INTERPRETATION ON PILE CAPACITY FROM INSTRUMENTED SACRIFICAL PILE LOAD TEST FOR DEEP FOUNDATION SYSTEM

NURUL HUSNA BINTI ABDUL RAZAK

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Faculty of Engineering
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DEDICATION

This master project is dedicated to my outmost supporter of all, my Glorious Allah S.W.T., the Ultimate Helper of all being, The Compassionate and Most Merciful. In all capacity which are truly by Him, I'm trying to realise my little roles in this world on the word of '*iqra*' and '*caliph*' appreciating my tiny existence.

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ABSTRACT

A deep foundation system often offers a lot of uncertainty even though it is the only option for the demanded highly loaded structure to be able to construct. Hence, to increase the level of confidence in the design, a lot of method and procedure have been established to evaluate the certainty of the pile design. This paper will discuss the prediction of geotechnical capacity of the pile from the instrumented pile load test conducted at very deep strata of more than 30m below ground level in a residual soil originated from the youngest metasedimentary rocks; Kenny Hill formation in Kuala Lumpur area. A sacrificial instrumented pile load test using both traditional static load method which is top-down maintained load test via anchor reaction system and alternative test using bi-directional load test with an axially compressive load are assessed to find and compare the behaviour of the geotechnical pile capacity. The comparison of pile capacity was attempted by using various method of interpretation such as Van der Veen, Chin, Decourt's extrapolation, Fuller and Hoy, Butler and Hoy, De Beer, and the Davisson method. From the study, the method of interpretation has been grouped accordingly namely as mathematical method group by Van der Veen, Chin and Decourt's extrapolation; settlement limitation group by Fuller & Hoy, Butler & Hoy and De Beer; and lastly the graphical construction group by the Davisson method. This grouping method is suggested by Hirany & Kulhawy, 1988.From the study, it can be concluded that the settlement limitation method is the most suitable to be adopted since the result are found consistent in producing the lower bound between three interpretation group. The skin friction evaluation also has been access using the said method and resulted in a good agreement with the pile capacity trend, hence it can be assured that the method of interpretation can be applied to find both total geotechnical capacity and skin friction of the geotechnical parameter in foundation design. In addition, the study has also helped to eliminate the variability of independent factor by having a similar type of sacrificial replacement pile namely barrette pile cast-in situ, cases are using static pile load test with similar axially compressive load and located in the identical region of ground profile. From this, it is found out that both type of pile load test is able to produce identical result irrespective the chosen traditional by head down top load method or even bidirectional method, irrespective the deep strata of soil condition and also irrespective the higher load applied at relatively more than 40MN.The comparison of these interpretation method could help the designers to interpret the most suitable prediction analysis for deep foundation analysis for a more robust and confidence design.

ABSTRAK

Sistem asas dalam sering kali memberikan banyak ketidakpastian walaupun merupakan satu-satunya pilihan untuk membina struktur yang membawa beban yang tinggi. Oleh itu, untuk meningkatkan tahap keyakinan terhadap reka bentuk, banyak kaedah dan prosedur telah dibuat untuk menilai kepastian reka bentuk cerucuk. Kajian ini dilakukan bertujuan membincangkan ramalan kapasiti geoteknik cerucuk dari ujian beban cerucuk berinstrumen yang dilakukan pada strata yang sangat dalam lebih dari 30m di bawah permukaan tanah di tanah baki yang berasal dari batuan metasedimen termuda; Formasi Kenny Hill di kawasan Kuala Lumpur. Ujian beban cerucuk instrumen pengorbanan menggunakan kedua-dua kaedah beban statik tradisional iaitu ujian beban dikekalkan dari atas ke bawah melalui sistem reaksi sauh dan ujian alternatif menggunakan ujian beban dua arah dengan beban mampatan paksi dinilai untuk mencari dan membandingkan tingkah laku cerucuk geoteknik kapasiti. Perbandingan kapasiti cerucuk dicuba dengan menggunakan pelbagai kaedah tafsiran seperti Van der Veen, Chin, ekstrapolasi Decourt, Fuller and Hoy, Butler and Hoy, De Beer, dan kaedah Davisson. Dari kajian tersebut, kaedah pentafsiran telah dikelompokkan dengan tepat iaitu sebagai kumpulan kaedah matematik oleh Van der Veen, Chin dan ekstrapolasi Decourt; kumpulan had enapan oleh Fuller & Hoy, Butler & Hoy dan De Beer; dan terakhir kumpulan pembinaan grafik dengan kaedah Davisson. Kaedah pengelompokan ini disarankan oleh Hirany & Kulhawy, 1988. Dari kajian ini, dapat disimpulkan bahawa kaedah had enapan adalah yang paling sesuai untuk digunakan kerana hasilnya didapati konsisten dalam menghasilkan batas bawah antara tiga kumpulan interpretasi. Penilaian geseran kulit juga dapat dicapai dengan menggunakan metode tersebut dan menghasilkan kesepakatan yang baik dengan tren kapasiti cerucuk, oleh itu dapat dipastikan bahawa kaedah penafsiran dapat diterapkan untuk menemukan kedua-dua kapasiti geoteknikal dan geseran kulit parameter geoteknik dalam reka bentuk asas. Di samping itu, kajian ini juga membantu menghilangkan variabel faktor bebas dengan mempunyai jenis tiang penggantian pengorbanan yang serupa iaitu barrette pile cast-in situ, kes menggunakan ujian beban tiang statik dengan beban mampatan paksi yang serupa dan terletak di kawasan yang sama profil tanah. Dari ini, didapati bahawa kedua-dua jenis ujian beban tiang dapat menghasilkan hasil yang sama tanpa mengira kaedah tradisional dengan kaedah beban atas atau kaedah dua arah, tanpa mengira lapisan tanah yang dalam dan juga tanpa beban yang lebih tinggi yang dikenakan pada lebih daripada 40MN. Perbandingan kaedah tafsiran ini dapat membantu para pereka untuk menafsirkan analisis ramalan yang paling sesuai untuk analisis asas mendalam untuk reka bentuk yang lebih mantap dan yakin.

