GEOMECHANICAL MODEL FOR SURFACE EXCAVATION IN TROPICALLY WEATHERED GRANITE

SEYED VAHID ALAVI NEZHAD KHALIL ABAD

UNIVERSITI TEKNOLOGI MALAYSIA

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SEYED VAHID ALAVI NEZHAD KHALIL ABAD

A thesis submitted in fulfilment of the
requirements for the award of the degree of
Doctor of Philosophy (Civil Engineering)

Faculty of Civil Engineering
Universiti Teknologi Malaysia

JULY 2014

DEDICATION

Specially Dedicated To…

My Beloved Father and Mother

My Brothers

Thanks for all the love, support, motivation and always being there whenever I need you.

My Supervisor

Assoc. Prof. DR. Edy Tonnizam Bin Mohamad

For his guidance and assistance throughout the whole thesis.

ACKNOWLEDGMENTS

First and foremost, gratitude and praises to Allah, The Most Gracious and The Most Merciful for his blessing in completing this thesis. Pursuing a Ph.D. thesis is a both painful and enjoyable experience. It is just like climbing a high peak, step by step, accompanied with bitterness, hardships, frustration, encouragement and trust and with so many people's kind help. When I found myself at the top enjoying the beautiful scenery, I realized that it was, in fact, teamwork that got me there. Though it will not be enough to express my gratitude in words to all those people who helped me, I would still like to give my many, many thanks to all these people.

First of all, I would like to express my sincere gratitude to my honorific supervisor Assoc. Prof. DR. Edy Tonnizam Bin Mohamad who accepted me as his Ph.D. student without any hesitation when I presented him my research proposal. I am extremely grateful for his continuous support in my Ph.D. study and research, patience, motivation, enthusiasm and immense knowledge. His guidance helped me in all the time of research and writing of this thesis. I have learned a lot from him, without his help I could not have finished my thesis successfully.

Special thanks are also given to my co-supervisors Prof. Emeritus Dato' DR. Ibrahim Bin Komoo and Assoc. Prof. Mohd For Bin Mohd Amin for their encouragement and insightful comments.

During my research, DR. Roohollah Kalatehjari offered me a lot of friendly help. I would like to give my sincere thanks to him for his encouragements and generous help. Also, I would like to express my appreciation to my dear friends Mr. Danial Jahed Armaghani and Mr. Mohammad Ridzuan Bin Jahidin for their kind encouragements and supports.

Last but not least, I am greatly indebted to my parents. Their love and support without any complaint or regret has enabled me to overcome all difficulties during my studies. I love you so much and you are my hero.

ABSTRACT

Mass heterogeneity, abrupt changes in weathering state and presence of boulders in tropically weathered granite lead to uncertainties in predicting the surface excavation performance. This study proposed a new geomechanical model for prediction of surface excavation rate by considering the complex characteristics and effective parameters of weathered granite. Beside the new model, a typical mass weathering profile of granite was proposed with details of rock mass characteristics including typical appearance, discontinuities characteristics, shape and size of boulder, homogeneity and rock to soil ratio in each mass weathering grade. Based on extensive study of fourty panels from four granite quarries, the effect of weathering on the mentioned parameters were established. Practical excavation was performed in excavable zones in the quarries. Statistical analysis using multiply linear regression was performed on the relation of the parameters and practical excavation rate to investigate effective parameters of rock mass and rock material in surface excavation. Then after, the correlation of each parameter with practical excavation rate was obtain utilizing Pearson Correlation Coefficient (PCC). Based on PCC and the results of laboratory tests and site investigation, a rating system in a chart know as Excavation Index in Granite (EIG) was proposed. EIG value was calculated for each weathering zone in each panel of the quarries. The correlation between the results of practical excavation and the values of EIG was obtain and then used to propose a chart of excavability classification in granite. The chart consists of excavation classes, the range of excavation rates and the excavability conditions. Finally, the applicability of the proposed model was verified by comparing the predicted ranges of surface excavation rate using the model and the results of practical excavation rate at another site. The proposed model contributes to the field of surface excavation in tropically weathered granite.

