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ANALYSIS OF FINITE ELEMENT METHOD FOR SETTLEMENT OF PILE FOUNDATION DUE TO TUNNEL CONSTRUCTION

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Abstract - *Day by day competition is increasing for surface space, to fulfil the objective of sustainable development, use of subsurface space becomes very important. Underground structures being difficult and uneconomical to construct were restricted to only special structures like tunnels, hydropower stations, railway platforms, defence purpose buildings and mining. But presently, in a increasing number of cases, public buildings are also being built underground in some of the metro cities for many reasons, most common reason being effective use of land and location.*

Construction of underground multi-storey building is provided with pile foundation. But in future, this pile foundation, being at large depths, may get affected by newly built tunnel passing close to it. This project mainly deals with analysis of pile foundation of building under the influence of tunnel with the use of finite element analysis software PLAXIS 2D.

For analysis purpose, a fully developed model was made and simulated for various positions and diameters of tunnel with respect to foundation of building. Results were analysed to find changes in the behaviour pile foundation in terms of total displacement. After thorough analysis of results of simulation, it was found that pile foundation of building is influenced by tunnel only when tunnel is in very close vicinity of pile and its influence is negligible if located far away from the structure. The distribution of internal forces induced by tunnel depend on the position of the pile with respect to the tunnel horizontal axis. The critical position of tunnel corresponds to pile with a tip just below of the tunnel. When tunnel is located at various depths, the variation of total displacement with depth of pile depends upon position of tunnel and the tip of pile. The diameter of tunnel also has small influence on displacement of pile. Displacement of pile is also influenced by diameter of tunnel to a small extent.

Key Words**: **Pile foundation, Settlement, Plaxis 2D, Tunnel etc.

1. INTRODUCTION

For hundreds of years, our natural dominion has been the surface of the ground. Insisted by necessity and curiosity, we have always tried to escape from this space, by searching for utilization of the remaining dimension, upwards or downwards. In these struggles, we have always encountered great difficulties, especially in the downward direction. Only the underground space can provide us the site for activities or infrastructures that are needed in the populated metro cities. Underground construction works have always been very difficult. However, rapid economic development in recent century made us dig in to the soil deeper and deeper, encouraged by numerous reasons.

Today, the main reasons which justify use of the underground space can listed as follows-

i. Land use & location

Presently, every mega city is fighting a losing battle for open spaces over the last few years. In fact this lack of space above the surface is not only the case in metro cities but in almost all cities around the world. It leaves us no option but to make use of the underground space in a more thoughtful and a well-organized way so that the advantage of location can be utilised.

ii. Isolation considerations

The soil is almost infinitely spaced, fully opaque and gives us many advantages in terms of isolation. It can provide protection against extreme climate, earthquakes and other natural disasters.

iii. Environmental preservation

Recent research suggests that a variety of the underground building cases the annual energy demand is below 10 kWh/m2, so we can almost consider such buildings as zero-energy buildings. . This is notably important aspect in designing facilities with a low environment impact. The ground can also provide us a variety of rewards in terms of safeguard of the surroundings, such as Aesthetics or ecology.

iv. Topographic reasons

Tunnels have been made in undulated surfaces, mainly to dig through mountains for both roads and railways. The use of tunnel advances or makes it possible several transport options, like roads, railways, canals, etc. in hilly and mountainous areas.

2. LITERATURE REVIEW

Though FEM analysis software like PLAXIS 2D/2D, GEO5, FLAC 2D are relatively new software in the field of geotechnical engineering, yet many researches were done great work recently on underground structures, deep excavation, tunnelling and tunnel-structure interaction. Some of them are mentioned here with their findings.

Mroueh H. and Shahrour I. (2002) did analysis of the impact of construction of urban tunnels on adjacent pile foundations. It was carried out using an elastoplastic three-dimensional finite element modelling. Numerical simulations were performed in two stages, which concern, respectively, the application of the pile axial loading and the construction of the tunnel in presence of the pile foundations. Analysis was carried out for both single piles and groups of piles. Results of numerical simulations show that tunnelling induces significant internal forces in adjacent piles. Analysis of the interaction between tunnelling and a group of piles reveals a positive group effect with a high reduction of the internal forces in rear piles.

