ROCK RESISTANCE OF BORED PILES SOCKETED INTO ROCK

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Dedicated to all those who’ve lost the fight and to those who won’t quit the fight,

My family,

My friends,

Engineering for a better tomorrow,

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ABSTRACT

In view of the large movement required to mobilize the bearing resistance of bored piles and difficulty in base cleaning, the bearing resistance often ignored in current design practice that will result in excessive rock socket length. Many attempts have been made to correlate the bearing resistance with the unconfined compressive strength of intact rock and the RQD but it is uncertain how applicable they are to rock type in Malaysia. This paper attempts to review the applicability of the formulas from previous studies to rock in Malaysia. A program of field testing tests for 13 bored piles with diameter varying from 1000mm to 1500mm constructed in Malaysian granite was conducted to measure the axial response of bored piles and tested using static load test and high strain load dynamic test to verify its integrity and performance. The results were evaluated and compared to the predicted rock bearing resistance. Based on the result obtained, method by AASHTO gives the best prediction of rock bearing resistance for granite in Malaysia and the trend of the rock compressive strength and rock discontinuities were also scattered with relationship to rock bearing resistance.

ABSTRAK

Memandangkan pergerakan yang besar diperlukan untuk menggerakkan rintangan galas cerucuk tuang situ dan kesukaran dalam pembersihan asas, rintangan galas sering diabaikan dalam amalan rekabentuk asas semasa yang akan menghasilkan panjang soket batu yang berlebihan. Banyak percubaan telah dibuat untuk mengaitkan rintangan galas dengan kekuatan mampatan batu dan RQD tetapi tidak pasti bagaimana aplikasi kaedah tersebut boleh digunapakai kepada jenis batuan di Malaysia. Kertas kerja ini cuba untuk mengkaji semula kesesuaian rumus dari kajian yang lepas untuk jenis batuan di Malaysia. Program ujian lapangan telah dijalankan bagi 13 cerucuk tuang situ dengan diameter yang berbeza-beza dari 1000mm sehingga 1500mm yang dibina dalam jenis batuan granit di Malaysia telah dijalankan untuk mengukur tindak balas paksi cerucuk tuang situ dan diuji menggunakan ujian beban statik dan ujian beban tekanan tinggi dinamik untuk mengesahkan integriti dan prestasi cerucuk tuang situ. Keputusan telah dinilai dan dibandingkan dengan rintangan galas batu yang diramalkan. Berdasarkan keputusan yang diperolehi, kaedah AASHTO telah memberikan ramalan rintangan galas batu yang terbaik untuk granit di Malaysia dan trend bagi kekuatan mampatan batu dan ketidakselanjaran batu juga berselerak dengan hubungan rintangan galas batu.

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Q_{ag}	-	Allowable geotechnical capacity
Q_{su}	-	Ultimate shaft capacity
Q_{bu}	-	Ultimate base capacity
f_{su}	-	Unit shaft resistance for each layer
f_{bu}	-	Unit base resistance for the bearing layer
A_s	-	Pile shaft area
A_b	-	Pile base area
F_s	-	Partial Factor of Safety for Shaft Resistance
F_b	-	Partial Factor of Safety for Base Resistance
F_g	-	Global Factor of Safety for Total Resistance
K_{su}	-	Ultimate unit shaft resistance of soil
K_{bu}	-	Ultimate unit bearing resistance of soil
α	-	Adhesion factor
s_u	-	Undrained shear strength
K_{se}	-	Effective stress shaft resistance factor
σ_v	-	Vertical effective stress
ϕ'	-	Effective angle of friction (degree) of soils
N_c	-	Bearing capacity factor
N_γ	-	Bearing capacity factor
N_q	-	Bearing capacity factor
γ	-	Effective density of rock mass
c	-	Cohesion of rock mass
B	-	Pile diameter
D	-	Depth of pile base below rock surface

