

# Seismic Analysis of RCC Building Resting on Sloping Ground Adjacent to Deep Excavation

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**Abstract** - Excavations for road construction, mining, building foundation, tunneling has become more common in urban areas. Not only in urban areas, even in hilly regions there may be a situation where excavation becomes necessary for any construction work. These kinds of deep excavations induce more displacement on the adjacent structures. If the building or structure lies on a sloping ground, the effect of slopes also contributes to the displacement of structure which in turn may cause failure of the structure.

In the present study, 2D seismic analysis by response spectrum method is carried out to know the seismic behavior of a RCC building resting on sloped ground adjacent to deep excavation using SAP 2000 software. Building models are analyzed by considering it to be resting on medium and soft soil. The results of the analysis in terms of displacement are obtained and displacement values are compared for building on medium soil and soft soil.

**Key Words:** Deep Excavation, RCC building, Sloping ground, Response spectrum method, 2D Analysis, SAP 2000, Displacement

## 1. INTRODUCTION

Excavations are done for various purposes which include excavating soil for construction of footing, tunnels, road construction, bridges, mining and so on. Excavation is of the following types

- Shallow excavation: Excavation which has depth less than 1.5m.
- Deep excavation: Excavation with depth above 4.5m

Deep excavations in urban areas can be considered as a serious issue. Due to deep excavations there is an adverse effect on adjacent structures. Since there is a limited space available in urban areas, in addition to safety measures taken for the construction site it is also important to consider safety of the bordering buildings and structures. Damage caused on buildings resting on sloping ground due to seismic load is very high compared to buildings on flat surface as there are different levels at which columns are placed, this may cause cracks in columns which in turn damage the complete structure. The effect of earthquake on buildings become more vulnerable when there is excavation next to it with the building resting on a sloping ground. In addition to this, variation in soil properties also contributes

to the behavior of building. Soil properties play an important role in the performance of structure, buildings on hard soil which has high internal strength are prone to less damage in comparison to buildings on medium and soft soil whose internal strength differ from medium to low respectively.

Bearing capacity of soil also gets reduced if there is any nearby excavation. Due to the presence of adjacent excavation there may be reduction in ultimate bearing capacity of the soil which causes failure of foundation.

Terzaghi's bearing capacity equation:

$$q_{ult} = cN_c s_c + q N_q + 0.5\gamma N_{ys}$$

There is a loss of ultimate bearing capacity if any excavation is present nearby. Hence the equation can be written as

$$q_{ult} = cN_c s_c + 0.5\gamma N_{ys}$$



Fig -1: Deep excavation for basement

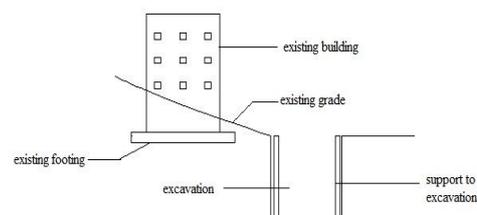


Fig -2: Building resting on sloped ground adjacent to excavation

### 1.1 Excavation support system

Excavation supports are used to keep the sides of deep excavation stable, and they help in avoiding the damage to the adjacent structures and utilities caused by deep excavation. In the present study, sheet pile is used as the excavation support.

### 1.2 Objectives

The main objective of this study is as follows

- Inquest the effect of important parameters affecting the behaviour of a building such as distance of excavation from the building, depth of excavation and properties of the soil.
- Compare the behaviour of building due to excavation of soil with different properties.
- To study the behaviour of building to excavation without and with supporting system.

## 2. METHODOLOGY

Behavior of a (G+9) storey building resting on sloping ground adjacent to deep excavation is analyzed and its response is studied by response spectrum method using SAP2000 software. Analysis is done for the building model on medium and soft soil with adjacent excavation with varying distance of 1m, 2m and 3m from the building and of depth 6m. Model parameters are defined in Table -1. Building adjacent to unsupported and supported excavation is shown in figure 3 and 4 respectively.

