PREDICTION OF ULTIMATE LOAD BEARING CAPACITY OF DRIVEN PILES

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A project report submitted in partial fulfillment
of the requirements for the award of the degree of
Master of Engineering (Civil – Geotechnic)

Faculty of Civil Engineering
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NOVEMBER 2006

ABSTRACT

Due to variation in soil layers, it is not easy for engineer to be assured that theoretical design of piles comply with the actual site condition. Thus, every design of piled foundations carries its own uncertainty and risk. This project evaluates the applicability of eight methods to predict the ultimate bearing capacity of spun driven friction piles. Analyses and evaluations were conducted on four piles of different sizes and lengths that failed during pile load testing. The load test interpretation methods, pile driving formulae, as well as the Meyerhof method (static analysis) were used to estimate the bearing capacities (Q_p) of the investigated piles. The failure loads were the maximum measured load carrying capacities (Q_m) from pile load test. The pile capacities determined using the different methods were compared with the measured pile capacities obtained from pile load tests. Three criteria were selected as basis of evaluation: the best fit line for Q_p versus Q_m, the arithmetic mean and standard deviation for the ratio of Q_p/Q_m, and the cumulative probability for Q_p/Q_m. Results of the analyses show that the best performing method is Butler and Hoy method (load test interpretation method). This method is ranked number one according to the mentioned criteria.

ABSTRAK

Adalah susah bagi seseorang jurutera untuk memastikan rekaan asas cerucuknya secara teori adalah sama dengan keadaan di tapak disebabkan oleh perbezaan lapisan tanah. Oleh itu, setiap rekaan asas cerucuk mempunyai ketidakpastian dan risiko yang tersendiri. Projek ini dijalankan untuk menilai kesesuaian lapan jenis kaedah menentukan keupayaan muktamad cerucuk geseran terpacu terputar. Analisis dan penilaian telah dijalankan ke atas empat cerucuk terputar yang berlainan saiz dan panjang dan telah gagal dalam ujian beban. Kaedah interpretasi ujian beban, formula-formula penanaman cerucuk dan kaedah Meyerhof (analisis statik) telah diguna untuk menentukan keupayaan muktamad (Q_p) cerucuk berkaitan. Beban gagal merupakan beban maksimum (Q_m) yang telah diukur semasa ujian beban dijalankan. Nilai yang ditentukan oleh kaedah-kaedah yang dinyatakan telah dibandingkan dengan beban maksimum yang telah diukur dari ujian beban. Tiga jenis kaedah penilaian telah dikenalpasti iaitu: garisan lurus terbaik untuk Q_p melawan Q_m, pengiraan purata dan taburan normal piawai untuk nisbah Q_p/Q_m dan kebarangkalian kumulatif untuk Q_p/Q_m. Keputusan analisis menunjukkan kaedah Butler and Hoy (kaedah interpretasi ujian beban) merupakan kaedah paling baik. Kaedah ini terletak pada tahap nombor satu mengikut kriteria yang dinyatakan.

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A, A_p	=	Pile cross-sectional area
c_u	=	Undrained cohesion of the soil
C	=	Coefficient for different types of hammers
C_N	=	Correction factor with variation of vertical overburden stress
CV	=	Coefficient of variation
D	=	Diameter/width of pile
E	=	Modulus elasticity of pile material
f_{av}	=	Unit friction resistance at any given depth
H	=	Drop of hammer
ID	=	Identification
K	=	Earth pressure coefficient
L	=	Pile length
L_b	=	Length of pile embedded into bearing stratum
n	=	Coefficient of restitution
N	=	Average standard penetration number
N_{cor}	=	Corrected average standard penetration resistance values
N_q, N_c	=	Bearing capacity factor
p	=	Perimeter of pile
p_a	=	Atmospheric pressure
P_{50}	=	50 percent cumulative probability
P_{90}	=	90 percent cumulative probability
Q, Q_{va}	=	Applied load during pile load test
Q_m	=	Maximum measured bearing capacity of pile
Q_p	=	Predicted failure/ultimate load
Q_s	=	Skin resistance of pile
Q_t	=	Ultimate point resistance
R^2	=	Coefficient of determinations

Δ	=	Correspond settlement of each applied load
Δ_u	=	Failure settlement
S	=	Final set
S_c	=	Column spacing
u_e	=	Excess pore water pressure
W_p	=	Weight of pile
W_R	=	Weight of the ram
γ'_v	=	Vertical effective/overburden stress
ϕ	=	Soil friction angle
α	=	Empirical adhesion factor
λ	=	Empirical adhesion factor
η	=	Efficiency factor (Janbu formula)
ε	=	Efficiency factor (ENR formula)
δ	=	Total settlement
δ_ϕ	=	Soil-pile friction angle
δ_a	=	Allowable total settlement
δ_D	=	Differential settlement
δ_{Da}	=	Allowable differential settlement
θ_a	=	Allowable angular distortion
ω	=	Tilt
μ	=	Mean
σ	=	Standard deviation

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Deep foundations are usually referred to as pile foundations. Pile foundations are normally used due to some situation as follows (Henry, 1986):

(i) When upper soil layers are weak and unable to support the structural loads.
(ii) When underground water level is not constant.
(iii) When upper soil layers are susceptible to large settlement.
(iv) When the structure is subjected to lateral loads.