β	-	Shaft resistance factor for coarse grained soils
q_{uc}	-	Unconfined compressive strength of intact rock
α	-	Reduction factor with respect to q_{uc}
β	-	Reduction factor with respect to the rock mass effect
q_s	-	Ultimate rock shaft resistance
σ_{uc}	-	Unconfined compressive strength of intact rock
σ_{cm}	-	Unconfined compressive strength of rock mass
$q_{b(max)}$	-	Maximum mobilised rock bearing resistance
f_s	-	Rock socket skin friction
q_b	-	End bearing capacity
J	-	Correction factor that depends on the normalized spacing of horizontal joints
N_{cr}	-	Modified bearing capacity factor, a function of the friction angle of the rock mass and normalized spacing of vertical joints
N_{ms}	-	Function of rock mass quality and rock type
α_E	-	Reduction factor with respect to rock quality designation

CHAPTER 1

INTRODUCTION

1.1 Background

The Klang Valley Mass Rapid Transit (also known as KVMRT) project is a planned three line mass rapid transit system to ease the severe traffic congestion in Kuala Lumpur. The proposal was announced in June 2010 and was approved by the Government of Malaysia in December 2010 together with the existing light rail transit (LRT), monorail, KTM Komuter, KLIA Ekspres and KLIA Transit systems, will increase the current inadequate rail network and able to serve a corridor with an estimated population of 1.2 million people. This first phase of this project involves the construction of 51km rail alignment from Sungai Buloh to Kajang with underground tunnel of 9.5km and 31 stations of which seven will be underground.

Locations of the KVMRT project are shown in Figure 1.1 and Figure 1.2. The construction of the Sungai Buloh to Kajang line involves the construction of thousands of large diameter bored piles ranging from 1.0 meter to 2.8 meter diameter to support the structures of viaducts and train stations that will be founded on a wide range of rock types comprising granite, kenny hill, limestone and kajang formations

