

Assessment and Management of Adjacent Excavations near Existing Buildings using PLAXIS 2D- A Review

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Abstract: Urbanization and geographical restrictions make it necessary to excavate deep holes for high-rise basements and underground facilities. But excavating near buildings makes the ground move sideways, relaxes the soil, and causes different parts of the building to settle. This study gathers new information on how deep excavation and stabilization affect pile foundations and buildings that already exist. The research says that diaphragm walls, continuous piles, and anchored sheet pile walls can make safe excavation depths greater than 25 meters and reduce wall movements to 0.1% to 0.3%. A comprehensive evaluation of Finite Element Method (FEM) software (e.g., PLAXIS 2D and 3D) reveals that numerical simulations consistently replicate horizontal displacement profiles of retaining walls; yet they frequently yield conservative, elevated settlement estimates compared to field measurements. The research indicates that pile deflection reduces with increasing diameter and length, whereas it increases with thicker weak soil layers and nearer to the excavation face. Specialized case studies on excavation beneath existing buildings show that cutting piles in a symmetrical way is better for structural integrity than cutting them in a clockwise order. This analysis helps engineers pick shoring methods and numerical models for complicated underground building projects that will secure city infrastructure.

Keywords – Urbanization; Deep excavation; Finite Element Method; Plaxis 2D; Diaphragm Wall.

I] INTRODUCTION

As cities grow and construct more buildings, roads, utilities, and other infrastructure, development in these highly populated and limited locations can be quite difficult from a geotechnical point of view. Many civil engineering projects in cities were built on top of existing underground systems, such as transit tunnels, utilities, and so on. When designing an excavation in an urban area, you should plan for ground movement and assess the stability of both the braced and unbraced excavation walls. When estimating the movement of the ground next to an excavation site, it is typical to also estimate the settlement of the building and the ground. Civil engineers are imposed to investigate extensive excavations for subterranean parking, basements, and vital infrastructure facilities because of the drastic reduction in accessible land resources caused by the fast growth of big metropolitan areas. The initial stress field of the soil is changed during these excavations, which can cause vertical settlements and lateral ground movements. These might have a negative impact on nearby buildings and subsurface utilities, especially in heavily populated areas. Damage to nearby structures, such as cracking, tilting, or catastrophic collapse, could occur as a consequence of excavation-induced deformations. Predicting and controlling these ground deformations to appropriate levels has thus become an important problem for stability management and geotechnical design. A lot of recent work has been done on simulating complicated interactions between soil structures and using finite element methods, specifically PLAXIS, to evaluate different retaining systems, such as diaphragm walls, contiguous pile walls, and anchored sheet piles. This review compiles the latest research on how different soil parameters, excavation depth, and supporting system stiffness affect the behaviour of adjacent foundations. It emphasizes the need for advanced modelling and customized construction sequences to keep nearby urban environments stable.

II] OVERVIEW OF LITERATURE

The Finite Element Method (FEM) is now the industry standard for looking into complex geotechnical issues since it can correctly show how soil and structures interact in diverse scenarios. Engineers can use modern FEM-based software like PLAXIS 2D and PLAXIS 3D to generate very realistic models of nonlinear soil behaviors, staged construction processes, groundwater effects, and complicated boundary conditions. These tools use complex constitutive models to show you stress, deformation, and failure mechanisms in detail. This means that they are quite good at predicting how excavations may damage buildings nearby. They are the best option for geotechnical analysis and design right now since they are adaptable, accurate, and have been well tested in both research and industry.

Choosing the right basic model for geotechnical numerical analysis is very important since it lets you accurately predict how the ground will act when it is loaded. The Mohr–Coulomb model is a basic linear-elastic model that is entirely plastic. It assumes that stiffness is constant and that cohesion and the angle of internal friction determine a linear failure envelope. It is fast to compute and often used for early research, but it has problems showing how soils behave when stress channels and loading conditions vary. The Hardening Soil model is more advanced since it has stress-dependent stiffness, plastic straining, and processes for both shear and compression hardening. This model can show how soil really acts, such as how it becomes less stiff, how stress varies over time, and how it acts as it is loaded and unloaded. The Mohr–Coulomb model is useful for simple and safe designs, but the Hardening Soil model is better for thinking about tough geotechnical problems in a lot of detail, like how soil and structures interact with deep excavations.