ABSTRAK

Kerencaman massa batuan, perubahan tahap luluhawa serta kehadiran batu bundar (boulder) yang tidak menentu membuatkan penilaian kerja pengorekan adalah sukar di kawasan beriklim tropika. Kajian ini membangunkan model geomekanikal yang mampu meramal kadar pengorekan berdasarkan sifat massa batuan terluluhawa yang bersifat kompleks dan kadang kala mengelirukan. Di samping itu, profil luluhawa yang kebiasaannya dijumpai di kawasan tropika juga diusulkan dengan mengambil kira ciri ciri massa batuan, ketakselanjaran, kerencaman massa batuan dan nisbah batuan kepada tanah untuk tahap luluhawa berbeza. Berdasarkan kajian terperinci empat puluh panel yang dikaji iaitu daripada empat buah kuari, kesan luluhawa terhadap parameter kejuruteraan telah dicadangkan. Ujikaji pengorekan sebenar telah dilaksanakan dalam zon luluhawa berbeza. Analisa statistik dengan menggunakan regresi linear berbilang dilakukan bagi mengkaji hubungan parameter batuan dan kadar pengorekan. Korelasi setiap parameter dengan kadar penggalian praktikal telah diperolehi menggunakan Pearson Correlation Coefficient (PCC). Berdasarkan PCC dan keputusan makmal serta kajian tapak, sistem pengkelasan Excavation Index in Granite (EIG) telah dibangunkan. Sistem ini mengambil kira kategori penggalian, kadar dan situasi ketika kerja pengorekan dijalankan. Sebagai penilaian keupayaan model, ianya telah diuji dengan meramal kadar pengorekan model dengan keputusan sebenar di sebuah tapak berbeza. Dengan hasil kadar peramalan yang jitu, adalah dijangkakan model geomekanikal yang dicadangkan ini berupaya menyumbang kepada bidang pengorekan yang melibatkan batuan granit terluluhawa.

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LIST OF ABBREVIATIONS

BS	-	British Standard
GSI	-	Geological Strength Index
ISRM	-	International Society of Rock Mechanics
M-RMR	-	Modified Rock Mass Rating
RMR	-	Rock Mass Rating
RQD	-	Rock Quality Designation
RSR	-	Rock:Soil Ratio
SHV	-	Schmidt Hammer Value
UCS	-	Uniaxial Compressive Strength
XRD	-	X-ray Diffraction

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CHAPTER 1

INTRODUCTION

1.1 Background

The planning of an excavation project relies greatly on the knowledge of geological and geotechnical conditions of the site. An appropriate investigation able to provide a picture and assessment, as realistic as possible, of conditions to be encountered. The goal of these investigations is the description and evaluation of the ground conditions as they affect the excavation work. Based on this, a proper design and planning of measures for excavation work can be produced. They should be adapted to the anticipated excavation process to provide specific details and data for designing, tendering and estimating the excavation work and selecting the type of contract and invoicing.

In tropical regions, wet and humid environment impedes and complicates the ground's engineering behavior. One of the issues in these areas is the abundance of weathered rocks that dealing with is a major concern in foundation, slope stability, embankment failure problems and excavation works. Weathering of surface rocks in tropical climates has produced thick weathering profiles that consist a number of sub classifications or weathering states that require adequate judgement of their characteristics for efficient excavation.

A major problem confronting geotechnical engineers in the tropics is how to characterize the local lithologies accurately and predict their in-service performance reliably. It should be pointed out that a realistic geotechnical characterization of tropically weathered rock mass requires a broad understanding of the engineering geology of the tropical environment, which relates specifically to an appreciation of the significant genetic consequences of the weathering process and its geotechnical implications. The key factors that should be considered in this geological engineering assessment include the geomorphology, groundwater condition, the position, mineralogy and fabric of the rock in the weathering profile.

The available literature has shown scholars' effort to classify systematically the characterization of rock masses with the purpose of evaluating their behavior as accurate as possible. The significance of rock mass classification scheme is also observable in creating a characterization and composition image of any rock mass for estimating the preliminary requirements of feasibility design. However, most of the classifications have shown rigorous application of the classical analytical methods to the design of excavation in tropically weathered rocks is not always successful, generally because of a limited knowledge of the engineering properties and the in-service performance of these lithologies. In addition, prudence dictates that the generalized weathering profiles in the published literature should be adapted for local conditions as appropriate.

In order to characterize weathering profiles, it is desirable to distinguish between residual soils and those zones of weathered rock that are essentially soil-like but retaining the original rock fabric. This is to enable judicious choice between the relevant rock mechanics and soil mechanics parameters to be employed in the design analysis. Most of researchers tried to develop the weathering profile and determine a method to estimate the engineering properties of granitic rock mass based on geological identification, engineering recognition and laboratory testing.

1.2 Problem Statement

There are several issues associated with weathered rocks, which may affect the surface excavation work in tropical region. Weathering profile of rock masses can be variable and unpredictable. They may contain materials of wide range of strengths together with structures inherited from the parent rock. This issue is called structural complexity or heterogeneity of the rock mass. Heterogeneity of weathered rock mass may cause difficulties for surface excavation works. Major changes in degree of weathering may lead to rapidly changing requirement both for method of excavation and for engineering design. Another specific feature of weathering in tropical region is boulder occurrence as blocks of fresh material within a matrix of severely weathered rock. This phenomena can be problematic in surface excavation design and performance because it can interfere the operation of mechanical excavator and decreased the efficiency of excavation. Although a set of researchers investigated the tropically weathered granitic rock, there are still confusions with behavior of the heterogenous zones that exist between the transition of the rock to soil.