Table -1: Model description

Number of stories	G+9
Floor height	3m
Grade of concrete	M25 for beams M30 for columns
Grade of steel	Fe 550
Beam size	0.2mX0.6m
Column size	0.2Mx0.45m
Footing size	2mX1m
Live load	3kN/m <sup>2</sup>
Weight of floor finish	2kN/m <sup>2</sup>
Soil type	Medium soil(II) Soft soil(III)
Poisson's ratio( $\mu$ )	0.25 for medium soil 0.2 for soft soil
Modulus of elasticity(E)	Medium soil- 17250kN/m <sup>2</sup> Soft soil- 10350kN/m <sup>2</sup>
Weight per unit volume	Medium soil- 18kN/m <sup>3</sup> Soft soil- 16kN/m <sup>2</sup>
Slope	1:4
Seismic zone	V
Response reduction factor	3

Importance factor	1
Damping ratio	5%

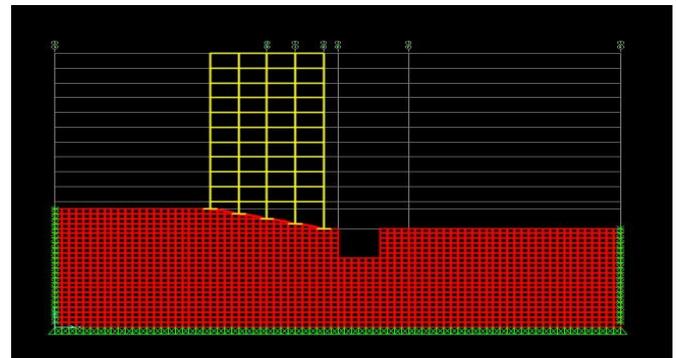


Fig -3: Building with adjacent excavation 1m distance, 6m depth

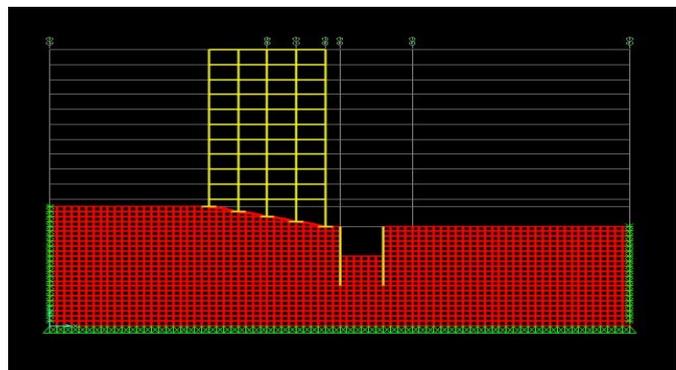


Fig -4: Building with adjacent excavation supported by sheet pile

## 3. RESULTS AND DISCUSSION

Comparative study is carried out with respect to top storey displacement of building with adjacent unsupported and supported excavation in medium and soft soil.

### 3.1: Top storey displacement

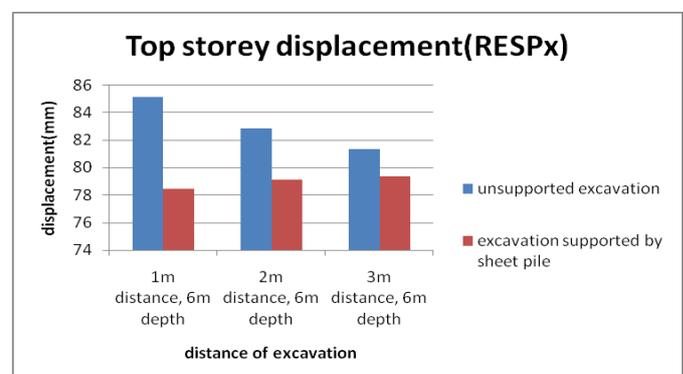
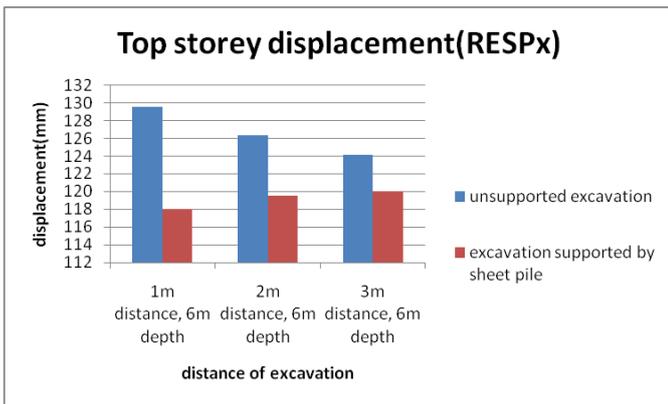
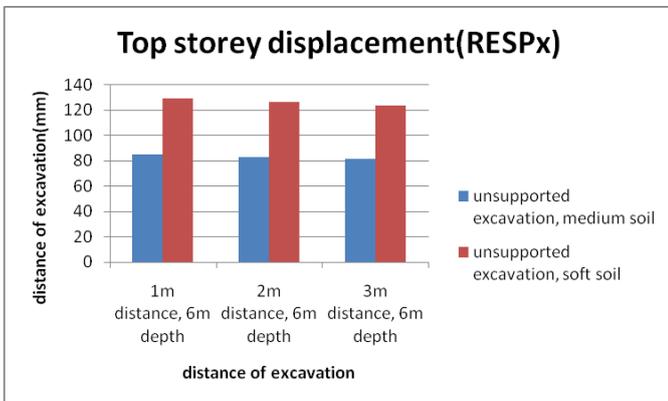