The principal function of a pile foundation is to transfer load to lower levels of the ground which are capable of sustaining it with an adequate factor of safety and without settling under normal working conditions by an amount detrimental to the structure (Henry, 1986).

There are many different types of pile in use today, such as timber piles, concrete piles, steel piles, composite piles and others. The choice of pile type for a particular job depends upon the combination of all the various soil conditions and the magnitude of the applied load; for example, timber piles are usually used in water structure while precasted concrete piles are usually used in housing estate.

Current practice of pile design is based on the static analysis for example Meyerhof Method, Vesic Method and Coyle & Castello methods. Due to the uncertainties associated with pile design, field tests (pile load tests) are usually conducted to verify the design loads and to evaluate the actual response of the pile under loading. Static pile load tests are a verification tool for pile design and they cannot be a substitute for the engineering analysis of the pile behavior. Maintained Load Test Method (ML Test) is considered as the standard method by Jabatan Kerja Raya (JKR). This test however takes 2-3 days to complete. Due to the long period of time needed to conduct ML Test, it contradicts with the current construction industry practice which is time-saving. Hence, Dynamic Load Test (DLT) especially Pile Driving Analyzer (PDA) is gaining popularity in construction industry. However, ML Test should have the final say on the ultimate bearing capacity of piles.

Due to variation in bearing stratum, it is not easy for engineer to be assured that theoretical design of piles comply with the actual site condition. Thus, every design of piled foundations carries certain amount of uncertainty and risk. This report presented the effort undertaken to identify the most appropriate methods for predicting the axial bearing capacity of piles driven to set. These methods include static analysis, pile driving formulae, and interpretation method. The static analysis is the Meyerhof Method. Five interpretation methods selected are Chin's Method, De Beer's Method, Brinch Hansen's 80 Percent Criterion Method, Butler and Hoy's Method, and Fuller and Hoy's Method. These methods are described in detail by Nor Azizi (2003).

1.2 Objectives

The aim of this study is to identify the most appropriate interpretation methods to estimate the ultimate axial bearing capacity of piles. The objectives of the study are:

(i) To determine the ultimate bearing capacity of piles from illustrated full-scale pile load tests.

(ii) To predict and calculate the bearing capacity of pile from static analysis, pile driving formulae, and interpretation method.

(iii) To identify the most accurate method to predict pile bearing capacity by comparing the predicted and calculated results with the actual results from pile load tests.

1.3 Scope of Study

This study is only considering the carrying capacity of spun piles of different sizes driven to set. Other pile types such as timber piles and steel pipes were not covered in the analyses. Four sets of data were acquired from Taisei Corporation. Their testing program was conducted in Mukim Jimah power plant on November 2005. Square concrete piles are obsolete in this study due to different load transferring mechanism (Hani and Murad, 1999). Only spun friction piles that tested to failure are considered in this study.

Data acquired includes soil investigation reports, piling reports and pile load tests reports. Soil investigation reports revealed the soil strata at the site and the soils' parameters, piling information and depth at which the piles set was revealed from piling records while pile load tests reports gave the actual carrying capacity of the piles.

This study focused on the applicability of proposed methods to predict the ultimate axial compression load carrying capacity of piles. Data from soil investigation reports was used in static analysis while pile load tests data is essential in interpretation method. Information from piling records was used in pile driving formulae. All of the methods are described in detail in the literature review section of this report. The predicted capacity was compared with the actual carrying capacity of piles from pile tests based on mentioned criteria. The method which ranked number according to mentioned criteria is considered as the most accurate method and is recommended for pile design practice.

1.4 Importance of Study

Static analysis formulae and pile driving formulae are not recommended as the sole means of determining the acceptability of a pile, except on small jobs (Fleming, 1985). These analyses do not describe the complex mechanics of pile driving in rational way and interaction between pile and the surrounding soil is poorly modeled. Thus, it is important to determine accuracy from these formulae through comparison with actual bearing capacity from site. The differences can be used as a guideline when pile load tests are not able to be conducted.

The problems with many of the interpretation methods are that they are either empirical methods or are based on set deformation criteria. Several methods are also sensitive to the shape of the load-settlement curve and it is preferable to use a considerable number of load increment to define the shape clearly; for example, Chin's Method assumes the load-deformation curve is hyperbolic and is an empirical method. An engineer may have difficulty in choosing the best method to interpret the static load test data. This study is able to help an engineer to identify the suitability of the proposed interpretation methods to predict the ultimate bearing capacity of spun piles driven to set. Moreover, through the analyses, the most appropriate method is identified.