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LIST OF ABBREVIATIONS

A_b	-	Area of pile base
A_c	-	Cross-sectional area of concrete
A_s	-	Area of pile shaft
A_{st}	-	Cross-sectional area of steel
ASSHTO	-	American Association of State Highway and Transportation Officials
ASTM	-	American Standard Testing Method
BS	-	British Standard
CRP	-	Cone Rate Penetration
CIRIA	-	Construction Industry Research and Information Association
DVL	-	Design Verification Load
E_c	-	Concrete modulus
E_s	-	Young's modulus of elastic in steel
E_{total}	-	Total modulus
f_{cu}	-	Characteristic strength of concrete
FHWA	-	Federal Highway Administration, United States of America
FS_b	-	Design safety factor for Base resistance, minimum 3.0
FS_s	-	Design safety factor for Shaft resistance, minimum 2.0
ICE	-	Institution of Civil Engineers, United Kingdom
JKR	-	Jabatan Kerja Raya Malaysia
K_b	-	Coefficient of base resistance factor
K_s	-	Coefficient of shaft resistance factor
N_s	-	N values along the pile shaft from Standard Penetration Test
N_b	-	N values at pile base from Standard Penetration Test
m	-	meter
mbgl	-	Meter below ground level
mm	-	milimeter

mRL	-	Meter reduced level
MLT	-	Maintain Load Test
MPa	-	MegaPascal
PTP	-	Preliminary Test Pile
O-cell	-	Osterberg cell
Q_b	-	Ultimate end bearing resistance
Q_{ps}	-	Positive ultimate skin friction resistance
Q_{ult}, P_{ult}	-	Ultimate pile capacity
SPERW	-	Specification for Piling and Embedded Retaining Walls
SPT	-	Standard Penetration Test
SS CP4	-	Singapore Standard Code of Practice 4
SWL	-	Specified working Load
UTM	-	Universiti Teknologi Malaysia
WL	-	Design Resistance of Single Pile

LIST OF SYMBOLS

δ	-	Displacement,differential
ε	-	Stran
σ	-	Stress,load
A	-	Area
D	-	Diameter
E	-	Young’s modulus
L	-	length
P	-	Load

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CHAPTER 1

INTRODUCTION

1.1 Overview of Topic

Throughout the history of engineering, founding a structure are always divided into two categories which is shallow foundation and deep foundation. During the design stage, the soil-structure interaction between the structural capacity of the founding structure and geotechnical capacity of the founding strata need to be scrutinized in order to have a more reliable, economical and robust design.

More often, the geotechnical capacity which comprises of skin resistance and end bearing are more critical where the certainty of the soil performance in the subsurface are more complex in a confined space underneath the ground. To cater this, the verification of the geotechnical parameters is introduced using in-situ soil testing. For a pile foundation, in-situ pile load test is commonly selected to justify the design assumption which could be tested on both whether on working pile or preliminary pile. However, as the pile load test is an in-situ test, the interpretation of the result would be vary considering the uncertainty of the ground response or behaviour, hence even though few methods currently available to interpret the result obtain, the end results still occupied at least only three quarter of design conformance. Hence, in this study, the comparison on the interpretation of maintain load test will be investigated to find a trend that suit a more reliable pile test interpretation for a residual soil overlying highly weathered limestone of Kenny Hill formation in Kuala Lumpur, Malaysia.

