LOAD RESISTANCE BEHAVIOUR AND INSTALLATION ASSESSMENT OF DRIVEN SPUN PILE

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Dedicated to the late Mr.Subramaniam, beloved brother who shared my every moment of joy and sorrow

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ABSTRACT

Three (3) numbers of fully instrumented with global strain gauges and extensometer test Spun piles, namely PILE-A, PILE-B and PILE-C were installed using 25Ton hydraulic hammer along the coastal area which represent various subsoil conditions based on soil investigations. The static load test on instrumented piles provide more information on pile behaviour when loaded such as shaft resistance at different layer and end bearing, elastic shortening, toe movement, development of shaft and base resistance during pile displacement. This information leads to a correlation between SPT-N value and ultimate shaft and end bearing resistance. Therefore an attempt was made on this study to analyze the load test results of these instrumented spun piles to develop the correlation for subsoil at coastal area. It is assessed that the ultimate shaft friction values in the upper soft clays generally range from about 12 kPa to 20 kPa. Ultimate Shaft friction values for lower lying materials below soft clays with SPT N values from about 4 to 50 (blows/300mm) range of 2N kPa and a limiting shaft friction value of about 150 kPa. The ultimate end bearing values correlate to about 80N to 120 N kPa. Spun piles need to be closely observed during installation using hydraulic impact hammer to avoid any damages on pile and at pile joints. All the piles are fully monitored during installation using PDA analyzer and the results assessed to verify the installation technique. The assessment shows that all 3 piles were successfully installed without integrity problems. A theoretical drivability study also carried out using GRLWEAP software to provide drivability assessment and compared with actual drivability of the piles. Results from GRLWEAP is very much similar to data occurred during pile installation and confirms the drivability of spun piles at this coastal area without integrity problem. The GRLWEAP software offers variety of model and analysis option which lead to proper selection of equipments at site.

ABSTRAK

Tiga cerucuk spun yang diinstrumentasi dengan alat-alat ukur gobal strain gauge dan Extensometer, iaitu PILE-A, PILE-B dan PILE-C didorong dengan menggunakan tukul hidrolik 25tan di sepanjang kawasan pesisir yang terdiri daripada pelbagai jenis lapisan tanah berdasarkan penyelidikan tanah. Ujian beban statik pada cerucuk spun yang diinstrumentasi memberi maklumat lebih lanjut mengenai perilaku cerucuk ketika dimuat dengan beban iaitu seperti geseran di antara pelbagai lapisan tanah dengan cerucuk dan komponen rintangan hujung, pemendekkan elastik, pergerakan hujung cerucuk, pembangunan rintangan dengan permukaan cerucuk dan hujung cerucuk terhadap pergerakan cerucuk. Maklumat ini membolehkan kepada korelasi antara nilai SPT-N dengan daya rintangan antara permukaan cerucuk dan rintangan hujung cerucuk. Oleh kerana itu satu percubaan dilakukan pada kajian ini untuk menganalisis hasil uji beban dari cerucuk spun yang diinstrumentasi untuk mengembangkan korelasi di anatara lapisan tanah bagi kawasan pesisir. Hasil daripada ujian ini menunjukkan bahawa nilai geseran permukaan cerucuk dengan tanah liat lembut marin (soft marine clay) adalah daripada 12 kPa hingga 20 kPa. Nilai geseran maksimum anatara permukaan cerucuk dengan tanah di bawah tanah liat lembut marin dengan nilai N SPT daripada 4 hingga 50 (blows/300mm) adalah 2N kPa dan nilai geseran maksimum permukaan cerucuk dihadkan kepada 150 kPa. Nilai rintangan hujung cerucuk dianggarkan sekitar 80N hingga 120N kPa. Pemanduan Cerucuk spun ke dalam tanah mengunakan tukul hidrolik 25tan perlu dilakukan dengan cermat bagi mengelakkan kerosakan pada cerucuk dan sendi cerucuk. Ketiga-tiga cerucuk spun dipandukan ke dalam tanah dengan mengunakan tukul hidrolik 25tan dan diperhatikan dengan PDA Analyzer bagi mengesahkan teknik panduan ini. Penilaian ini menunjukkan bahawa ketiga-tiga cerucuk ini berjaya dipandukan tanpa sebarang masalah integriti. Sebuah kajian secara teori dilakukan terhadap

teknik panduan ini dengan menggunakan perisian GRLWEAP untuk mengesahkan teknik pemanduan ini dan juga dibandingkan dengan keputusan diperolehi oleh PDA Analyzer di tapak. Keputusan analisis daripada GRLWEAP sangat mirip dengan keputusan PDA dan ini mengesahkan teknik memandu cerucuk di kawasan pesisir tanpa masalah integriti. Perisian GRLWEAP menawarkan pelbagai pilihan model dan analisis yang mendorong pemilihan peralatan yang sesuai di tapak pembinaan.

