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Plaxis 2D Modelling of an Anchor Sheet Pile for Soil Slope Strengthening at Segamat, Johor

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Abstract

In soil engineering, the soil slope is one of the important issues in geotechnical and environmental engineering that can fail due to settlement behaviour. Due to soil slope instability, roads near the Segamat River's slopes have seen severe settlement. Therefore, this study was carried out to determine how the geometry of the soil slope and the properties of the soil affect soil stability and deformation. Because of the varying slope geometries along the river, this study used two alternative slope geometries in its modelling. A comparison was made between the existing slope and the slope stabilised with sheet piling by using Plaxis 2D. Other parameters that affect slope stability are also being investigated, such as anchor length and anchor installation angle. The anchor sheet pile's presence is intended to improve the slope's stability. As a result of this analysis using PLAXIS 2D software, the optimal anchor length depends on the passive pressure of the soil behind the sheet pile. According to the results, installing an anchor with a 60° angle is more stable because the safety factor obtained is 3.26 which is greater than that of a 45° angle which is 1.33. It shows the anchor is the best support of the sheet pile for the soil slope stability.

1. Introduction

As the number of deeper and broader excavations in communities grows, the usage of retaining structures to address settlement and load carrying difficulties becomes increasingly widespread. Slope surface, landslide stability is a key problem when movement of existing or prospective slopes impacts the safety of people and property, or the availability and value of the area. Tie-back retaining walls are a frequent procedure in geotechnical engineering, particularly for deep excavations [1]. Because nearby structures and buildings must be secured, the performance of tie rods and walls used to secure deep excavations in urban areas is critical.

Slope stability is defined as assessing a soil's failure by determining if the stress in the soil paralleled the strength of the soil, as reported by [2]. This assessment is crucial for ensuring the safety of structures built on or near soil slopes, as a failure of the slope can lead to damage or collapse of these structures. There are many factors that can affect slope stability, including the properties of the soil, the slope geometry, and the presence of water or other external loads. Engineers use a variety of methods, such as limit equilibrium and finite element analysis, to evaluate slope stability and design measures to improve it.

The anchor of the sheet pile is the one of the factors to strengthening of soil slope stability. The stability of the soil slope is influence by various of factor which are the length, spacing and geometry of the anchor that will be installed. Thus, the soil slope of geometry and the parameter of anchor sheet pile will be design by using software Plaxis2D to estimate the characteristics or behaviors and to proposed the best design.

The aim of this study to determine how the geometry of the soil slope and the properties of soil affect the soil slope stability and obtain the best design of anchored sheet pile. Two locations of the chainage were selected, which are chainage 50 and chainage 150. The stability of the soil slope is determined by the value of the safety factor for each chainage.

2. Properties and Methods

Plaxis 2D is a computer software that provides the capabilities for analysis and simulation in geotechnical engineering. It is important in this study as it simulate the soil, anchor, and sheet pile. Plaxis 2D enable simulating and constructing the soil qualities, layer and profile based on the parameters obtained. This study used the software to conduct Finite Element Analysis (FEA) which examines the load applied and the soil slope model to obtain the factor of safety at the end simulation. Numerical analysis programs are used when traditional problem-solving methods are insufficient [3]. This are useful for solving nonlinear problems, optimization, parametric studies, and understanding the effect of input variations on analysis outcomes via sensitivity analysis and uncertainty quantification. The illustration in Fig. 1 depicts the representation of the anchor sheet pile on a soil slope to being simulated in Plaxis 2D. The design of the anchor sheet pile can be seen in Fig. 2, which was created using Plaxis 2D.

