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Case Study of Basement Construction In Jakarta

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Abstract – In geotechnical engineering, an excavation requires special attention including accurate construction planning and control. In this article, the researcher wants to know the critical condition of the excavation before the failure occurred for the short term and long term analysis condition. As the retaining structure component, secant pile which is reinforced by soil nailing can be used for the alternative. The excavation is analyzed by 2D finite element method using PLAXIS 2D. The Soil was modeled with the Mohr-Coulomb soil model. Secant pile's horizontal deformation (U_x) and bending moment will be the major component to be analyzed in this study. From the calculation, the maximum horizontal deformation and the bending moment of secant pile, respectively are around 49 mm and 549.6 kNm.

Index Terms - Secant pile, Soil nailing, Finite Element Method, PLAXIS 2D, Mohr-Coulomb, Wall deformation, Ground surface settlement

1 Introduction

The availability of sufficient parking space in high rise buildings is a thing that must be considered by the developer. The more complex structure of the building, the greater parking space needed to accommodate the existing vehicles. One of the solution to overcome this problem is to construct a basement which is certainly involved with the deep excavation. The selection of an appropriate earth retaining structure system should be considering the soil behavior, the location of the project, the depth of excavation and also the method construction. In general, the excavation in the South of Jakarta area are usually constructed with a combination of secant piles and reinforced with soil nailing or anchors. The selection of secant pile as the retaining wall is a good choice for the excavation protection system in the soil which is relatively good. While the selection of soil nailing is considered to be more effective than the use of anchors because of the limitations of space in the urban area.

The stability of the deep excavation will be dependent on two main parameters, namely soil shear strength parameters and soil modulus parameters. These two main parameters aim to control the magnitude of deformation for the existing earth retaining structure system. Practically, the value of soil shear strength parameters and soil modulus can be determined based on empirical correlation from the results of Standard Penetration Tests, SPT (ASTM D1586). Later, a 2D model of the excavation was conducted thoroughly via the finite element method software, namely PLAXIS 2D to obtain and investigate the performance of the earth retaining structure system.

2 Projects Description

An excavation project was located in the South of Jakarta with the average excavation was 12 m. The earth retaining structure was secant pile with 80 cm diameter and 1.2 m spacing centre to centre with the effective length of 23.5 m. In addition, soil nailing with 12 m length was installed with an inclination of 30° and 45°, alternately. The excavation location and the geometry also the arrangement of secant pile and soil nailing are illustrated in Fig. 1 and Fig. 2, respectively.