Schweckendiek Timo (2007) studied structural reliability analysis of deep excavations using PLAXIS generic probabilistic toolbox called "Pro Box", which performs reliability analysis automatically with output of PLAXIS. The influence coefficients as result of the analysis provide useful information for optimization purposes and also for the physical understanding of the model behaviour close to failure.

Stoel Van Der et all.(2007) studied risk management during renovation of the new Rijksmuseum Amsterdam. The geotechnical design calculations are carried out by using the PLAXIS. The calculations are part of the risk assessment strategy in order to predict and judge the influence of ground deformations due to the excavations on the surrounding building. Horizontal deformation of the sheet pile wall, horizontal and vertical deformations in a horizontal cross-section at surface level were determined from analysis.

Finite element analysis (i.e. PLAXIS 2D) is carried out using Mohr-coulomb failure criteria to represent two dimensional soil models. Foundation is aimed to model as square footing and prescribed settlement of 10% of footing width is provided to obtain corresponding bearing capacity.

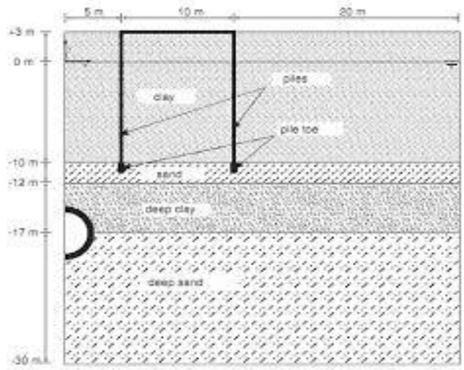
Zhandos Y. Orazalin and Andrew J. Whittle (April 2014) carried out finite element analysis of a complex excavation. The project involved a complex sequence of berms, access ramps and phased construction of the concrete mat foundation. The non-uniform soil excavation resulted in the three-dimensional effects which were well-captured by the 2D model predictions. The analysis results show a good agreement with the measured data and provide keys to explain many features of the observed performance including the differences in diaphragm wall deformations associated with sections supported by tieback anchors. A general pattern of measured movements at the centre of a wall typically correspond to an initial cantilever movement of approximately 10-20 mm during the excavation to the first tieback support level.

Pornkasem Jongpradist et all. (October 2012) performed numerical simulations of geotechnical works in Bangkok subsoil using advanced soil models available in PLAXIS. Three constitutive models with enhancing levels of complexity are used to simulate three types of geotechnical works (embankment construction, deep excavation and tunnelling) on Bangkok subsoil conditions. All problems which are from well-documented case histories having reliable monitored data are analysed by PLAXIS 2D assuming plane strain condition with the appropriate analysis condition.

2. METHODOLOGY

The finite element method (FEM) is a numerical method for finding fairly accurate solutions of partial differential equations as well as integral equations. The solution approach is based either on eliminating the differential equation completely (steady state problems), or rendering the PDE into an approximating system of ordinary differential equations, which are then numerically integrated using standard techniques such as Euler's method.

For carrying out elasto-plastic analysis in this project, commercially available geotechnical software PLAXIS 2D is being used which uses Finite Element Analysis (FEA) for simulation of model.



PLAXIS 2D

PLAXIS 2D is a finite element analysis software generally used for three-dimensional analysis of deformation and stability in geotechnical engineering. It is embedded with features to find solution to various aspects of complex geotechnical structures and construction processes using robust and theoretically sound computational procedures. Complex geometry of soil and structures can be defined in two different modes, which is one of the advantages of PlAXIS 2D. These modes are specifically defined for soil or structural modelling. In this software, independent solid models can automatically be intersected and meshed. The staged constructions mode is another advantage, this mode enables a realistic simulation of construction and excavation processes by activating and deactivating soil volume clusters and structural objects, application of loads, changing of water tables, etc.