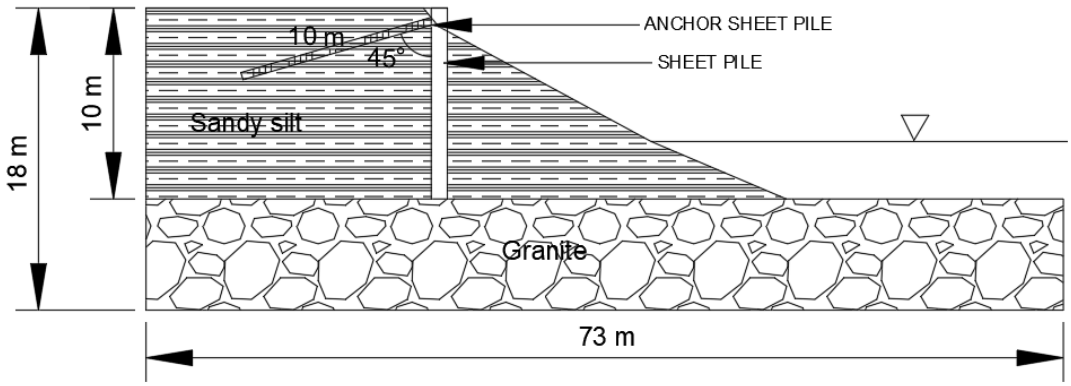

Fig. 1 *Modelling of anchor sheet pile*

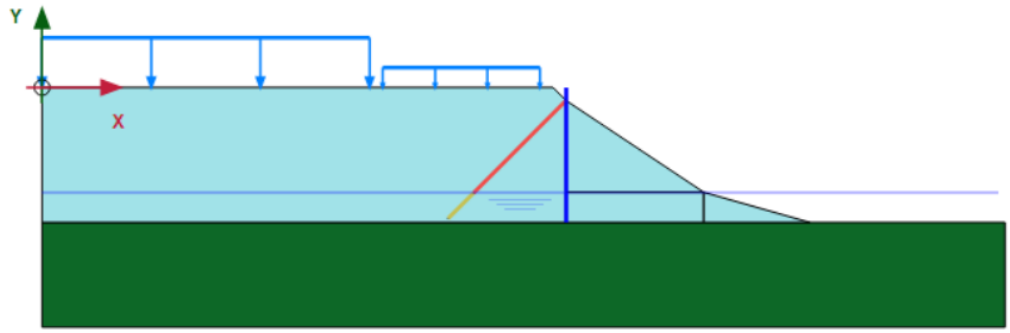

Fig. 2 *Modelling of anchor sheet pile by using Plaxis 2D*

2.1 Soil Properties for Modelling

Table 1 and Table 2 show the soil properties for each section of a slope known as chainages. These tables include information such as soil type, density, and moisture content. These soil properties are important for determining the stability of the slope and are considered when designing the anchor sheet pile, a structural element that reinforces and stabilizes soil slopes. The soil properties may vary between different sections or chainages of the slope, and it is important to consider these differences when designing the anchor sheet pile to ensure the stability of the slope.

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Table 1 *Soil properties for modelling at chainage 50 [4]*

Parameter	Sandy Silt	Granite	Unit
Type material behaviour	Drained	Non-porous	-
Material model	Mohr-Coulomb	Elastic	-
Bulk Density	1.73	-	Mg/m^3
Dry Density	1.10	-	Mg/m^3
Young's modulus, E	12000	50000	kN/m^2
Poisson's ratio	0.20	0.1	-
Undrained shear strength, S_u	42		kN/m^2
Frictional angles	32	-	°
SPT	8	-	-

Table 2 *Soil properties for modelling at chainage 150 [4]*

Parameter	Sandy Silt	Gravel Silt	Sandy Silt	Granite	Unit
Type material behaviour	Undrained	Undrained	Undrained	Undrained	-
Material model	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Elastic	-
Bulk Density	1.7	1.71	1.722	-	Mg/m^3
Dry Density	1.23	1.31	1.268	-	Mg/m^3
Young's modulus, E	16000	40000	18000	50000	kN/m^2
Poisson's ratio	0.3	0.28	0.35	0.1	-
Undrained shear strength, S_u	25	120	60	-	kN/m^2
SPT	6	18	11	-	-

2.2 Modelling of Anchor Sheet Pile

The obtained soil properties and parameters, simulation for modeling the anchor sheet pile was carried out (Table 3). The main objective of anchor sheet pile is to provide additional stability for soil slope. Parameters already determined will be compared to the selected slope geometry to produce better outcome of anchor sheet pile modeling. These parameters such as soil properties, anchor sheet pile parameters, loads applied on the slope, and boundary conditions will be entered in the data for simulation on Plaxis 2D software, which will result in anchor sheet pile modeling and prediction of safety factor.

Table 2 *Soil properties for modelling at chainage 150 [4]*

Parameter	Value
Spacing	1 metre and 2 metre
Length	10 metre and 15 metre
Angle	45° and 60°

3. Results and Discussions

The results obtained from numerical modeling of the slope using Plaxis 2D software. The objective of the study is to understand how the slope geometry and soil properties affect soil slope stability and deformation, and to find the best design for an anchored sheet pile to improve soil slope stability.