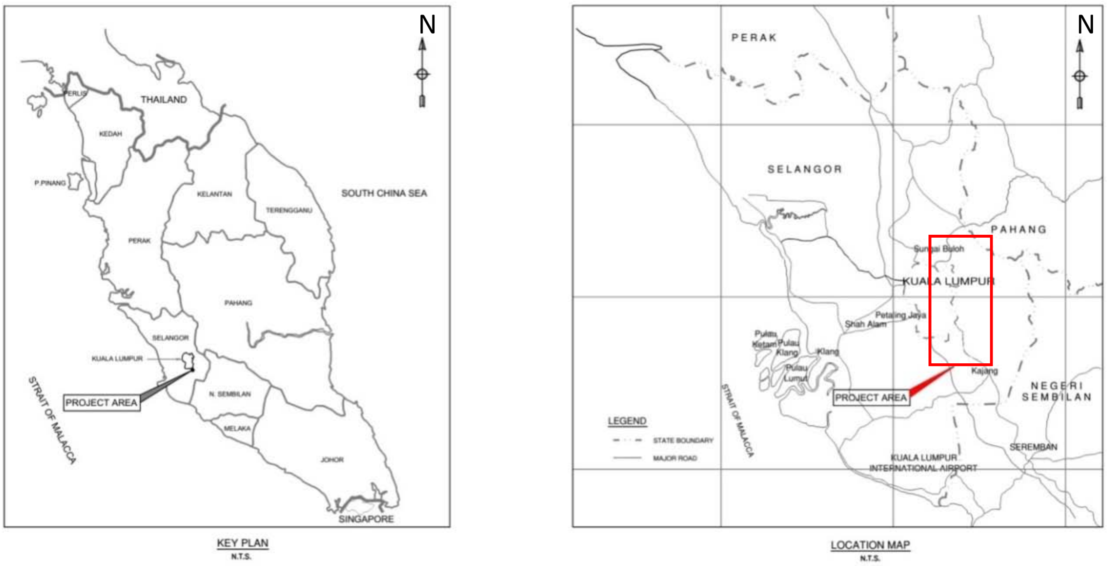

Figure 1.1 Key Plan and Location Map

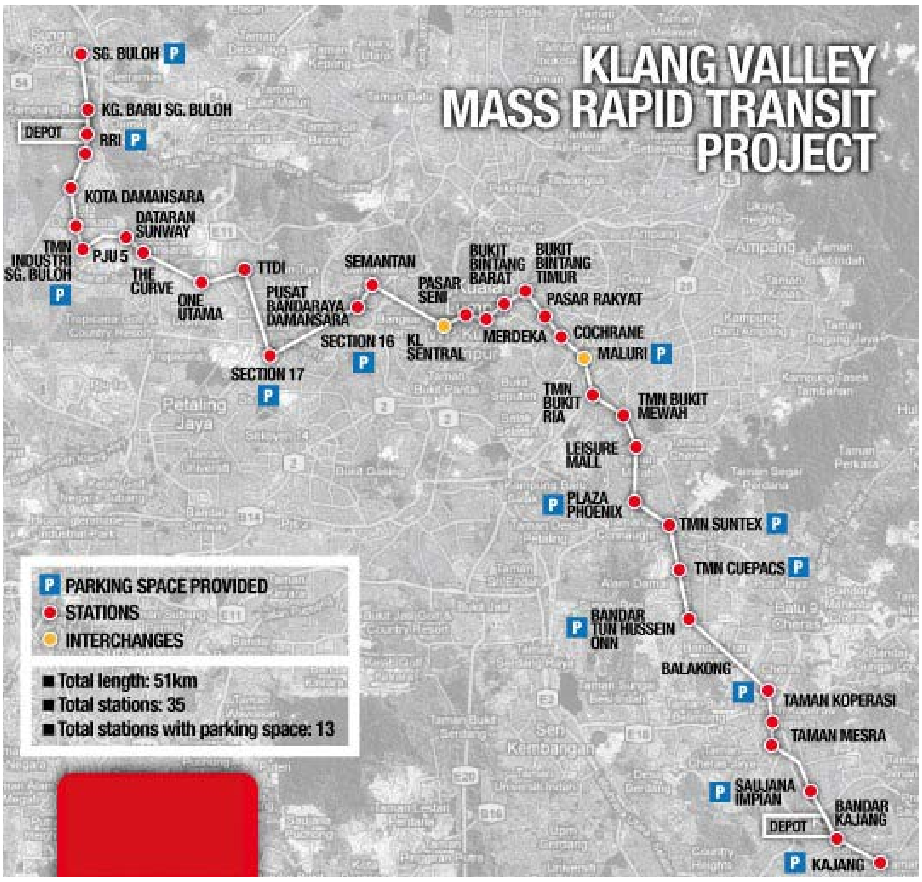

Figure 1.2 Proposed MRT Alignment (Sungai Buloh to Kajang)

Bored piles was chosen as the foundation system to transmit the dynamic load raised from the moving train due to the minimal vibration during construction phase, large lateral load resistance, flexibility of size to suit different subsoil conditions and can be installed into rock bearing strata. In most cases, the axial compression loads from superstructures are designed to be transferred by bored piles to the soil layer. However, in some situations, bored pile is design to transfer load to the rock layers. Loads applied to the bored pile are supported by the rock socket through side shear resistance and end bearing resistance (Horvath et al. 1983).

The bearing resistance is often ignored in current design practice in Malaysia due to difficulty in obtaining proper and consistent base cleaning during construction of bored piles. Neglecting the bearing resistance in design will result in excessive rock socket lengths. Crapps and Schmertmann (2002) suggested that accounting for bearing resistance in design and using appropriate construction and inspection techniques to ensure quality of base cleaning is a better approach than neglecting end-bearing resistance.