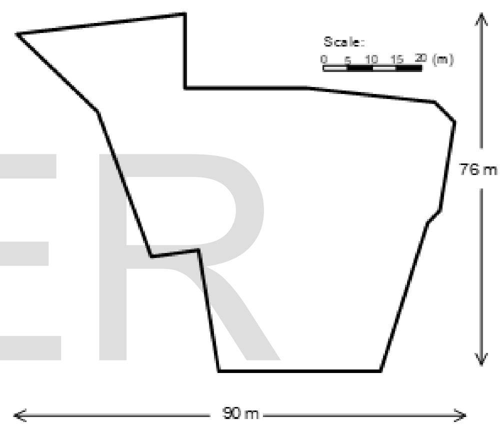

Fig. 1. The Plane View of The Construction Area

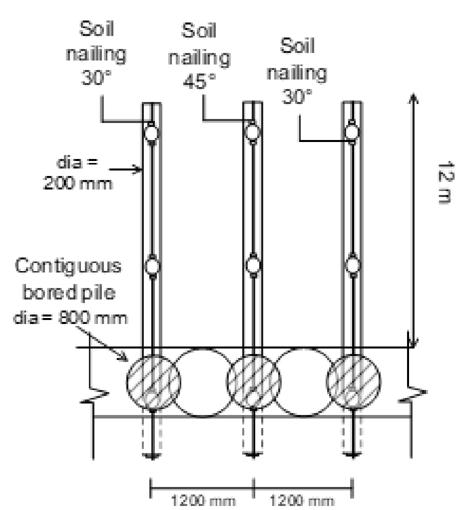

Fig. 2. The Arrangement of Secant Pile and Soil Naling

3 Soil Stratifications

From the results of Standard Penetration Tests (SPT) ac-

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cording to two boreholes, the soil stratifications can be classified as the following stratum: the first layer with the thickness about 5 m is a silty clay layer (MH-1) with a medium stiff consistency. The second layer is the same as the first layer with a soft to stiff medium consistency silty clay (MH-2) and the thickness about 11 m. The third layer is sandy soil layer (SM-1) with a very dense consistency until the depth of 35 m below the ground surface. In addition, the groundwater level was observed at 10 m below the ground surface. As indicated by the site inverstigation, the soil parameters obtained from Standard Penetration Test are summarized in Fig. 3.

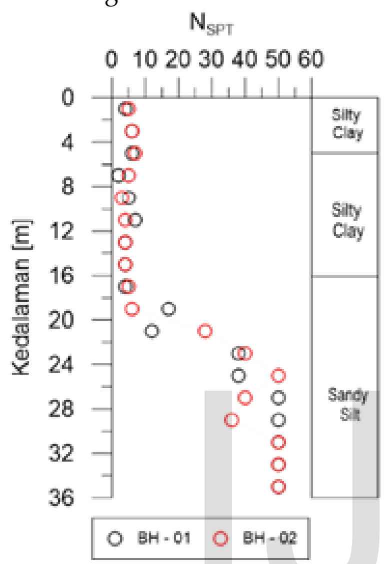

Fig. 3. The Standard Penetration Test Result

4 Finite Element Modelling

PLAXIS as the numerical software based on finite elemet method nowdays often used for the simulation related to deep excavation cases all around the world (*Wang et al*, 2018; Cheng, C. and Likitlersuang, S., 2017; Zheng *et al*, 1999; Zolqadr *et al*, 2015). In this study, the numerical model of 12 m excavation depth (H_e) and 22 m excavtion width (B) was developed using the plane strain finite element software, namely PLAXIS 2D.

Fifteen-node triangular element were used to simulate the soil cluster, five-node plate elements were used to simulate the secant pile, five-node plate elements were used to simulate the soil nailing and ten-node interface elements was applied to model for the soil-structure interaction. Fig. 4 illustrated for the details of the numerical model and finite element meshed.

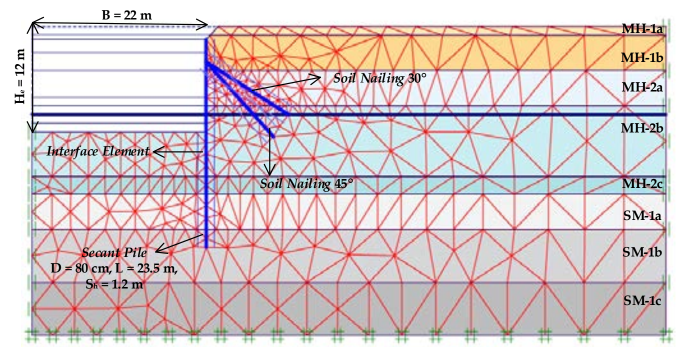

Fig. 4. Typical Finite Element Mesh and Boundary used for Analysis

4.1 Soil Constitutive Models and Soil Parameters

To simulate the real behavior in the field, the Mohr-Coulumb models were used in this study. For unloading case, the poisson's ratio is taken to be 0.2. In the simulation, the undrained behavior of clayey soil will be modeled using an Undrained (B) drainage type in terms of effective stress analysis in both shear strength and soil modulus while for the sandy soil using a drained drainage type. Table 1 shows the summary of the input parameter for the soil in this study.

4.2 Structural Parameters

Structural components such as secant piles are simulated using plate element which is assumed to be liner-elastic. In this study, secant pile has a dimension of 80 cm in the diameter with a length of 23.5 m.