The study comparing angles of 45° and 60° with different lengths and spacings shows that the length and spacing of the anchors placed on the soil slope affect the factor of safety. The results indicate that the angle of 60 degrees, in combination with the right length and spacing, makes the slope more stable and erosion more controlled. The research demonstrates that the slope geometry has an impact on the factor of safety. The erosion condition is used to show how the factor of safety is affected by the installation of the anchors and sheet piles. The results indicate that angles of 60 degrees, along with the appropriate length and spacing, have a positive influence on the factor of safety and are more cost-effective and suitable for long-term slope stability.

Furthermore, the results show that increasing the length of the anchor installed can lead to an increase in the factor of safety, making it stable and more rigid. From the Table 3 and Table 4 shows the comparison of safety factor on chainage 50.

Table 3 *The installation of a 45-degree geometry anchor results in safety factors*

Angle 45°				
Length, m	10		15	
Spacing, m	1	2	1	2
CONDITION	FOS	FOS	FOS	FOS
Initial	2.37	2.37	2.37	2.37
Sheet Pile	2.47	2.47	2.47	2.47
Anchor and Sheet Pile	2.57	2.57	2.57	2.57
Erosion with anchor and sheet pile	1.33	1.32	1.34	1.32

Table 4 *The installation of a 60-degree geometry anchor results in safety factors*

Angle 60°				
Length, m	10		15	
Spacing, m	1	2	1	2
CONDITION	FOS	FOS	FOS	FOS
Initial	1.41	1.41	1.41	1.41
Sheet Pile	1.57	1.57	1.57	1.57
Anchor and Sheet Pile	1.61	1.61	1.61	1.61
Erosion with anchor and sheet pile	2.05	2.34	3.26	3.1

The research compared the effects of different angles (45° and 60°), lengths, and spacings of anchors on soil slopes, and found that these factors greatly impact the stability of the slope. Specifically, the study found that using 60-degree anchors with appropriate lengths and spacings leads to increased stability and less erosion. The results suggest that the geometry of the slope plays a significant role in determining the stability, and that using anchors at a 60-degree angle, with appropriate length and spacing, is more effective and cost-efficient in the long-term. Additionally, the study found that increasing the length of the anchors can improve the stability even more. The Table 5 and 6 shows the result obtained of the comparison factor of safety on chainage 150.

Table 5 *The installation of a 60-degree geometry anchor results in safety factors*

Angle 45°				
Length, m	10		15	
Spacing, m	1	2	1	2
CONDITION	FOS	FOS	FOS	FOS
Initial	2.37	2.37	2.37	2.37
Sheet Pile	2.47	2.47	2.47	2.47
Anchor and Sheet Pile	2.57	2.57	2.57	2.57
Erosion with anchor and sheet pile	1.33	1.32	1.34	1.32

Table 6 *The installation of a 60-degree geometry anchor results in safety factors*

Angle 60°				
Length, m	10		15	
Spacing, m	1	2	1	2
CONDITION	FOS	FOS	FOS	FOS
Initial	2.37	2.37	2.37	2.37
Sheet Pile	2.47	2.47	2.47	2.47

Anchor and Sheet Pile	2.57	2.57	2.56	2.58
Erosion with anchor and sheet pile	1.40	1.41	1.40	1.42

4. Conclusion

The main conclusions of this study are that the installation of piles and anchors can significantly impact the stability of soil slopes. The results indicate that by using piles and anchors, the stability of the slope can be increased by approximately 8%. Additionally, the length and geometry of the pile installation, as well as the soil properties and slope conditions, all play a significant role in determining the stability of the slope. This study also suggests that when erosion is present, the installation of anchors and sheet piles can help to maintain the stability of the slope. The result obtained would follow the required factor of safety based on the types of slopes" means that the outcome of a simulation or calculation will conform to a specific level of safety determined by the characteristics of the slope, such as a higher safety level being required for a slope stability [5]. Overall, the study highlights the importance of considering various factors when installing anchors and sheet piles to ensure optimal stability and safety of soil slopes.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Mohd Fairus Yusof;* ***data collection:*** Mohamed Izzad Najmi Mohamed Azam*;* ***analysis and interpretation of results:*** Mohamed Izzad Najmi Mohamed Azam, Mohd Fairus Yusof*;* ***draft manuscript preparation:*** Mohamed Izzad Najmi Mohamed Azam, Mohd Fairus Yusof, Mohd Khaidir Abu Talib*. All authors reviewed the results and approved the final version of the manuscript.*

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