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The Slope Failure of Weathered Granite Boulders by Using the Finite Element Method

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Abstract

An assessment of weathered granite profile of a research area at Mukim Senai, Kulai, Johor was conducted using PLAXIS 2D method. The slope stability of weathered granite is closely related to the geometric strength of the slope, slope height, soil type (sand or clay), slope gradient and depth to determine factor of safety. The aim of this research is to model and determine the factor of safety of the weathered granite slope with homogeneous characteristics using Plaxis 2D. In addition, it also aims to analyses and correlate the effect of shapes, size and distribution of boulders to the safety factor of the slope. Finite Element Method (FEM)) had been used through the application of PLAXIS 2D software. By comparing between the 2 methods that have been analyzed, safety factors for the slopes analyzed together with groundwater data is less safe. The Safety Factor has found less than 1.5 indicates a slope prone to landslides.

1. Introduction

Granite soils can be generally recognized as very sensitive to weathering and prone to landslides. According to the researcher [1] stated that in Japan there have been many disasters in areas of granite soil where it is following heavy rains, in which great disasters as a result of these rainstorms were caused landslides that occur on weathered granite slopes. In fact, [2] explained that slope instability at the ends of upland areas is more likely to occur more frequently in granite soil formation compared to metasediment in most places in Malaysia.

Slope failure is a characteristic of sudden slope failure that results in the transport of debris downhill by sliding, rolling, falling and slipping [3]. The phenomenon that occurs when a slope collapses suddenly as a result of poor self- retention of the earth under the influence of rain or an earthquake is called slope failure.

To analyze the slope stability a 2D slope scheme was developed which isbased on the slope geometry and the nature of the soil itself that exists at the site. A typical strain model was selected to analyze the slope stability. It assumes an infinite length perpendicular to the plane part and outside the plane displacement is zero. The 15-node element is used for modeling in which the failure load and safety factors are correctly predicted [4]. The Mohr-Coulomb model is a perfect linear elastic plastic involves five input parameters, namely E and ν for soil elasticity; φ and c for soil plasticity and y as angles dilation. In general, the effective stress conditions on failure are well described using the Mohr-Coulomb failure criteria with effective strength parameters tan φ and c [4].

1.1 Finite Element Method (FEM)

The Finite Element Method (FEM) is a widely used method for numerically solving differential equations arising in engineering and mathematical modelling [5]. Typical problem areas of interest include the traditional fields of structural analysis, heat transfer, fluid flow, mass transport, and electromagnetic potential. The FEM is a general numerical method for solving partial differential equations in two or three space variables (i.e., some boundary value problems [6]. To solve a problem, the FEM subdivides a large system into smaller, simpler parts that are called finite elements.

By using the Plaxis Finite Element program used to develop a numerical model of the reference problem to be studied on slopes. With PLAXIS, it is possible to model heterogeneous soil types, complex stratigraphy and slip surface geometry, and variable pore water pressure conditions using many soils model options. The program has been used to analyze several slope stability problems including the influence of free layers and surfaces on slope. Fig. 2 below shows the overview of overall structure of research method.

As computer performance has improved, applications FEM in geotechnical analysis has improved ordinary. According to [6], his method has several advantages: for the model gradient with a very high degree of realism (complex geometry, loading sequence, presence of material for reinforcement, water action, laws for complex soil behavior and to better explain deformation land in its place. However, it is important to understand the output of the analysis is due to the larger number of variables offered to engineers.

2. Methodology

The study area for this research study is at Mukim Senai, which is located at Kulai, Johor, Malaysia. The Mukim Senai is as shown in Fig. 1. The Latitude is 1°29'33.5724"N and the longitude is 103°44'28.8924"E. The study is structured into three phases.

