UNIVERSITI PUTRA MALAYSIA

THE DEVELOPMENT OF AN ALGORITHM TO DETERMINE AXIAL CAPACITY OF PILES FROM SPT N-VALUES

JASMIN A/L AMBROSE

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JASMIN A/L AMBROSE

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To God, Appa, Amma, Anan, Tangai, and Abhe.

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Chairman: Dr. Rosely Ab.Malik

Faculty: Engineering

An algorithm was developed to determine axial capacity of piles in sand and clay. The standard static formulae to determine pile capacity in clay were selected (α-API, λ, SEMP and RAND) and the calculated capacities were calibrated using measured results to produce prediction formulae. For capacity prediction in sand, comparison of results using other methods (Davisson and Chin's formulae) were selected and re-calibrated according to the iterative technique (IT). The combined calibrated formulae (The Algorithm) were later tested using five static loading test results. The comparison between measured and predicted capacities was conducted using standard deviation values to determine the amount of error in the prediction.

Final analysis showed that a combination of capacity prediction formulae calibrated from Davisson's failure criterion for piles in

sand and America Petroleum Institute formula for piles in clay, [D]+[API], compared to measured capacity from Butler & Hoy failure criterion was the most consistent algorithm. Another comparison between measured capacity from Pile Dynamic Analyzer (PDA), predicted capacity using [D]+[API] and calculated capacities from iterative technique for piles in sand and clay [IT]+[IT] was conducted. Results indicate that [IT]+[IT] is more consistent with PDA analyzer results than [D]+[API] results.

In the search to determine a consistent yet suitable and advanced method of determining pile capacity, an iterative technique was also developed whereby IT has long been used in numerical analysis for microcomputers (engineering software). The developed IT was used for all cases of algorithm testing. It is speculated that better correlation values can be obtained if more loading test data are available during the course of this study.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Master Sains

MEMBENTUK SUATU ALGORITMA UNTUK MENENTUKAN BEBANAN CERUCUK MENEGAK MENGGUNAKAN NILAI SPT-N

Oleh

JASMIN AMBROSE

November 2000

Pengerusi: Dr. Rosely Ab.Malik

Fakulti: Kejuruteraan

Suatu algoritma telah diwujudkan untuk menentukan beban menegak cerucuk tertanam dalam tanah pasir dan tanah liat. Formula static yang biasa digunakan untuk menentukan beban menegak yang telah dipilih (α-API, λ, SEMP dan RAND) dan beban menegak yang dikira telah dibetulkan menggunakan data dari beban menegak yang diukur untuk menentukan formula menganggar beban menegak. Untuk menentukan beban menegak cerucuk didalam pasir, data yang telah dibetulkan oleh penulis lain telah dianalisa semula mengikut kaedah iterasi, IT. Kombinasi formula yang telah diubahsuai telah diuji menggunakan data lima ujian bebanan statik. Perbandingan telah dijalankan untuk menentukan tahap deviasi formula yang dibetulkan daripada nilai yang diukur.

Analisa terhadap data menggunakan formula yang dihasilkan dari criteria kegagalan Davisson untuk cerucuk dalam tanah pasir dan

formula yang dihasilkan oleh American Petroleum Institute untuk cerucuk dalam tanah liat, [D]+[API], dibandingkan dengan data ujian menggunakan criteria kegagalan Butler & Hoy menunjukkan bahawa kedua-dua kombinasi perbandingan ini adalah yang paling sesuai untuk ujian bebanan statik. Kajian juga dijalankan terhadap data bebanan menegak dari alat PDA dengan bebanan menegak daripada [D]+[API] dan [IT]+[IT]. Didapati bahawa [IT]+[IT] adalah lebih sesuai digunakan untuk menganggar bebanan menegak yang dibandingkan dengan bebanan menegak PDA.

Adalah dijangka bahawa keupayaan menegak cerucuk dapat diramal dengan lebih baik jika lebih banyak data ujian cerucuk dapat dikumpulkan dalam jangkamasa kajian ini dijalankan.