It is crucial to meticulously model staged construction to mimic real-world circumstances to obtain precise numerical results for excavation systems. Excavating layers and installing struts, anchors, or retaining walls at the proper times should be the exact sequence that the simulation should follow. Soil deformation, stress distribution changes, and structural response are all accurately modelled by this methodical model. If you don't pay attention to the several stages of construction or make them all one step, you could make big mistakes when trying to forecast how the ground will move and how the structure will behave. This would cast doubt on the validity of the study.

III] COMPARATIVE ANALYSIS OF SUPPORT SYSTEMS

Diaphragm walls are one of the finest techniques to keep the soil from moving in deep excavations, especially in cities where it's crucial to keep the earth still. The walls are made of reinforced concrete and are built in trenches that are filled with slurry. They are quite strong and continuous, which means that the soil doesn't move sideways as much and structures nearby don't settle as much. They are naturally rigid and can go deep, so they can be used as both a retaining wall and a cut-off system. This makes the overall excavation more stable. Diaphragm walls are quite good at keeping the ground from moving in soils that are medium strength. When employed with the correct support systems, like struts or anchors, they can be used to excavate safely to a depth of 25 m. Because of this, diaphragm walls are regarded to be a safe and useful approach to keep people and the environment safe during deep excavation projects.

For deep excavations, especially in sandy clayey soils that don't stick together well and have minimal frictional resistance, contiguous pile walls and sheet pile walls are often used to hold back the earth. The way they work in these kinds of soil depends on how hard the soil is, how powerful the shear strength parameters are, and how the groundwater is. In sandy clayey layers, these walls usually display controlled lateral movement. But if they don't have enough support, the risk of too much movement and basal instability grows up as the excavation gets deeper. For design, the idea of "critical depth" of excavation is very essential. It is the deepest unsupported depth when things like wall deflection or ground collapse can happen. Adding anchors or tiebacks to a wall system makes it significantly more stable by giving it more resistance to bending and lowering the bending moments in the wall system. Anchors move loads to deeper, more stable soil layers. This raises the critical depth and makes it safer to dig further. To have the maximum performance and stability on sandy clayey soil, you need to use both contiguous or sheet pile walls and well-designed anchorage systems.

Underlying piles are a distinctive and crucial choice for situations where you need to dig right beneath existing buildings without changing their structural soundness. Steel pipe piles are typically utilized in these situations because they are strong, easy to put up, and can be pushed or drilled into tight spaces. Through these piles, the underpinning process distributes the structural loads from the current foundation to deeper, stronger soil layers. This makes sure that support stays in place throughout and after the excavation. Most of the time, the piles are put in place in phases and connected to the foundation that already exists using needle beams or pile caps. This lets the load to spread out in a controlled fashion. This tactic works best in cities where space is tight and it's crucial to prevent damage to buildings and settlements to a minimum. Steel pipe piles also make construction more efficient and accurate, which makes them great for complicated staged excavation projects where it is important to protect the integrity of nearby and overlying structures.

IV] CRITICAL PARAMETERS AFFECTING STABILITY

- i. **Geometry and Distance:** Controlling the effects of soil-structure interaction depends a lot on the shape of the excavation and its distance from the building. A lot of research has shown that as we move farther away from the excavation, both building settlement and pile deflection tend to go down in a straight line. This pattern can be explained by the ground moving away from the excavation face and stress redistribution slowly going away. This makes the supports around the excavation face less likely to deform. It's easier to see how the ground is moving and unloading near the excavation, which

- ii. makes piles bend and settle more in buildings nearby. But as the distance between them grows, these effects get weaker over time. This shows that there is an expected zone of attenuation.
- iii. **Structural Dimensions:** While excavating, it is important to know the structural measurements, especially the diameter and length of the piles, because they show how things change shape. When you make a pile bigger, it gets stronger and can hold more weight. This means that when you put weight on it, it will bend less. If you make the pile longer, it goes deeper into the ground and makes the dirt more resistant, especially in layers that are deeper and more stable. This makes a big difference in lowering movement. Numerical studies using PLAXIS 2D regularly show that longer and bigger piles make structures more stable and effectively stop ground and structure movements. To make sure that nearby buildings are safe during excavation and to reduce deflection, it is important to make sure that the piles are of right size.
- iv. **Support Stiffness:** It is very important that the supports are stiff so that the side wall doesn't bend during deep excavations. It makes a big difference in how rigid the retaining system is when piles are next to each other in terms of width. When you have bigger pile sizes, the moment of inertia is bigger. This makes the system stiffer and lessens the wall's ability to bend side to side. Smaller bulk piles, on the other hand, are more likely to be flexible, which means they bend more when the same load is applied on them. The distance between the anchors and how they are arranged are just as important as the pile's width. Anchors that are close to each other provide more support along the sides of the excavation. This makes the support system more stable by spreading the forces from the earth more evenly. When the anchors are farther apart, however, the wall is less restrained and can move more.

