PREDICTION OF SHAFT RESISTANCE OF BORED PILE IN LIMESTONE FORMATION

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Dedicated to my beloved family and all my friends

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ABSTRACT

Piles socketed into limestone are commonly used in Malaysia especially for deep foundation of high rise building at Kuala Lumpur area. The heavy structural loads are transmitted to the bedrock through the contact surface between concrete and the limestone. However much uncertainty involved in the selection of appropriate design procedures for the piles in limestone. Several analytical and empirical methods have been used to evaluate the shaft resistance of piles from three sites located at Kuala Lumpur limestone area. The data of instrumented static load tests were collected for verification purpose. Comparison and analysis were carried out to select the most appropriate method in determining the shaft resistance of rock. Design methodologies by empirical methods that commonly used in Malaysia adopted working rock socket friction based on the rock quality and subject to minimum 5% of rock strength and concrete strength. Some other empirical approaches encounter the strength of intact rock and nature of discontinuities in rock mass to predict the unit shaft resistance in limestone. The other analytical method by modifies friction reduction factor with respect to various rock socket roughness and rock intact strength. The study shows that the predicted skin frictions are highly dependent on unconfined compressive strength and rock quality designation. Findings indicate that Tan (2009) and Salgado (1998) methods well predicted the shaft friction for q_u more than 60MPa. By comparing both Salgado (1998) and Tan (2009) methods, it is found that Tan (2009) method is more appropriate for the bored pile design in Kuala Lumpur limestone as it can provide reasonable predictions of shaft resistance all range of rock quality designation whereby Salgado (1998) method required well establish interpretation of the coefficient of weakness of rocks from the rock coring sample.

ABSTRAK

Cerucuk soket di dalam batu kapur biasa digunakan di Malaysia terutama bagi asas dalam pembinaan bangunan tinggi di kawasan Kuala Lumpur. Pembebanan berat struktur yang hantar kepada batu hampar adalah melalui permukaan sentuhan antara konkrit dan batu kapur. Walau bagaimanapun, didapati banyak ketidaktentuan terlibat dalam pemilihan cerucuk dalam prosedur reka bentuk yang sesuai di dalam batu kapur. Metodologi reka bentuk dengan kaedah empirikal yang biasa digunakan di Malaysia ialah mengguna kaedah yang berdasarkan kualiti batu, dimana tertakluk kepada minima 5% kekuatan batuan dan kekuatan konkrit. Dalam senario ini, beberapa kaedah analitikal dan empirikal telah dijalankan untuk menentu rintangan aci cerucuk dari tiga lokasi yang terletak di kawasan batu kapur Kuala Lumpur. Dan data-data dari ujian beban statik teralat juga dikumpulkan untuk tujuan pengesahan. Perbandingan dan analisis juga dijalankan untuk memilih kaedah yang paling sesuai dalam menentukan rintangan aci dalam batu kapur. Di samping itu, beberapa pendekatan empirikal yang lain juga diguna untuk meramal rintangan aci dalam batu kapur iaitu mengambil kira kekuatan batu utuh dan sifat ketakselanjaran dalam jisim batu. Kajian menunjukkan bahawa ramalan geseran permukaan adalah sangat bergantung kepada kekuatan mampatan dan penetapan kualiti batu. Penemuan menunjukkan bahawa kaedah Tan (2009) dan Salgado (1998) adalah paling munasabah dalam ramalan geseran aci untuk q_u yang lebih daripada 60MPa. Dengan membandingkan kedua-duanya kaedah, didapati bahawa kaedah Tan (2009) adalah lebih sesuai untuk reka bentuk cerucuk di kawasan batu kapur Kuala Lumpur kerana ia boleh memberi ramalan yang lebih tepat dalam mengira rintangan aci untuk pelbagai jenis kualiti batu. Kaedah Salgado (1998) pula memerlukan tafsiran yang baik dalam menentukan pekali kelemahan batu daripada sampel batu yang diperolehi.