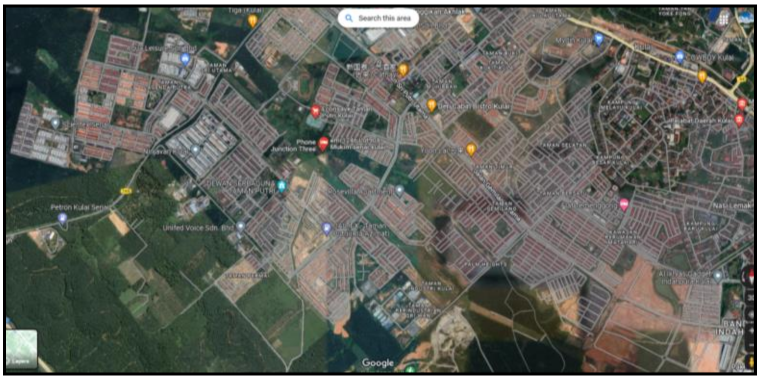

Fig. 1 *Location of Mukim Senai, Kulai, Johor, Malaysia*

In Phase 1, the literature review focused on understanding the weathering profile, formation, and physical characteristics of boulders. This be followed by the identification of problems related to boulders, a review of previous studies, and the establishment of aims, objectives, and the scope of the study. Subsequently, site identification and field observation be conducted, involving a detailed field study and site observation. Phase 2 will primarily focus on data collection through field works, which include the classification of weathering zones and the assessment of the physical and material characteristics of boulders.

In Phase 3, the collected data had analyzed, and the findings had classified and discussed. This involve determining the factor of safety, measuring the factor of safety of weathered granite slopes with homogeneity, and establishing the correlation between the shape, size, and distribution of boulders and the safety factor of the slope. The study concludes with recommendations for future research based on the findings. Fig. 2 shows the movement chart overview of overall structure of research method.

2.1 Analysis

For this research, several parameters such as cohesion and friction angle have been included in this 2D Plaxis application. Table 1 shows the parameters that have been used. In this study, the analysis for slope stability is by using 2 methods: slopes that have a layer of groundwater and slope with no layer of groundwater. The parameters used in this investigation are shown in Table 1 below. Based on the data, it was found that the study site has a content of silt medium brown, orange silt and also medium red mottled in the first layer while the second layer at a depth of 17.20 meters has a content of dark red sandy silt with white and yellow spots.