There are some parameters of rock material and rock mass that affect surface excavation of rock mass. There is no single method that can define all the properties of rock, while many tests and site investigations give either a direct or an indirect value of these parameters. Consequently, effective parameters of rock material and rock mass for surface excavation have to be determined to avoid performing redundant, time consuming and costly laboratory tests and site surveys. The importance of rock parameters in each study may differ because of the differences in rock type and weathering process due to different climate conditions.

In tropical regions, weathering and environmental issues such as mineral decomposition, discontinuities characteristics, presence of iron pan and reduction of strength due to moisture content should be considered as unique features in developing a weathering profile. Moreover, climate condition in tropics can significantly decompose and disintegrate rock mass which results in the production of thick weathering profile. Moreover, one of the issues in surface excavation is related to highly and completely weathered rock mass which makes it difficult to determine the best excavation method and to predict the excavation rate. An important consideration in this regards is determining the differences between mass weathering grades in the weathering profile. Although many researchers have studied the changes of geological and engineering properties of different types of weathered rocks, few if any have focused on a detailed weathering profile of granite in tropical region based on both material and mass properties including special features such as heterogeneity, boulder occurrence and abrupt changes as a result of tropical weathering process.

1.3 Objectives of the Study

Based on what has been discussed, the ultimate aim of this study was to advance and at the same time simplify the currently available rock mass classifications for excavation purposes in weathered rocks. To this end, the following objectives have been set.

i. To propose a typical mass weathering profile of tropically weathered granite.
ii. To investigate the effective parameters of rock material and rock mass for surface excavation in tropically weathered granite.
iii. To propose a geomechanical model for surface excavation in tropically weathered granite.

1.4 Research Questions

In line with the objectives of this research, the following research questions are defined.

i. What is the typical weathering profile of tropically weathered granite?
ii. What are the effective parameters of rock material and rock mass for surface excavation in tropically weathered granite?
iii. What is the possible gemechanical model for surface excavation in tropically weathered granite?

1.5 Scope and Limitations of the Study

In this study special attention is provided to classify geological engineering properties of weathered granite in tropical region for surface excavation work. Therefore, this research was carried out in granite quarries at suitable sites where the profiles of weathering exist clearly and assessable. Based on weathering perspective regarding to excavation, interested zones were identified in these sites. This study comprises of field investigations and measurements as well as laboratory tests and data analysis. Consideration of this study emphasizes on problematic zones of the rock mass where highly to completely weathered rock is located.

The field work was carried out at four granite quarries namely Segamat Quarry, Seri Alam Quarry, Transcrete Quarry and Wax Green Quarry in Johor Bahru, Johor. In addition, another quarry namely Menang Granite Quarry was studied for verification of the applicability of the proposed model. These quarries were chosen because they provide a good exposure of weathering profile and active excavation works are available for this research. These particular areas are underlain by granite, which is of Late Cretaceous to early Tertiary age.

Taking into account the objectives of the research, the facilities available in the studied area and the excavation equipment in the quarries, the present study was carried out within the following limitations.

i. The location of the study was limited to five granitic quarries in South Malaysia.
ii. The studied excavation method was limited to surface excavation with direct mechanical excavation without the aid of any drilling or blasting operations.
iii. The utilized hydraulic excavators were selected upon their avaiablilty in the quarries.

1.6 Significance of the Study

The prime importance in rock mass description and characterization for any engineering design is to find out the relevant significant parameters. To contribute to the feasibility study of surface excavation, rock mass and material characterization are important to be correlated to mass weathering grades. The important contribution of this study to the body of knowledge was providing comprehensive understanding of mass and material properties of weathered granite in tropical region, providing a typical mass weathering profile of granite and developing a geomechanical model for surface excavation in granite. Ultimately, the mentioned profile and model led to simplified characterization of the complex behavior of weathered granite in tropical region. It is hoped that this work would lead to systematic study of weathered rock mass with the aim of surface excavation.

1.7 Study Area

The research was carried out based on the study at the five active quarries located in Johor, Malaysia as listed below. The locations of the sites are shown in Figure 1.1.

