation technique utilized to forecast the dynamic behaviour of structures. The seismic analysis of irregular building is performed by using non-linear time history method as per IS 1893-2016. Through this analysis, the response parameters such as base shear, story deflection, story drift, and story shear were calculated using SAP 2000 software. The findings of this research displace that plan irregular multi story building resting on medium soil strata under $15^{\circ}$ slope angle has given less deformation as compare to hard soil strata and soft soil strata of other sloping angles.**

***Index Terms*—irregular building, non-linear time history, sloping angles, soil structure interaction.**

## I. INTRODUCTION

Due to the growing population and swift urban development, there has been a shortage of level ground. As a result, buildings are being constructed on hilly terrain. Building in such areas is more challenging than in flat regions. Certain hilly areas around the world are particularly susceptible to seismic activity, and in India, the northern and northeastern regions feature extensive sloping land where the construction of reinforced concrete (RC) buildings is common. Earthquakes induce ground shaking, and structures placed on slopes will feel the movement at their foundations. Although the base of the structure moves with the ground, the roof tends to remain in its original position. However, since the walls and columns are linked to the roof, they pull the roof along with them. [1] In India, there are currently no regulations or guidelines governing construction on sloping terrain. Nevertheless, landslides pose a significant natural risk globally, with dangers similar to those of earthquakes. A rapid displacement of a substantial mass of earth can lead to considerable damage to buildings, endangering lives. Furthermore, the increasing population in various Indian cities has spurred the demand for multi-story buildings. Additionally, the trend towards developing on sloping land (due to landslide risks) is growing, primarily because of the lack of available flat land for construction. However, several studies have emerged recently in this domain. [2]

Buildings constructed on sloped terrain have a distinct design compared to those built on flat land. As a result, structures on hilly surfaces exhibit irregularities both in vertical and horizontal alignment, which can make them more susceptible to significant damage during seismic events. The columns on the uphill side, which are shorter and stiffer, encounter much higher lateral forces, raising the likelihood of damage. According to IS 1893: (part 1)2016, different configurations of vertically irregular buildings have been specified. [3]

### A Soil Structure Interaction

Soil-structure interaction refers to the way the foundation material influences the behavior of a building. In seismic evaluations, this may be neglected for constructions situated on rock or rock-like materials. The study of soil-structure interaction (SSI)

is a crucial element of earthquake engineering. It is important to recognize that the response of a structure is mainly determined by the soil-structure interaction forces that affect it. Free-field ground motion signifies the movement detected on the surface of the soil without any structural influence. A structure's response during an earthquake is significantly affected by the interactions between three connected systems: the structure itself, the foundation, and the soil below. Soil-structure interaction analysis involves assessing the overall response of these three components in relation to particular ground motion. Soil-structure interaction can be understood as the process in which the soil's response impacts the movement of the structure, and at the same time, the movement of the structure affects the soil's behavior. This phenomenon shows that the displacements of both the structure and the ground are not solely reliant on one another. Interaction forces between the soil and the structure are generally present for every building, though they do not always influence the soil's movement in every situation

B *Non- Linear Time History Method*

The time history analysis method, when employed, will rely on a suitable ground motion and should adhere to established dynamics principles. This method examines the dynamic behaviour of the structure at each time increment as its foundation experiences a specific ground motion time history. Time history analysis is a computational simulation technique used to forecast the dynamic response of structures by incorporating real-time varying loads. In contrast to simplified static analysis, which presumes a constant and instantaneous application of loads, time history analysis considers the changing nature of forces over time.

## II. LITERATURE REVIEW

Anjeet Singh Chauhan, Rajiv Banerjee, (2021) "Seismic Response of Irregular Building on Sloping Ground".

The assessment and modeling of the Step Back building are performed using Etab software, following the guidelines of IS 1893:2016, to evaluate the building's dynamic response features, including mode period, base shear, story deflection, story drift, and story shear, while also recognizing the frame's susceptibility to structural irregularities on inclined terrain.. [4]

Ajit C. Suryawanshi, V. M. Bogar, (2019) "Seismic Analysis of Building Resting on Sloping Ground with Soil Structure Interaction".

This research evaluates the behavior of structures using response spectrum analysis. G+19 structures are examined in ETABS 2016, incorporating both scenarios of considering and not considering soil-structure interaction. The calculated values for parameters like displacement, story drift, story shear, and base shear are then compared. [5]

Ravindra Navale, Pramod Kharmale, (2017) "Analysis of Unsymmetrical Building Resting on Sloping Ground by Dividing In 2D Frame".