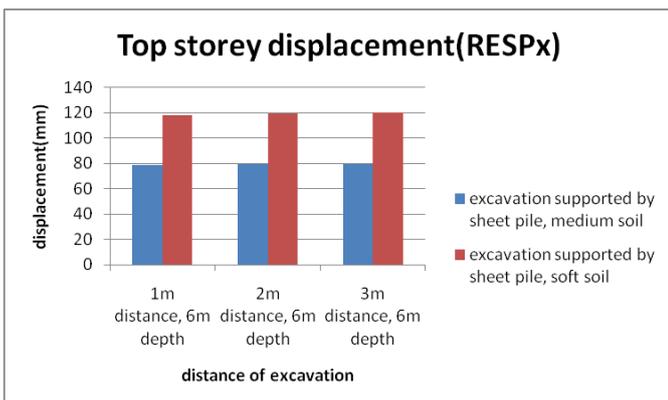
Chart -1: Comparative graph for top storey displacement of building resting on medium soil with adjacent unsupported and supported excavation



**Chart -2:** Comparative graph for top storey displacement of building resting on soft soil with adjacent unsupported and supported excavation



**Chart -3:** Comparative graph for top storey displacement of building resting on medium soil and soft with unsupported excavation



**Chart -4:** Comparative graph for top storey displacement of building resting on medium soil and soft soil adjacent to excavation supported by sheet pile

#### 4. CONCLUSIONS

- 1) Displacement of the building gets reduced as the distance between excavation and the building increases i.e. the building gets displaced more when excavation is very near to it. In this study, we can observe that displacement is more when excavation

of 6m depth is at a distance of 1m from the building and reduced as the distance is increased to 2m and 3m.

- 2) In this study, displacement of building is also computed when excavation is supported by sheet pile and comparison is made for displacement induced by unsupported excavation and displaced induced by excavation supported by sheet pile (for depth of 6m and 1m away). Unsupported excavation induces higher displacement.
- 3) It can be observed that, when excavation is supported by sheet pile, the building is more stable when the support system is near the building since it induces less displacement.
- 4) Displacement is more for building resting on soft soil than building resting on medium soil.

#### 4.1 Scope for future work

- This project can be carried out considering different seismic zones.
- Analysis can be carried out on building resting on layered soil.
- 3D analysis can be carried out.

#### REFERENCES

- [1] Horn-Da Lin, Hoang-Minh Truong, Huu-Phuoc Dang, and Cheng-Cheng Chen, "Assessment of 3D Excavation and Adjacent Building's Responses with Consideration of Excavation-Structure Interaction", Tunnelling and Underground Construction, ASCE, 2014.
- [2] Navid Yeganeh, Jafar Bolouri Bazaz and Ali Akhtarpour, "Seismic analysis of the soil-structure interaction for a high rise building adjacent to deep excavation", Soil Dynamics and Earthquake Engineering, ELSEVIER, pp. (149-170), 2015.
- [3] Ma'ruf M. F. and Darjanto H, "Excavation Adjacent To The Existing Building: A Study Case", Proceedings of the 2nd Makassar International Conference on Civil Engineering, Makassar, Indonesia, 2015.
- [4] Salajka V, Kalab Z, Kala J and Hradil P, "Response of the residential building structure on load technical seismicity due to mining activity", World Academy of Science, Vol 50, pp. 214-222 , 2009.
- [5] Suresh and Jyothi, "Response of Reinforced Concrete Buildings Close To Deep Excavation", International Journal of Civil and Structural

Engineering Research, ISSN: 2348-7607, Vol. 3, Issue 1, pp: (185-189), 2015.

- [6] Mo Y.L. and Hwang J.M., "Seismic response of reinforced concrete buildings close to deep excavation", Computer methods in applied mechanics and engineering , Vol 145 , pp. 117-134, 1997.
- [7] Bureau of Indian Standards: IS-1893, part 1 (2002), "Criteria for earthquake resistant design of structures: Part 1 General provisions and buildings", New Delhi, India.
- [8] "Advanced Soil mechanics" by Braja M.Das.
- [9] "Earthquake Resistant Design Of Structures" by S.K. Duggal
- [10] IS 875 Part 1 " unit weight of materials "
- [11] IS 875 Part 2 " Imposed loads on floors due to use and occupancy"