A. Segamat Quarry (1˚ 36′ 15.19″ N, 103˚ 46′ 40.63″ E) located in Ulu Tiram, Johor, Malaysia for initial data collection.
B. Seri Alam Quarry (1˚ 30′ 58.66″ N, 103˚ 51′ 21.94″ E) located in Masai, Johor, Malaysia for initial data collection.
C. Trans Crete Quarry (1˚ 31′ 21.63″ N, 103˚ 52′ 60.00″ E) located in Masai, Johor, Malaysia for initial data collection.
D. Wax Green Quarry (1˚ 31′ 17.17″ N, 103˚ 55′ 12.13″ E) located in Masai, Johor, Malaysia for initial data collection.
E. Menang Granite Quarry (1˚ 41′ 51.32″ N, 103˚ 29′ 46.29″ E) located in Kulai, Johor, Malaysia for verification of the study.

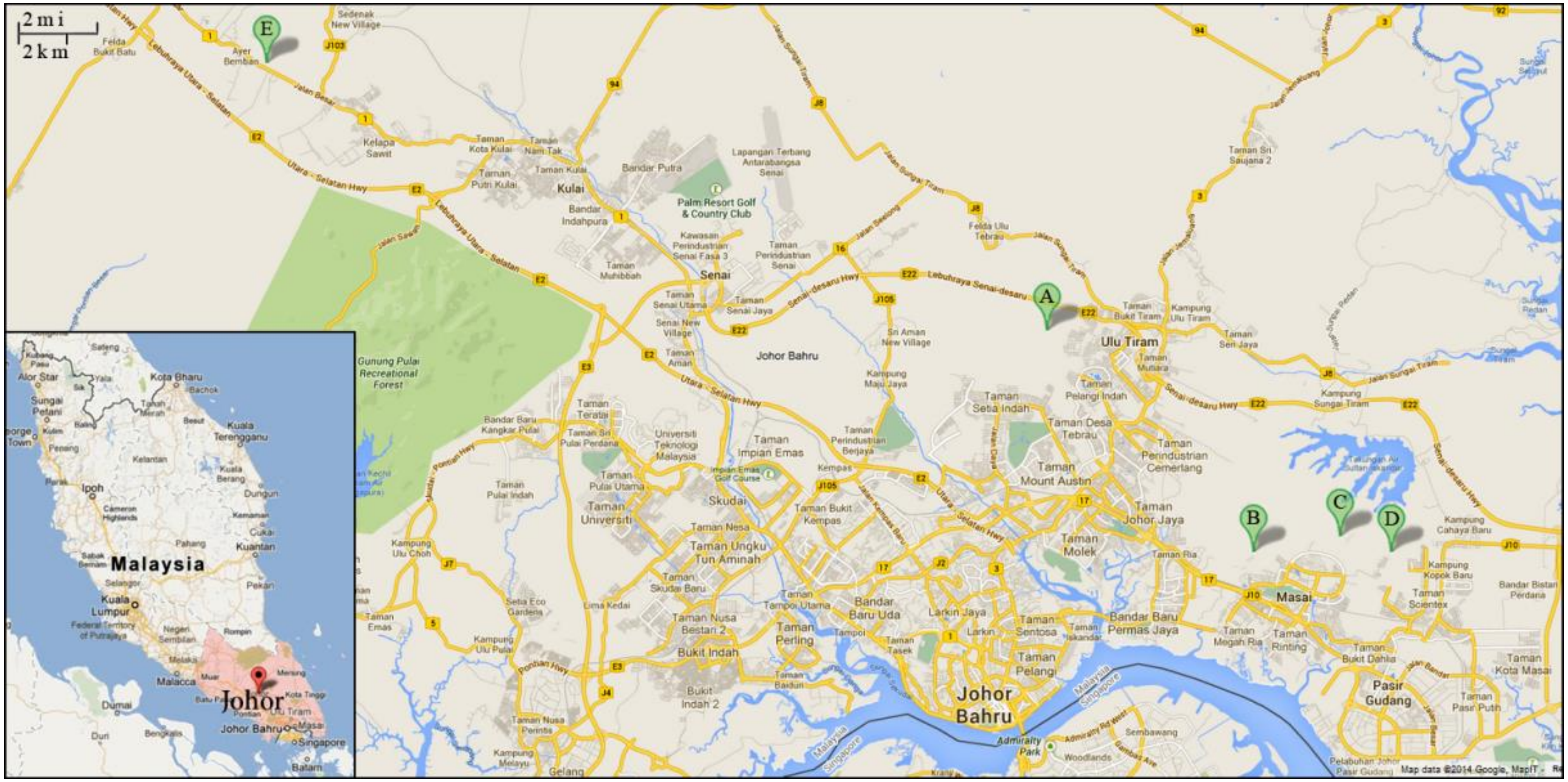

Figure 1.1 Location map of the studied sites

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