This study investigates the effects of sloped terrain on structures by utilizing 2-D frames in ETABS. It considers different floor heights and bay configurations in both the x and y directions. The research compares buildings on level ground to those on inclined ground by showcasing graphs of bending moments. The results highlight the simultaneous impacts on both short and tall columns. [6].

Qudsia Bhavikatti, Swapnil B. Cholekar, (2017) "Soil structure interaction effect for a building resting on sloping ground including infill subjected to seismic analysis".

This investigation conducts a seismic assessment of a building situated on sloped ground with inclines of 16, 20, and 24 degrees, taking into account the impacts of soil-structure interaction. The effect of infill on the structure has been factored into the evaluation. A linear seismic analysis is conducted in line with IS-1893:2002, utilizing ETABS 2003 software, and the response parameters, such as base shear, fundamental time period, storey displacement, and axial force, are analyzed for both fixed and flexible base structures. [7]

## III. OBJECTIVES

*A Research Objective*

The objectives of research are as follows:

1. To study the behavior of multistory plan irregular building resting on different soil strata interaction.
2. To carry out dynamic analysis of plan irregular multistory building using nonlinear time history method.

## IV. ANALYSIS

*A. Geometrical details of plan irregular multistory building resting on sloping ground.*

The geometrical details considered for the analysis of plan irregular multistory building. (See Table 1).

Table 1. geometrical details of plan irregular multistory building.

| PARAMETERS | PARTICULARS |
|---|---|
| Plan dimension | 45 x 45 m |
| Number of story | G+20 |
| Number of bays in x direction | 10 |
| Number of bays in y direction | 10 |
| Height of each floor | 3 m |
| Grade of Concrete | M 30 |
| Grade of Steel_Fe | 500 |
| Column size | 300 x 900 mm |
| Beam size | 300 x 600 mm |
| Slab Thickness | 150 mm |
| Seismic Zone | V |

*B. Modeling and analysis of plan irregular multistory building.*

Modelling and analysis of irregular building is done by SAP 2000 software. Analysis of G+20 story irregular building with different sloping angles $15^0$, $20^0$, $25^0$ and different soil strata soft, medium, hard. Various models are prepared by using nonlinear time history method in Sap 2000 software for calculating optimum sloping angle and soil strata. Total 9 model of G + 20 irregular building were developed for different slope angles like $15^0$ slope angle (see Fig. 1 a), $20^0$ slope angle (see Fig. 1 b), $25^0$ slope angle (see Fig. 1 c) considering soft, medium, hard soil structure interaction.

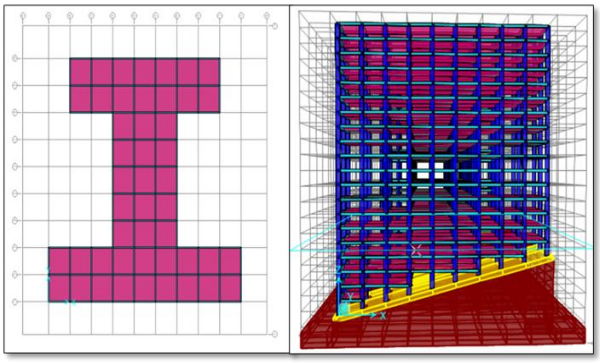

Fig. 1a ($15^0$ Slope Angle with Soft, Medium, Hard Soil Structure Interaction)

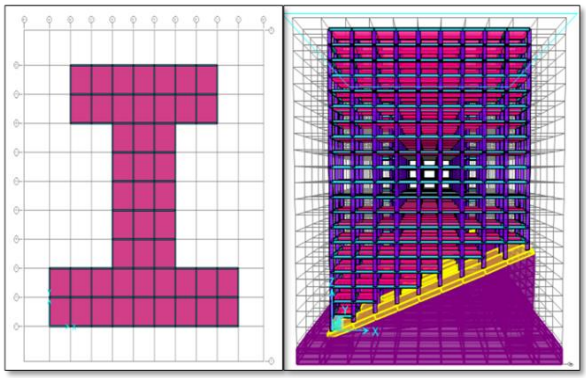

Fig. 1b ($20^0$ Slope Angle with Soft, Medium, Hard Soil Structure Interaction)

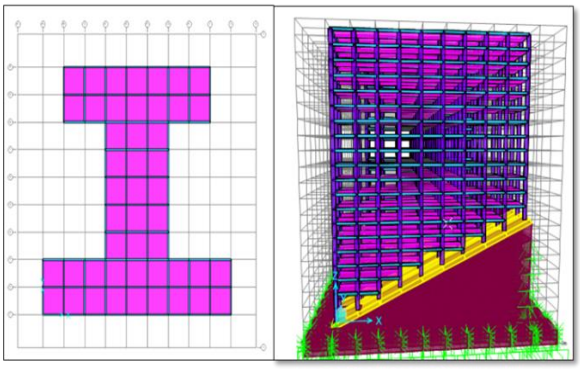

Fig. 1c ($25^0$ Slope Angle with Soft, Medium, Hard Soil Structure Interaction)

## V. RESULT AND DISCUSSION

The analysis of the soil-structure interaction for an irregular multistory building situated on sloped terrain is conducted using a non-linear time-history approach across various models, taking into account multiple parameters. The study compares the effects of different slope angles while also considering the interactions between the soil and the structure. This research examines how story displacement, base shear, and story drift change in relation to the variations in different sloped ground conditions.