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LIST OF SYMBOLS

f_s	-	Unit shaft resistance for each layer of embedded soil
f_b	-	Unit base resistance for the bearing layer of soil
A_s	-	Area of pile shaft
A_b	-	Area of pile tip
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 shaft resistance factor
K_{bu}	-	Ultimate base resistance factor
α	-	Adhesion factor
S_u	-	Undrained shear strength
K_{se}	-	Effective stress shaft resistance factor
σ_v'	-	Vertical effective stress
$\emptyset'$	-	Effective angle of friction of fine grained soils
β	-	Shaft resistance factor for coarse grained soils
q_t	-	Splitting tensile strength of the rock
φ	-	Open joints factor
γ_c	-	Unit weight of concrete
Z_i	-	Depth to middle of layer in meters
f'_c	-	28 day compressive strength of the concrete
P_a	-	Atmospheric pressure
RF	-	Dimensionless roughness factor
Δr	-	Average height of the rough edge
r	-	Nominal socket radius to the base of rough edge
L_t	-	Total distance along the socket wall profile
L_s	-	Nominal socket length

E_m	-	Young's modulus of the rock mass
E_c	-	Young's modulus of intact rock cores
E_s	-	Estimated Young's modulus of the material in seams
L_c	-	Length of core
t_s	-	Thickness of each seam
t_c	-	Thickness of intact rock
ψ	-	Dimensionless factor that reflects variations in the intact strength of the rock and roughness of rock socket.
c_w	-	coefficient of weakness of rocks as a function of rock-jointing
C_s	-	Interface factor

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CHAPTER 1

INTRODUCTION

1.1 Background

Limestone formation covers a large area in Peninsular Malaysia, such as Kuala Lumpur, Ipoh and Langkawi Islands. This type of sedimentary rock consists of mineral calcite or also knows as calcium carbonate. The Kuala Lumpur Limestone is generally described as finely crystalline grey to cream Upper Silurian marble, thickly bedded and variably dolomitic rock. This formation is also well known for its highly erratic karstic features. Sinkhole, slump zone, pinnacles, cavities are common geological hazards in limestone formation.

Bored piles have been used widely in Malaysia to carry heavy loads from structure in the limestone formation. Rock socket frictions in limestone contribute partly for the bored pile capacity, where it helps to transfer the load to the bedrock. Regard to this, there is a difficulty to quantify all the aspects which including surface roughness of rock socket, shearing of rock interface, strength and stiffness of rock socket and profile of socket friction distribution in the rock socket pile design.

Empirical methods are commonly to carry out the estimation of shaft resistance of bored pile in rock. Correlations between the unconfined compression strength of the rock and rock socket bond stress can be used to obtain the shaft resistance of piles in rock. Few analytical methods such as limit unit shaft resistance concept, nonlinear relationship approach have also been developed. Local engineers like Tan (2009) and Neoh (1998) have recommended a typical design or working socket friction values for limestones formations in Malaysia based on their previous experiences. According to Tan (2003), the design rock socket friction is the function of surface roughness of rock socket, unconfined compressive strength of intact rock, confining stiffness around the socket in relation to fractures of rock mass and socket diameter, and the geometry ratio of socket length-to-diameter.

1.2 Problem Statement

Design of deep foundation of high rise building at Kuala Lumpur area have relied heavily on rock socket in bedrock as the principal means of achieving bearing capacity of the bored pile. In current practice, end bearing is usually neglected due to the uncertainty on the cleanliness of pile base, hence; rock sockets in limestone are designed to develop the axial capacity based on side shear. Both analytical and empirical formulations have been widely used in predicting the friction resistance of the pile (Tan, 2009 and Neoh, 1998). Hence, it is essential to study the applicability of these methods applicable in the design of bored pile.

1.3 Objectives of Study

The aim of this project is to review and expose current practices of bored pile design adopted in Malaysia with regard to limestone formation. Therefore the objectives of this study are as below:

(i) To evaluate the available design methodologies for bored piles in limestone formation.

(ii) To estimate the shaft friction of bored pile in limestone by various methods.

(iii) To compare the shaft resistance estimation by the analytical and empirical methods with the results of static load test.

1.4 Scope of Study

The study for this project is based on case studies of bored pile installed in Kuala Lumpur limestone. The locations of the site are at Jalan Yap Kwan Seng, Jalan Stonor and Off Jalan Ampang. The scopes of this study consist of summarization of bored pile design methodologies which include empirical method for geotechnical capacity in soil and rock socket friction empirical and analytical methods for geotechnical capacity in limestone. Shaft resistance calculations of bored pile were performed for each case study is based on the available empirical and analytical methods for estimation of the shaft resistance in rock socket. Field data for analysis were based on site investigation report and instrumented static load test report. Appropriate material properties of limestone through laboratory tests and characterisation of intact rock samples was collected.