TABLE 1
The Input Parameter For The Soil

Depth [m]	USCS Soil Type	N_{SPT}	γ [kN/m³] unsat	sat	K_x [m/day]	K_y [m/day]	S_u [kPa]	E_u [kPa]	E′ [kPa]	c' [kPa]	ϕ' [°]
0 - 1	Silty Clay (MH-1a)	5	16	17	0.000432	0.000864	27	6750	5400	-	-
1 - 5	Silty Clay (MH-1b)	6	16	17	0.000432	0.000864	37.5	9375	7500	-	-
5 - 9	Silty Clay (MH-2a)	4	16	17	0.000432	0.000864	22.5	5625	4500	-	-
9 - 17	Silty Clay (MH-2b)	5	17	18	0.000432	0.000864	27	6750	5400	-	-
17 - 19	Silty Clay (MH-2c)	12	17	18	0.000432	0.000864	69	17250	13800	-	-
19 - 23	Sandy Silt (SM-1a)	30	20	21	0.432	0.864	-	-	29500	5	39
23 - 29	Sandy Silt (SM-1b)	44	20	21	0.432	0.864	-	-	44000	5	43
29 - 35	Sandy Silt (SM-1c)	50	20	21	0.432	0.864	-	-	50000	5	44

The stiffness parameter of the plate element, which is the concrete modulus of elasticity based on the American Concrete Institute, is determined by the equation:

$$E_c = 4700\sqrt{f_c'}\ (\text{MPa}) \quad (1)$$

Since secant piles have a circular cross-section and were installed in a certain horizontal space (S_h), it's necessary to determine equivalent axial stiffness (EA) and equivalent bending stiffness (EI) for the correction while simulated circular secant pile as rectangular plate element in PLAXIS according to the equation 2 and 3, respectively. Table 2 shows the summary of the input parameter for plate element in this study.

$$EA_{eq} = \frac{EA}{S_h} \quad (2)$$

$$EI_{eq} = \frac{EI}{S_h} \quad (3)$$

TABLE 2
THE INPUT PARAMETER FOR THE PLATE ELEMENT

Structure	S_h [m]	EA [kN/m]	EI [kNm²/m]	w [kN/m/m]	ν
Secant pile	1.2	13921033	556841	4.16	0.2

A 20 cm diameter and 1.2 m horizontal spacing (S_h) of soil nailing will be simulated using node-to-node anchor element to describe the interaction between soil and structure. The node-to-node anchor element can be used to simulate the "soil flow" between the soil nailing. Because of soil nailing is a composite that consist of steel and grouting, the magnitude of equivalent elastic modulus (E_{eq}) between these two materials is determined according to the equation:

$$E_{eq} = E_n\left[\frac{A_n}{A}\right] + E_g\left[\frac{A_g}{A}\right] \quad (4)$$

Where E_g is the modulus elasticity of grout material; E_n is the modulus of elasticity of nail; A is total cross-sectional area of grouted soil nail; A_g is the cross-sectional area of grout cover; A_n is the cross-sectional area of reinforcement bar. Table 3 shows the summary of the input parameter for embedded beam element in this study.

TABLE 3
THE INPUT PARAMETER FOR THE NODE-TO-NODE ANCHOR ELEMENT

Structure	S_h [m]	E_{eq} [kN/m²]	A [m²]	D [m]
Soil nailing	2.4	37759228	0.031416	0.2

4.3 Stages of Construction

To simulate the stages of construction of the deep excavation, the 2D finite element model will be divided into several stages which are summarized in Table 4.