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f_{su}	-	Ultimate shaft resistance
f_{bu}	-	Ultimate base resistance
K_s	-	Ultimate shaft resistance factor
K_b	-	Ultimate base resistance factor
N	-	SPT value
L	-	Length in soil
D	-	Diamater of pile
Q_d	-	Applied load
Q_b	-	Tip load
Q_s	-	Shaft load
f	-	Unit load transfer in skin friction
q	-	Unit load transfer in end bearing
A_b	-	Cross section area of base
A_s	-	Side surface area of pile
Q_t	-	Ultimate point resistance
α	-	Adhesion factor
s_u	-	Undrained shear strength (kPa)
K_{se}	-	Effective stress shaft resistance factor (can assumed as K_o)
σ_v '	-	Vertical effective stress (kPa)
Φ'	-	Effective angle of friction (degree) of fined grained soils
N_c	-	Bearing capacity factor
K	-	Coefficient of lateral earth
σ'	-	Effective stress pressure at the point of interest
Φ	-	Friction angle between soil and pile wall
q_b	-	End bearing
σ'_v	-	Effective vertical stress

N_q	-	Bearing capacity factor
W	-	Ram weight
H	-	Ram drop height
R	-	Pile capacity
s	-	Pile penetration per blow
Rd	-	Dynamic soil resistance
Js	-	Smith damping value
Vp	-	Pile element velocity
Rs	-	Static soil resistance
P	-	Pile load along shaft
ε	-	Strain
E_c	-	Concrete secant modulus
A_c	-	Cross section area of pile section
M_t	-	Tangent modulus of composite pile material
β	-	Shaft resistance factor for coarse grained soils.
σ	-	Stress (load divided by cross section area)
$d\sigma$	-	Change of stress
$d\varepsilon$	-	Change of strain
A_p	-	Cross-sectional area of the shaft at the plane of strain gauges
E_{comp}	-	Composite modulus of concrete & steel at the strain gauge plane
E_s	-	Secant modulus of composite material
E	-	Young's modulus
υ	-	Poisson's ratio
A	-	Slope of tangent modulus
B	-	y-intercept of tangent modulus line
D	-	Diameter of the pile,

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CHAPTER 1

INTRODUCTION

1.1 Background

Foundation is an essential and important part of any structure that transmits the structural loads safely to the underlying soils or rock. Foundations can be classified into shallow foundations and deep foundations. Unlike structural materials such as steel or concrete that can be manufactured to specifications, the subsoil condition and geology varies from location to location and foundations are to be designed to suit specific site conditions. Where competent soils to sustain the structural loads are not available at a shallow depth, deep foundations such as driven piles and bored piles are commonly used. In Malaysia, to support high loading structures such as tall rise buildings and bridges, deep foundations are commonly used. Considering the economy and ease of pile installation, deep foundation comprising of driven piles are common when the method is assessed feasible at a particular project site.

In Malaysia, pre-cast pre-stressed spun concrete piles are manufactured locally and are commonly used to support bridges and heavy coastal structures such as jetties and ports. They have been installed in deep marine deposits in the coastal areas. Spun piles are basically driven into soil by two methods; with hydraulic impact hammer for high loading capacity achievement, and by jacked-in method to minimize the noise and vibration to surrounding environment in urban areas.

Geotechnical capacity of Spun piles are normally designed based on the standard penetration test results (soil investigation) in Malaysia and pile capacity verified by pile tests such as high strain Pile Dynamic Test (PDA) and Static Loads (maintain load) Test. In order to get more accurate and detailed verification, fully instrumented pile with multi level strain gauge and extensometer can be subjected to static load test to establish site specific correlation of the shaft and end bearing parameters against the field test results such as Standard Penetration Tests (SPT).

Spun piles installation need to be closely observed while using hydraulic impact hammers to avoid any damage. During driving, the piles can be monitored continuously for driving stresses and pile integrity using a Pile Driving Analyser. Proper pile installation and quality control is an important element in every driven piling project. The piles must be driven to the required capacity without integrity problems**.** Some drivability studies need to be carried out prior to installation using existing data to refine the driving methods and equipments to be used.

Since the usage of large diameter spun piles driven with hydraulic impact hammer is being commonly used, and in many occasions, installation difficulties related with pile breakage due to improper choice of driving equipment and installation methods have been experienced, an attempt has been made to assess the installation of Driven Piles and also study its load resistance behaviour in this project.

1.2 Problem Statement

There are many methods are studied to verify the load and settlement of piles. But for the driven spun pile, the most appropriate method to verify the capacity and pile integrity is static load test and pile driving analyser method. However, it is difficult to verify the shaft friction contributed by each different soil layers and load transfer behaviour of pile.

Since the large diameter spun piles driven with hydraulic impact hammer is being commonly used, and in many occasions, installation difficulties related with pile breakage due to improper choice of driving equipment and installation methods have been experienced. During construction Stage, verification of suitability of the pile driving equipment, hammer performance, driving stresses induced in piles, pile integrity; verification of the capacity at end of driving and with time and pile settlement need to be observed.

1.3 Objectives

The aim of conducting this study is to analyze spun pile installation by driven method and load resistance behaviour of driven spun pile. In order to achieve the purpose of study, three objectives had been identified:

1) To develop a correlation in between ultimate shaft and base resistance and SPT-N value using load transfer behaviour of spun pile based on instrumented test pile.
2) To assess the drivability of large diameter spun piles at coastal area using available continuous PDA monitoring results.
3) To compare the PDA results with GRLWEAP software output and confirms the drivability of large diameter spun piles at this coastal area.

1.4 Scope

In this project paper special attention is provided to the fully instrumented large diameter driven spun pile by hydraulic drop hammer method at coastal area (marine Clay) and underlain by residual soils. The spun piles are vertically tested with both static load test and high strain dynamic test.

The data for this paper is obtained from real time projects conducted in construction industry. In this case, the piles are fully instrumented and continuously monitored using Pile Driving Analyser during installation.

1.5 Importance of Study

Pile instrumentation with strain gauges and extensometer should be installed at appropriate depth will provide developed shaft friction capacity and end bearing capacity at different type of layer and load transfer behaviour of pile during loading and settlement. This valuable data will lead to optimization in pile length and safe foundation as well as huge cost saving in the project. Spun pile drivability analysis using existing continuous PDA results available and soil investigation results enable evaluation of driving methods, pile stresses to be controlled to avoid integrity problem, and equipment type and ability of spun pile to be driven at require depth.