*A Base shear in X- Direction*

Base shear denotes the highest expected lateral force that will act on the building's foundation due to seismic occurrences. As per the result base shear in x direction (Fig. 2a), $20^0$ slope angle given the maximum base shear in medium soil strata compare to $15^0$ slope angle and $25^0$ slope angles.

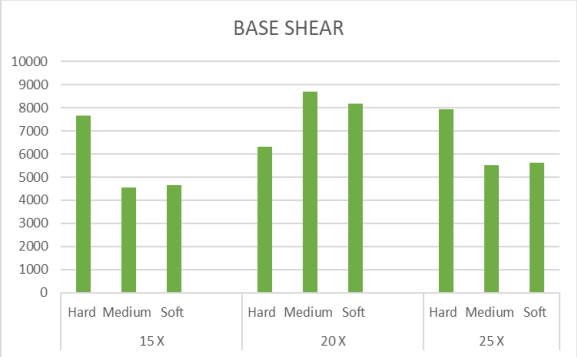


Fig. 2a Base Shear In X-Direction

*B Base shear in Y- Direction*

As per the result base shear in y direction (Fig. 2b), $20^0$ slope angle given the maximum base shear in soft soil strata compare to $15^0$ slope angle and $25^0$ slope angles.

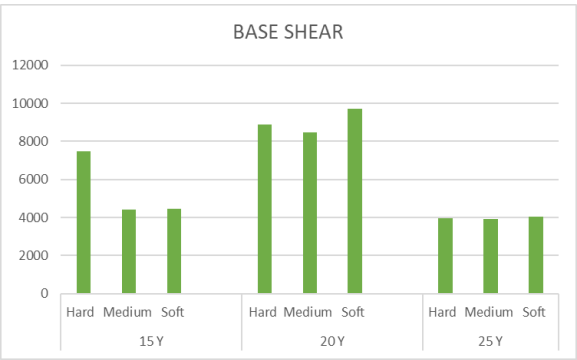


Fig. 2b Base Shear In Y-Direction

*C Story Drift of $15^0$ Slope Angle*

Story drift of $15^0$ slope angle is major at $8^{th}$ no. story of building for hard and soft soil strata and major at $7^{th}$ no. story of building for medium soil strata. (Fig.3a)

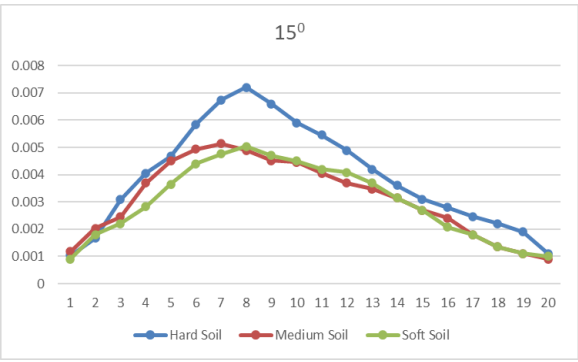


Fig. 3a Story Drift of $15^0$ Slope Angle

*D Story Drift of $20^0$ Slope Angle*

Story drift of $20^0$ slope angle is major at $8^{th}$ no. story of building for hard and medium soil strata and major at $9^{th}$ no. story of building for soft soil strata. (Fig.3b)

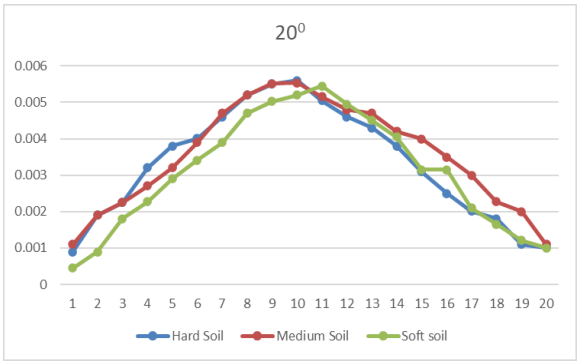


Fig. 3b Story Drift of $20^0$ Slope Angle

*D Story Drift of $25^0$ Slope Angle*

Story drift of $25^0$ slope angle is major at $11^{th}$ no. story of building for hard soil strata and major at $10^{th}$ no. story of building for soft soil strata and medium soil strata. (Fig.3c)