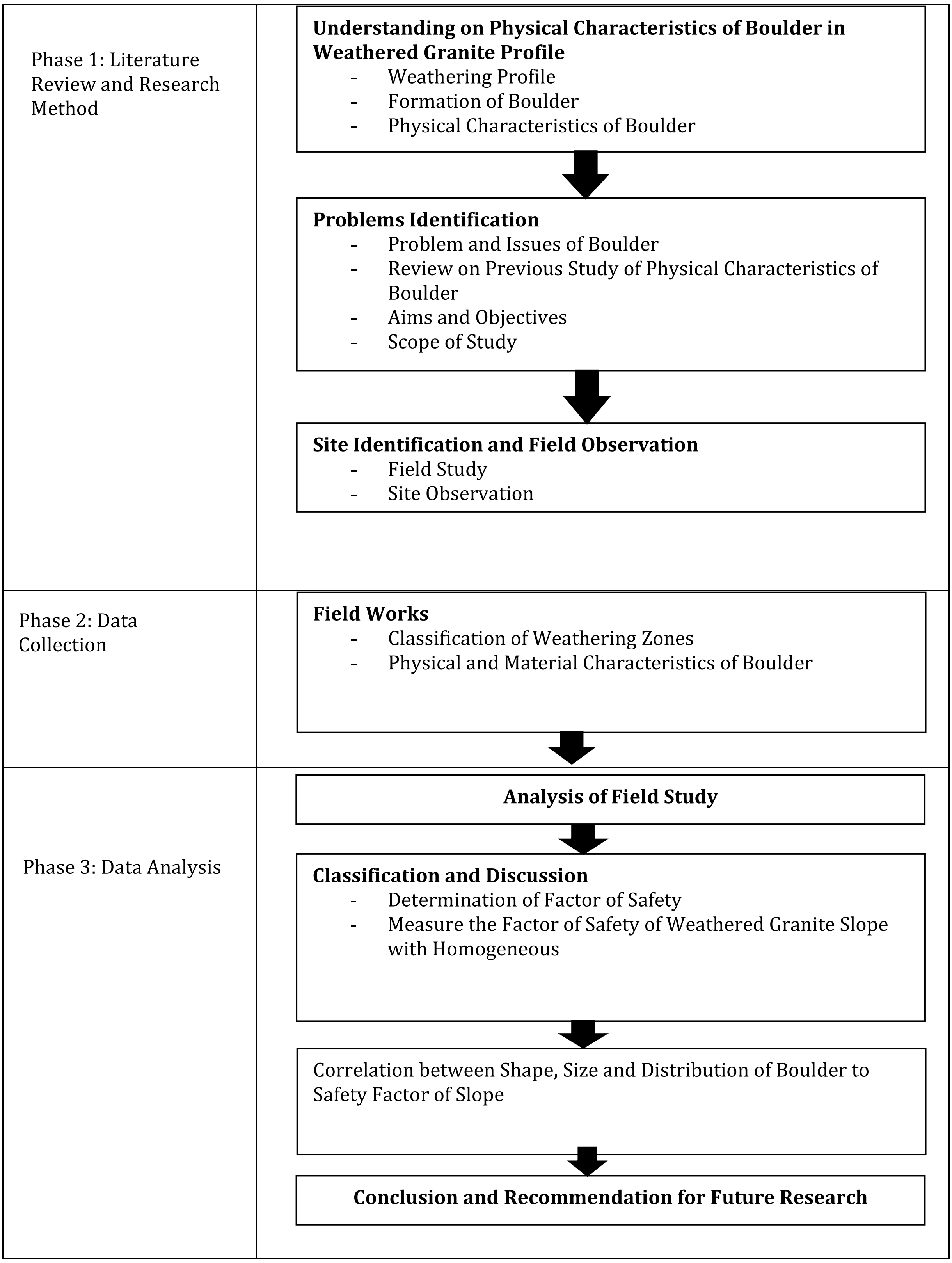

Fig. 2 *Overview of overall structure of research method*

Table 1 *Soil parameter used in Plaxis 2D*

Borehole (BH)	Sample No	Depth (m)	C.L.U Test			
			c	ø	c'	ø'
BH 4	Undisturbed 1	7.00	34	11	5	30
	Undisturbed 2	16.00	53	12	6	32

Based on the above data and test results, there were two undisturbed samples that were taken at the site of hole drill 1 which had different values after the test was carried out. As a result, there is a variation of the readings obtained. This is due to the difference in depth of different samples taken. The value effective cohesion and effective shear angle for undisturbed 2 are higher than the value of undisturbed 1.

3. Results and Discussion

3.1 Results

The data obtained from Table 1 then be modelled in PLAXIS 2D. In this simulation, using data from previous researchers, to model and measure the factor of safety of the weathered granite slope with various sizes, shapes, and soil ratio of granite boulder using Plaxis 2D. The next step is to determine the size and shape of the boulder. For this study the size of boulder to be taken to analyze the safety factors in weathered granite slopes is in the range of 256 millimetres (10.1 in) to 1.5 meters.

The most accurate method is to model slope stability by using the Finite Element Method (FEM) to determine the slope safety factor. Thus, it can be known that soil and slope properties obtained from test results and field observations were used during the FEM analysis.