V] CASE STUDY INTERPRETATIONS

In the Surabaya 17-story building project, computer simulations showed that local excavation at pile cap locations is better than global excavation for reducing deformations in densely populated metropolitan areas. The initial design called for excavation down to a depth of 3.2 m across the whole site. However, studies found that this "global" unloading of the soil would cause dangerously high lateral displacements in the soft-to-medium soil layers that are typical of the area. The project successfully kept the ground stable and limited deformations in nearby buildings, such as a hospital surgery room, to less than 5 mm by using a different method in which the final excavation depth was reached one pile cap at a time, only after the previous sections had been cast. This scenario shows that a confined, staged construction sequence is the best way to regulate neighbouring deformation and keep nearby buildings safe.

Numerical calculations and in situ data from the Ganshuixiang basement building project show that the order in which underpinning supports are taken out is very important for keeping the structure stable. Research findings reveal that symmetrical pile cutting is more helpful than clockwise sequences because it preserves a more balanced distribution of stiffness across the foundation system. Clockwise sequences can cause uneven stiffness, which can lead to an asymmetrical support structure throughout the removal process. This can make new structural pillars behave badly when they bear weight. During the pile cutting stage, there is a sudden rise in superstructure settlement because loads are being moved. Using a symmetrical technique helps control the redistribution of axial forces better to keep the new basement columns safe.

The Bengaluru case study offers essential insights into the geotechnical uncertainties that may result in structural failure, particularly concerning the collapse of a 20-meter-deep slope near to an operational high-rise building. The failure was caused by a number of unexpected things, but the main one was the fact that the subsoil strata were not all the same. They had sedimentary formations with sloped beddings and pockets of very worn or loose patches that were not fully detected in the first examinations. The geological risks were made worse by the fact that construction equipment was constantly moving. For example, vibrations from excavators and rock cutters loosened rock particles at the toe of the contiguous piles, which caused unanticipated slippage and a loss of end bearing. To deal with this emergency, two steps were taken: first, backfilling was done right away to make a safe, protected slope that stopped further erosion; then, a permanent solution was put in place with grouted nails and micro-piles to hold the soil under the existing building's footing and make sure it stays stable for a long time.

VI] CONCLUSION

- i. The distance between an excavation and a nearby building has a direct effect on how it affects the building.
- ii. Increasing the diameter and length of piles significantly reduces lateral deflection.
- iii. Numerical models frequently exaggerate superficial settlements in relation to actual field data.
- iv. The use of diaphragm walls, neighboring piles, and sheet pile walls is essential to maintain stability.
- v. Studies indicate a "critical distance," typically estimated at 3 meters, where the implementation of support systems such as sheet piles and anchors yields optimal advantages in enhancing the critical depth of excavation and minimizing building displacement.

- vi. As the depth of excavation increases, the horizontal ground displacement increases to a specific maximum value and subsequently decreases. The bending moment goes down at the place where the anchor is installed.
- vii. Continuous field monitoring is necessary for confirming and improving numerical models, especially when digging near existing structures that are complicated. So, employing tools like inclinometers, strain gauges, settlement markers, and piezometers to keep an eye on things in real time becomes quite important.

VIII] FUTURE SCOPE

Future study should emphasize the use of modern numerical methodologies, real-time monitoring, and intelligent predictive systems. For better accuracy, it is important to move from two-dimensional to three-dimensional modeling, use more complicated soil constitutive models, and make nearby structures look more realistic. Also, using artificial intelligence, risk-based design methods, and digital twin technologies can greatly improve safety and prediction. Creating standard norms and long-lasting excavating methods will also be very important in solving problems in crowded cities.

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