1.2 Problem Background

According to British Standard BS 8400, pile load test generally was made in purpose on finding the expected load-settlement behaviour or even determining the ultimate bearing capacity of the pile. Loading tests on pile can be classified either by static load test or by dynamic load tests. The static pile load test is conducted at low strain where the loading rate may have taken more than 24 hours which takes longer time than the dynamic pile load test, which is conducted at considerably higher strain. Dynamic pile load test consists of estimating soil resistance and its distribution from force and velocity measurements obtained near the top of a pile by impacting a hammer or drop weight as a simulation of loading rate hence the result obtain is more immediate (Hussein et.al. 2012).

While, for a static load test, several subdivisions of the test can be further categorized based on type of load imposed to i.e (compression load, tension load or lateral load). A compression load which normally be applied vertically to represent load transfer from the above superstructure to foundation are the most common pile load test adopted in the industry currently. It is also known that the pile load test using compression load also have developed into few methods of implementation namely statically vertical maintain load test, quick maintained load test, cone rate penetration and also bi-directional pile load test. Each method is unique on their own and the designer should use their sound engineering judgement to choose the suitable method to suit their objective. A conventional maintain load test is always come in a costly and timely consuming rather than dynamic pile load test, hence, the choice of the pile load test procedure relatively concurs due to many reasons.

There are two type of maintained pile load test that will be study which is Maintained pile load test via reaction pile and bi-directional pile load test. Both tests are using the same dimension of pile test which is barrette pile of a size 2.8m width and 1.5m breadth. These instrumented pile load tests are simulated for a replacement type of pile which taking a pile load test at almost three times working load of 57,300 kN for PTP-1 and 48,879kN for PTP-2 respectively. The test is meant for a pile to load until failure by assuming a test load of almost three times working load. The pile length for PTP-1 which are using bi-directional test is 57.5m while for PTP-2 using static load test by anchor reaction system, the pile length is 27.3m respectively. These pile tests are conducted in a residual soil overlying limestone bedrock with a layer of highly weathered limestone interfacing both layers.

1.3 Problem Statement

In construction works, to substantiate the piling work for structure with high loading in difficult ground condition often require either greater penetration length of pile or a total of summation of high amount of pile group. This is relatively not probable for a constraint workspace especially in term of construction mobilisation accessibility where the activity may require more space to place a huge or numerous numbers of machinery to accommodate the longer pile length. Greater penetration length of pile use in the design may also post a query on the reliability of the design whether it is design in an overly conservative approach. Hence, to cater this issue, pile test usually would be conducted to verify the design even though the cost incurred is high for a short term finding, but in term of overall cost of the design, it is very prudent to conduct pile test for a greater saving on the whole project. As such, once a pile test result is obtained, the interpretation of the result is another set of challenge. Often, the interpretation of the result is aiming to find the geotechnical capacity of the test field. The interpretation can be in term of many approach available in the literature which will give a misperception of which method is the best to be adopted. This study aims to find the suitability of different method of pile load test interpretation for a deep pile with layer of soil containing a range of residual soil and highly weathered limestone.

1.4 Research Aims

This research aims to study the interpretation of static pile load test namely maintained load test and bi-directional load test with respect to Kenny Hill geological formation of Kuala Lumpur on sacrificial barrette pile using various method of interpretation. The interpretation will cover all three type of method of interpretation which is mathematical model, settlement limitation and graphical construction.

1.4.1 Research Objectives

The objectives of the research are:

a. To determine the pile capacity of the pile load test using various method of interpretation

b. To determine the mobilised skin friction of the pile load test using various method of interpretation

c. To evaluate the suitable method in interpretation of pile capacity and skin friction

1.5 Scope of Work

The study is carried out based on Maintain Load Test (MLT) using anchor reaction and Bi directional with single layer of O-cell. The load test is performed for axially loaded compression piles up to some pre-assigned load cycle or load up to failure. The chosen pile is barrette pile where it can be grouped as replacement pile. The case area for this study is residual soil in Kenny Hill formation of Kuala Lumpur, Malaysia which is one of the major geological formation of Kuala Lumpur particularly where the geological stratigraphy could also be classified under a group of sedimentary rock formation.

1.5.1 Limitation of Research

The following limitation used in this study also listed as below:

(a) The field subsurface of this study is classified as residual soil which originated from limestone; also known as Kenny Hill formation, the youngest known metasedimentary rocks in Kuala Lumpur area.

(b) The method of interpreting the pile load test data is by empirical methods such as Van der Veen, Chin, Decourt's extrapolation, Fuller and Hoy, Butler and Hoy, De Beer, and the Davisson method

(c) The comparison of the interpretation will be limited to the method used in this study

(d) This study will look into the skin friction only.

1.6 Expected Finding

The expected finding in this study is to generate a pile capacity and mobilised skin friction from the interpretation method. The result will then be compared to find the most suitable interpretation method for a deep replacement pile casted in a layer of soil containing a range of residual soil and highly weathered limestone in Kuala Lumpur, Malaysia.

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