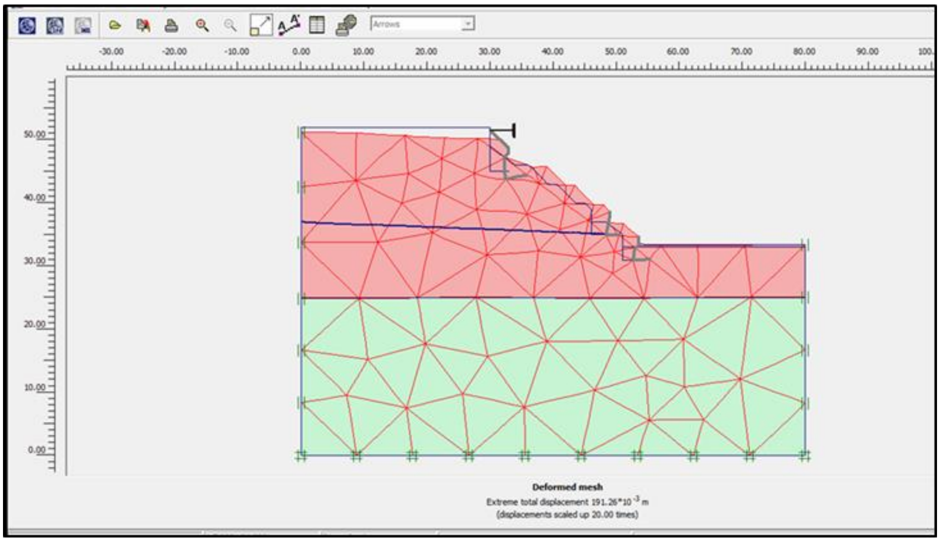

Fig. 3 *Analysis data deformed mesh with groundwater*

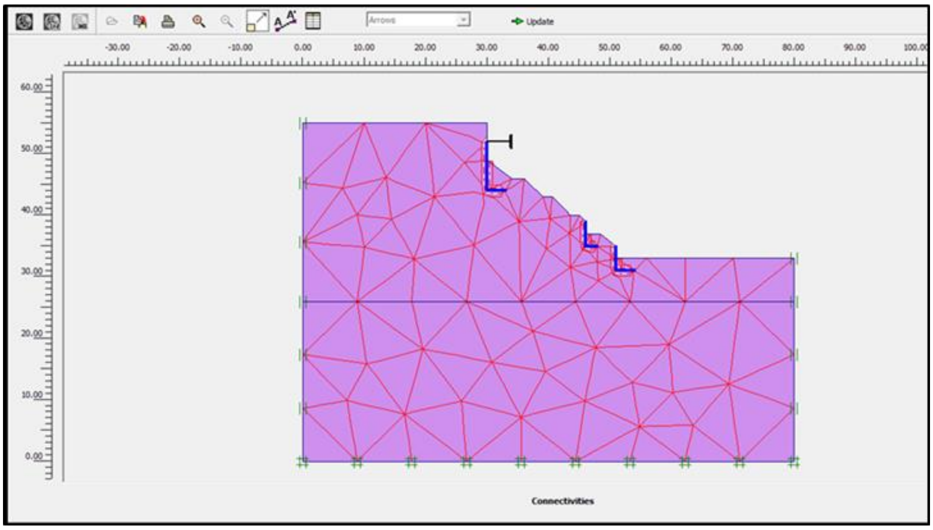

Fig. 4 *Deformed mesh with no layer of groundwater*

3.2 Discussions

In this study, it was found that slope failure occurred at the study site using data obtained from the developer. Among the factors that cause slope failure in this study are due to. One of the reasons is the occurrence of a complete change of any phenomenon in physical or mechanical terms such as the behavior of slope or fluid structures which is ever-changing. The next factors are the geological conditions, geomorphology and geological structure also play a role in influencing the pattern of slope change at the study site. In addition, the effects of cohesion and groundwater levels also played a role in this study.

4. Conclusion

In this research, from the data analysis performed using the PLAXIS 2D application obtained, it was found that the slopes where there is a layer of groundwater is most likely to experience slope instability. This can be observed from the analysis data, if the groundwater layer is present on the slope, it causes the slope structure to change physically slowly.

By analyzing the data from the 2D plaxis, it was found that the parameters present on the slope are important factors in determining the stability of the slope. From the analysed data can be observed, the effective stress conditions on failure are well described using the Mohr-Coulomb failure criteria with effective strength parameters tan φ and cohension. By comparing between the 2 methods that have been analyzed, using the same parameters will find the safety factors for the slopes analyzed together with groundwater data is less safe. The Safety Factor has found less than 1.5 indicates a slope prone to landslides. Moreover, using FEM, the slope failure pattern obtained from the FEM analysis was found to be similar to the actual failure pattern.

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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:*** *Widyawati Mohd Robi, Mohd Firdaus Md Dan @ Azlan;* ***data collection:*** *Widyawati Mohd Robi;* ***draft manuscript preparation;*** *Muhammad Aminuddin Khalid, Melvern Goh Keat Heng, Noor Hakim Basri. All authors reviewed the results and approved the final version of the masucript.*

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