EFFECT OF ROCK MASS PROPERTIES ON SKIN FRICTION OF ROCK SOCKET.

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Specially dedicated to my beloved husband, kids, parents and friends

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ABSTRACT

Reliable design of foundation in rock requires an in depth knowledge on its mass properties. Most rock types exhibit high strength and therefore soketed bored pile is often the preferred method for foundation of major structures. However, *in situ* properties of a rock mass can be so much different from intact rock due to its discontinuous state. In addition, these *in situ* properties are difficult to determine reliably and this often leads to some degree of uncertainties in the design of the bored pile. Consequently, bearing capacity of the *in situ* rock is often being underestimated. The underestimation is mainly contributed by application of various reduction factors and correlations in the design process. For example ultimate skin friction (f_s) and rock socket length (L) are determined empirically, which is based on rock mass properties which are indirectly estimated using intact rock properties. This study is to highlight the importance of obtaining reliable properties of the *in situ* rock mass for proper utilisation of the rock mass strength. Data obtained from *in situ* measurement on rock mass, namely *in situ* modulus (E_m) and RQD, have been used to obtain a proper estimation of f_s. To verify the positive contribution of these mass properties on the performance of bored pile, comparison was made with f_s and L estimated using *in situ* measurement and empirical approach. Despite of limited field data, this study does indicate that design using rock mass properties from *in situ* measurement, gives a more reliable value of f_s and L, as compared to the empirical approach. Field measurement such as Pressuremeter test does help in obtaining a reliable rock mass properties consequently, this allows for effective utilisation of the rock mass strength as an effective foundation.

ABSTRAK

Kefahaman mengenai sifat-sifat jasad batuan amat penting dalam merekabentuk asas binaan yang melibatkan kekuatan massa batuan. Batuan kebiasaanya mempunyai kekuatan semulajadi yang tinggi, oleh itu cerucuk tergerek yang disoketkan ke dalam jasad batuan merupakan pilih yang lazim bagi asas struktur mega. Walaubagaimanapun perlu diingat bahawa sifat-sifat jasad batuan yang diperoleh dari ujikaji makmal berkemungkinan tidak melambangkan sifat batuan sebenar, berikutan kewujudan satah ketakselarasan di dalam batuan di tapak. Tambahan pula, parameter sebenar yang diperlukan untuk merekabentuk cerucuk adalah sukar untuk diukur secara lansung di tapak dan ianya pula dipengaruhi oleh ketidaktentuan. Akibatnya keupayaan galas sebenar jasad batuan tidak dimanfaatkan secara berkesan. Keadaan ini wujud kerana penggunaan beberapa faktor penurunan dan korelasi semasa proses merekabentuk. Sebagai contoh, geseran muktamad cerucuk (f_s) dan panjang soket (L) direkabentuk menggunakan pendekatan empirikal di mana sifat-sifat jasad batuan dianggarkan secara tidak lansung menggunakan sifat-sifat bahan batuan yang sempurna. Kajian ini menekankan tentang kepentingan memperolehi sifat-sifat massa batuan di tapak yang bertepatan bagi membolehkan kekuatan jasad batuan dimanfaatkan sepenuhnya. Data-data pengukuran di tapak seperti modulus perubahan bentuk di tapak (E_m) dan RQD telah digunakan bagi memberikan rekabentuk nilai f_s yang lebih baik. Bagi tujuan menilai prestasi cerucuk, perbandingan telah dibuat di antara f_s dan L yang diperolehi menggunakan kaedah empirikal dan kaedah pengukuran di tapak. Walaupun dengan data di tapak yang terhad, kajian ini telah menunjukkan nilai rekabentuk f_s dan L yang menggunakan pengukuran parameter di tapak dapat memberikan nilai yang lebih baik berbanding dengan kaedah empirikal. Pengukuran di tapak seperti menggunakan ujian Pressuremeter, dapat membantu untuk memperolehi sifat-sifat jasad batuan sebenar, dan ini secara tidak langsung dapat membantu ke arah memanfaatkan kekuatan semulajadi jasad batuan.