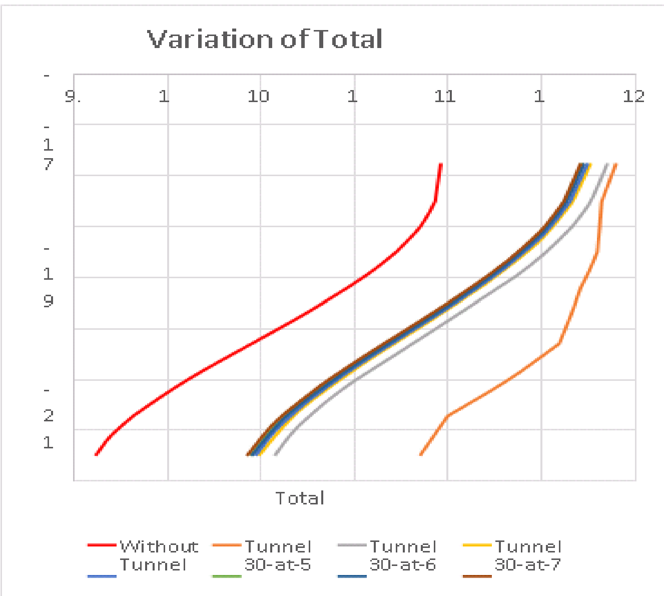
The output consists of a full suite of visualization tools to check details of the complex inner structure of a full 2D underground soil-structure model. PLAXIS 2D is a very much user friendly 2D geotechnical program, which offers flexible and interoperable geometry, realistic simulation of construction stages, a robust and reliable calculation kernel, and comprehensive and detailed post-processing, making it a complete solution for daily geotechnical design and analysis.

3. RESULT AND DISCUSSION

Because of construction of tunnel the pile foundation is affected, maximum total displacements shown in figure 6 and 7 depict the evolution of the displacement of the structure foundations after tunnelling. Though the displacement is small (0.25 mm), it shows that the lateral displacement of each foundation increases after tunnel is built.

It is known that the displacement of pile increases with the presence of tunnel, but it also varies the location of tunnel. Here since tunnel '35-AT-5' is completely located in fractured basalt rock, it will not give more displacement, whereas the tunnel '30-AT-5' is located in stiff clay and is very close to the tip of pile and which gives maximum displacement. Though the tunnel '20-AT-5' is located in clayey soil, still the position of tunnel is very far from the tip of the pile, so the displacement is lowest of all.

Variation of total displacement of pile over depth of pile, because of tunnel 'A' at various horizontal distances from the pile:



Displacement of pile over depth of pile, because of tunnel 'A' at various horizontal distances from the pile

4. CONCLUSIONS

In practical scenario, to manage heavy loads of multi storied building the provision of pile foundation becomes necessary. But in future, this pile foundation, being at large depths, may get affected by newly built tunnel passing close to it, so to predict effect of such tunnel on pile foundation becomes necessary. This project mainly deals with analysis of such pile foundation under the influence of tunnel with the use of finite element analysis software PLAXIS 2D.

After thorough analysis of results of simulation, following conclusions can be drawn out

1. Pile foundation of building is influenced by tunnel only when tunnel is in very close vicinity of pile and its influence is negligible if located far away from the structure.

2. The distribution of the tunnel induced internal forces strongly depends on the position of the pile tip with regard to the tunnel horizontal axis. The critical configuration corresponds to piles with a tip just below of the tunnel. When tunnel is located at various depths, the variation of total displacement with depth of pile depends upon position of tunnel and the tip of pile.

3. The diameter of tunnel also has small influence on displacement of pile. As the diameter increases the displacement of pile also increases.

5. FUTURE SCOPE OF STUDY

In following ways this work can be extended to get better results-

The parameters other than displacement like skin friction, pile capacity can also be analysed. These result will be improved if tunnel loads are also considered.

This analysis was carried out without considering vibration forces of the tunnelling process and also dynamic loading conditions when under traffic operational condition. Taking into account these forces, model can be made more realistic to get excellent results.

If modelling of the advancement of Tunnel Boring Machine (TBM) is done with tunnel slowly approaching the neighboring building, then various forces like grout pressure, face pressure of TBM also can be taken into account which may result.

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