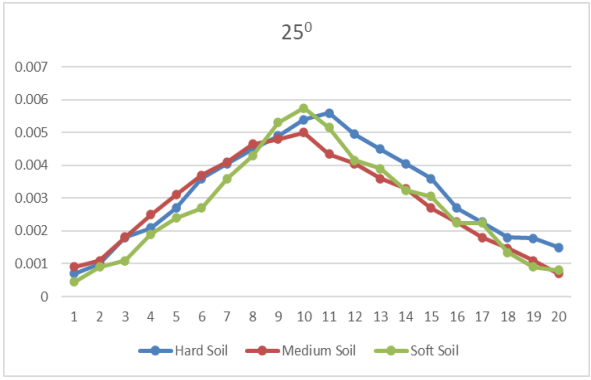


Fig. 3c Story Drift of $25^0$ Slope Angle

*E Story Displacement of $15^0$ Slope Angle*

Story displacement is major at $20^{th}$ story height of building for soft soil 0.08775 mm, medium soil 0.06075 mm and hard soil 0.06075 mm. (Fig.4a)

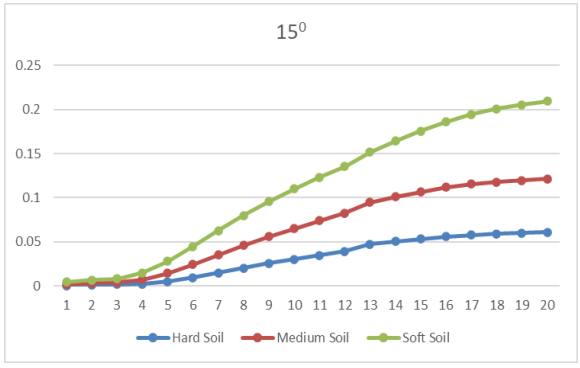


Fig. 4a Story Displacement of $15^0$ Slope Angle

*F Story Displacement of $20^0$ Slope Angle*

Story displacement is major at 20th story height of building for soft soil 0.07155 mm, medium soil 0.06345 mm and hard soil 0.06345 mm. (Fig.4b)

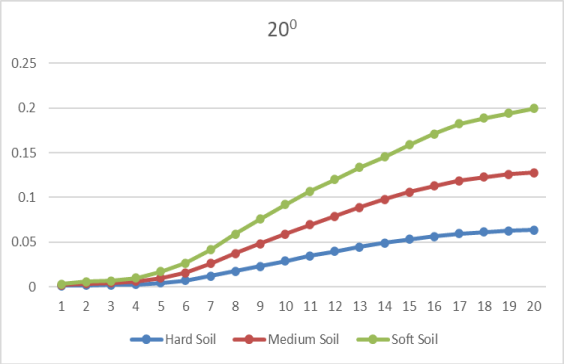


Fig. 4b Story Displacement of $20^0$ Slope Angle

*G Story Displacement of $25^0$ Slope Angle*

Story displacement is major at 20th story height of building for soft soil 0.06255 mm, medium soil 0.0504 mm and hard soil 0.0504 mm. (Fig.4c)

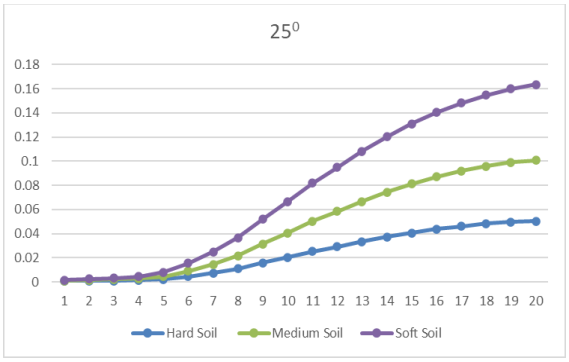


Fig. 4c Story Displacement of $25^0$ Slope Angle

## VI. CONCLUSION

as per the above results of plan irregular multistory building resting on sloping ground It has been concluded that,

1] Plan irregular multi story building resting on medium soil strata under 15˚ slope angle has given less deformation as compare to hard soil strata and soft soil strata.

2] Plan irregular multi story building resting on hard soil strata under 20˚ slope angle has given less deformation as compare to medium soil strata and soft soil strata.

3] Plan irregular multi story building resting on soft soil strata under 25˚ slope angle has given more deformation as compare to and hard soil strata medium soil strata.

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