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LIST OF ABBREVIATION AND SYMBOLS

A	-	Area of bored pile (skin area)
B	-	Footing Width
CKJG	-	Cawangan Kejuruteraan Jalan Dan Geoteknik
D	-	Diameter of Foundation
E_i	-	Intact Modulus
E_m	-	*In situ* Modulus
E_s	-	Secant Modulus
E_t	-	Tangent Modulus
FOS	-	Factor of Safety
f_s	-	Ultimate Skin Friction
h	-	Depth of Rock Socket
j	-	Mass factor
JKR	-	Jabatan Kerja Raya
N_d	-	Depth Factor
Nj	-	Empirical Coefficient depending on Spacing Discontinuities
P_f	-	Creep Pressure
P_L	-	Limit Pressure
PMT	-	Pressuremeter Test
q_a	-	Allowable Bearing Pressure
q_c	-	Average laboratory UCS
Qu	-	Ultimate Geotechnical capacity
q_{uc}	-	UCS from intact rock
RMR	-	Rock Mass Rating
RQD	-	Rock Quality Designation
S	-	Spacing of Joint
SBP	-	Safe Bearing Pressure
SRF	-	Strength Reduction Factor

UCS		Unconfined Compression Strength
UCT	-	Unconfined Compression Test
VW	-	Vibrating Wire Extensometer
VWSG	-	Vibrating Wire Strain Gauge
α	-	Rock Socket Reduction Factor
β	-	Rock Socket Correction Factor
δ	-	Joint Opening

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CHAPTER 1

INTRODUCTION

1.1 Introduction

A reliable and design of a structure is certainly expensive particularly if parameters related to its design require detailed and complex investigation as to reduce degree of uncertainty. Disagreement between project owners, contractors and designers are common in the process of achieving the ultimate design state and serviceability of a structure at minimal cost. The client tends to minimize the cost, while the designers prefer to design conservatively as professional obligations.

In Malaysia, foundation design for mega structures is one of the problems faced by key players in construction industry. In particular, difficulties are arise in estimating and evaluating rock mass properties and strengths that are relevant for design of bored pile socketed in rock. Some of the rock mass properties require direct measurements (*in situ* tests) on the rock body for reliability of data. However these *in situ* tests are complex and costly, consequently, the design of the socket length for the bored pile is often based on empirical approach. The empirical approach is based on past experience and as such, may not be that reliable for rock masses which are known to vary significantly with respect to locality and prevailing geological environment.

Difficulties in determining *in situ* properties and strength of rock mass often lead some degree of uncertainties in the design of bored pile socket length. Consequently, bearing capacity of the *in situ* rock is often being underestimated or over-designed of the rock socket length. The underestimation is mainly contributed by application of various reduction factors and factor of safety in the design process. For example, ultimate skin friction (f_s) determined using empirical is based on rock mass properties which are indirectly estimated from its intact properties. Accuracy of such estimation therefore subjected to uncertainties and leads to over-designed.

In practice, bored piles with diameter less than 300mm are called as micropiles due to the difficulties in boring small shaft diameter size and using grout instead of concrete to form the pile shaft.

1.2 Problem Statement

Design of effective bored pile requires reliable input parameters, especially the mass properties of the in situ rock mass. These properties include *in situ* modulus and Rock Quality Designation (RQD). Use of these actual rock mass properties will ensure the utilisation of full strength rock capabilities where the bored pile is to be socketed. Although to acquire these *in situ* properties is expensive and time consuming, however it gives the advantage that the pile is not over designed.

1.3 Objectives

The objectives of this research are:-

i) To understand the strength and properties of rock mass which are essential for design of socket for bore piles in limestone.

ii) To collect secondary data on rock mass properties and bore pile tests, and to evaluate bore pile performance (f_s) based on measured rock mass properties and empirical approach.

iii) To proof that design of rock socket length using data from actual measurement on *in situ* rock mass gives a more reliable design of f_s as compared to empirical approach.

1.4 Research Methodology

Methodology is framed to meets the objectives, the raft methodology in carrying out this study are stated below. Details research methodology will be explained in chapter 3.

i) To search and review (i.e from books, journals, technical reports) the strength and properties of rock mass which are essential for design of socket for bore piles in limestone.

ii) To collect secondary data from relevant authority; Jabatan Kerja Raya (JKR), pressure meter test (PMT) specialist on rock mass properties and bore pile tests, and for bore pile performance (f_s) evaluation based on measured rock mass properties and empirical approach.

iii) To analyse and to verify that design of rock socket length using data from actual measurement on *in situ* rock mass gives a more reliable design as compared to empirical approach.

1.5 Scope of Study

This study is aimed at looking into the effect of mass properties of limestone on socket length of bored pile and its f_s. Specifically, the study compares the resulting socket length, for a given load on pile, using rock mass properties derived from *in situ* measurement and those properties derived by empirical approach. The interest mass properties of limestone are RQD and *in situ* modulus (E_m) of limestone where the bored pile is to be socketed. Effect of weathering on rock and structural capacity of bored will not be considered in this research.

1.6 Significance of Study.

Reliable and representative properties of *in situ* rock mass are essential for proper design of cast in situ bored pile socket length and f_s. Such approach also enables for proper utilisation of strength of the *in sit*u rock, which may not possible in empirical approach. *In situ* measurement of rock mass parameters such as E_m and RQD using specific field test are among the procedures being recommended.

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