TABLE 4
THE STAGES OF CONSTRUCTION

Stage of Construction	Description	Calculation Type
Stage 1	Initial phase using K_0-procedure	Plastic
Stage 2	Reset displacement to zero	Plastic
Stage 3	Secant pile installation	Plastic
Stage 4	1st excavation	Plastic
Stage 5	2nd excavation	Plastic
Stage 6	3rd excavation and soil nailing installation	Plastic
Stage 7	4th excavation	Plastic
Stage 8	5th excavation	Plastic
Stage 9	6th excavation	Plastic
Stage 10	Global safety factor calculation	Safety

5 ANALYSIS AND RESULT

5.1 Wall Deflection and Ground Surface Settlement

From the analysis result, it was found that the maximum lateral deformation that occurred around 49 mm and the maximum ground surface settlement occurred around 30 mm. The maximum lateral wall deformation and ground surface settlement occurs at the 6th excavation (stage 9). The shape of the maximum lateral deformation profile and the ground surface settlement are concave type which can be caused by the use of a relatively high retaining stiffness system. In addition, it can also be seen that the horizontal influence distance of the ground surface settlement is around 55 m from the excavation face.

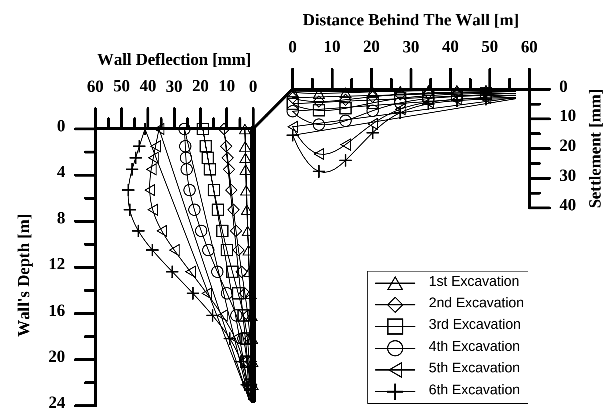

Fig. 5. Wall Deflection and Ground Surface Settlement Profile

5.2 Secant Pile's Internal Forces

Again, the analysis result shows that the magnitude of the forces namely bending moment, shear force and axial force respectively are 549.6 kNm/m; 182.4 kN/m and 532.1 kN/m. The forces from the PLAXIS output can be used in carrying out reinforcement of the secant-pile and also can be the evaluations of the installed reinforcement capacity of the pile. Installed reinforcement configurations in this study sufficient to cover the internal forces that occurred until the final excavation.

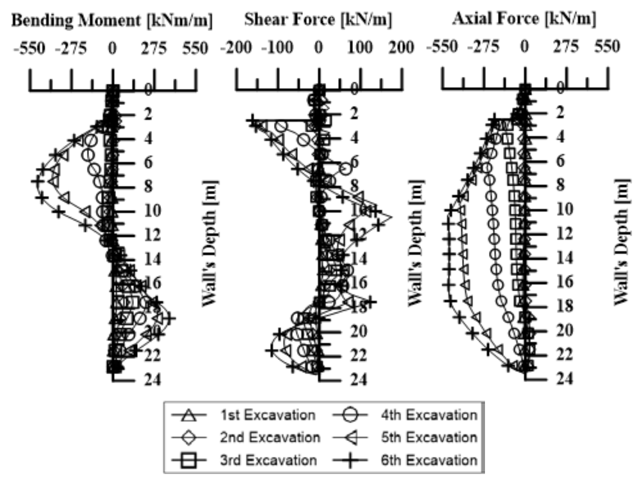

Fig. 6. Internal Forces Profile of Secant Pile

6 Conclusion

The use of the finite element method that combined with a suitable constitutive model can be used to predict the magnitude of maximum lateral wall deflection and ground surface settlement. PLAXIS is one of the software based on the finite element method can be used to simulate excavation work on stages of construction according to the real conditions in the field. Based on the analysis result, the maximum of wall deflection (δ_{hm}) and maximum ground surface settlement (δ_{vm}) are 49 mm and 30 mm respectively. Meanwhile, maximum internal forces of secant pile namely bending moment (M_{max}), shear force (Q_{max}) and axial force (N_{max}) respectively are 549.6 kNm/m; 182.4 kN/m and 532.1 kN/m.

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