Due to uncertainties associated with pile design that may affect safety and economy of a project, pile load tests are usually conducted to verify the design assumptions and load carrying capacity of the piles. Static load tests (SLT) are among the reliable testing method to ensure the satisfactory pile performance with particular reference to the capacity, settlement and structural integrity. Usually, 1 to 2% of the total number of piles is selected for load test. During the test, static load were applied and maintained using a hydraulic jack and were measured with a load cell.

It is a common practice in Malaysia for the pile to be loaded up to twice of the working load, which is regarded as the Test Load of the pile. On most occasions, the results of this test do not show a distinct plunging ultimate load, therefore the results need interpretation to estimate pile capacity or ultimate load.

1.2 Significance of Study

Many attempts have been made to correlate the bearing resistance with the unconfined compressive strength of intact rock and the rock quality designation. A few methods have been proposed for predicting the bearing resistance of bored piles. Of these different methods, empirical and semi-empirical relations have been used most widely. The method used by previous literatures correlates the maximum rock bearing resistance with respect to rock compressive strength and rock quality designation obtained from laboratory test results conducted on the intact rock core samples. However, there is still no such study conducted in Malaysia. It is uncertain how applicable these methods to rock types specifically in Malaysia.

The significance of this study is to ensure the correlations by previous study adopted for design of bearing resistance are satisfactory and in order to be implemented in Malaysia. This study will also provides better understanding on the trends of rock discontinuities particularly of rock quality designation (RQD) and rock compressive strength with respect to maximum rock bearing resistances.

1.3 Objective of the Study

The aim of this study is to identify the most appropriate interpretation methods to estimate the rock bearing resistance of rock specifically granite in Malaysia. The objective of the study comprises of the following:

(i) To review the available design relationship addressing bearing resistance of piles socketed to rock.

(ii) To validate the established empirical designs relationship with respect to field pile load test results.

(iii) To identify the trends in behaviour of rock discontinuities and unconfined compressive strength with respect to maximum rock bearing resistance.

1.4 Scope of the Study

This study is based on the real time construction project of the proposed Klang Valley MRT Jajaran Sungai Buloh to Kajang. Thousands of bored piles have been proposed for foundation supports to the MRT viaducts and station developments which to be founded in wide range of rock types comprised on granite, kenny hill, limestone and kajang formations. The summary of preliminary test piles with types of geological formation is as described in Table 1.1.

However for this study, only the rock bearing resistance of bored piles with diameter varying from 1000mm to 1500mm which were constructed in granite formation has been considered. All of these bored piles were socketed from 1m up to 7.3m into rock and tested with pile load testing.

Table 1.1 : Summary of Preliminary Test Pile with Types of Geological Formation.

Test Pile No.	**Geological Formation**
V1 – PTP 1	Kenny Hill
V1 – PTP 2	Granite
V2 – PTP 1	Granite
V2 – PTP 2	Granite
V3 – PTP 1	Granite
V3 – PTP 2	Granite
V3 – PTP 3	Granite

Table 1.1 : Summary of Preliminary Test Pile with Types of Geological Formation (cont'd)

Test Pile No.	Geological Formation
V4 – PTP 1	Kenny Hill
V4 – PTP 2	Kenny Hill
V5 – PTP 1	Limestone
V5 – PTP 2	Granite
V6 – PTP 1	Granite
V6 – PTP 2	Granite
V6 – PTP 3	Granite
V7 – PTP 1	Granite
V7 – PTP 2	Kajang
V8 – PTP 1	Kajang
V8 – PTP 2	Kajang

The scope of this study is to focus on the prediction of bearing resistance rather than socket shaft resistance. The data for this study was acquired from MMC-Gamuda KVMRT (PDP) Sdn Bhd. These include Soil Investigation Reports, bored piling records and pile load testing results. In total, 13 pile testing results which consists of 4 using static load test and 9 using dynamic load test were reviewed and evaluated.

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