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Q_c	Calculated axial pile capacity
Q_m	Measured axial pile capacity
Q_p	Predicted axial pile capacity
Q_a	Allowable axial pile capacity
Q_{tm}	Measured toe capacity
Q_{sm}	Measured shaft capacity
L_e	Effective embedded pile length
d	Effective pile diameter
c_u	Undrained shear strength
σ_v'	Overburden stress
API	Pile capacity analytical formula developed by the American Petroleum Institute
RAND	Pile capacity analytical formula developed by Randolph
S&R	Pile capacity analytical formula developed by Semple and Rigden
λ	Pile capacity analytical formula in clay developed by Focth and Vijaygerjaya and later corrected by Kraft
Q_{cs}	Calculated pile shaft capacity in clay layer
F_{ss}	Shaft correlation factor for piles in sand
F_{ts}	Toe correlation factor for piles in sand
F_{bs}	Bias factor for piles in sand
F_{sc}	Shaft correlation factor for piles in clay
F_{bc}	Bias factor for piles in clay

s_s	Site variability factor for piles in sand
s_c	Site variability factor for piles in clay
s_{sc}	Site variability factor for piles in layered soil
ϑ	Dimensionless factor
N	SPT N-Values
N_q	Bearing capacity factor
q_b	Tip bearing capacity
S_t	Ratio of radial effective stress to end bearing pressure in vicinity of the pile
ϕ'	Effective angle of shearing resistance
γ_n'	Effective unit weight of soil
γ_n	Total unit weight of soil
γ_w	Unit weight of water
σ'_v	Effective overburden stress
τ_s	Unit shaft friction capacity
[D]	Interpretation method of loading test using Davisson's failure criterion
[C]	Interpretation method of loading test using Chin's failure criterion
[IT]	Calculated pile capacity using Iterative Technique
[API]	Pile prediction formula for piles in clay layer derived from API method
[RAND]	Pile prediction formula for piles in clay layer derived from Randolph's method
[S&R]	Pile prediction formula for piles in clay layer derived from Semple and Rigden's method

[λ]	Pile prediction formula for piles in clay layer derived from λ method
[X]+[Y]	Combination of pile prediction formula in sand derived from X and pile prediction formula in clay derived from Y
[X]+[Y]+[Z]	[X]+[Y] Prediction is compared with [Z] failure criterion
[X]	[D], [C] or [IT]
[Y]	[API, [RAND], [S&R] and [λ]
[Z]	$Q_{m[PDA]}$, $Q_{m[D]}$, $Q_{m[C]}$, $Q_{m[F]}$ or $Q_{m[B]}$
$Q_{m[PDA]}$	Measured capacity from PDA test
$Q_{m[D]}$	Measured capacity using Davisson failure criterion
$Q_{m[C]}$	Measured capacity using Chin failure criterion
$Q_{m[F]}$	Measured capacity using Fuller and Hoy failure criterion
$Q_{m[B]}$	Measured capacity using Butler and Hoy failure criterion
Q_m/Q_p Or Q_p/Q_c	Capacity ratios
σ"	Interpreted standard deviation

CHAPTER 1

INTRODUCTION

1 Introduction

Piled foundation was previously differentiated from shallow foundation using the ratio of embedded pile length to pile diameter ($L_e/d>4$). This method of differentiating deep and shallow foundation has long been used for carrying the superstructure load into the soil stratum (Berezantzev, 1965). Pile design is usually based on the requirement that the pile and the soil surrounding it must be able to withstand the maximum load, which can occur during the life span of the structure, (Meyerhof, 1970). The analysis involved is usually carried out by introducing a safety factor on the pile capacity, and this is known as **deterministic** design. However, the safety factors are arbitrarily chosen.

For this reason **reliability** methods were introduced into the capacity analysis procedure. Reliability technique is recognized as well as suited for pile capacity studies since piles are one of the few civil engineering materials that are routinely tested to failure, (Bourguard, 1987). Reliability methods are nowadays recognized as a powerful tool in geotechnical engineering. The Bayesian rule, which is the principal reliability method used in this study, allows prior probability distribution to be upgraded. The reliability method has been used extensively in geotechnical engineering related problems for at least the past two decades. Previously Ab.Malik, (1992), has developed an algorithm for capacity determination in sand, whereby a simple static formula and reliability method (Bayesian-theorem) was applied to rationally determine the allowable capacity. This was probably a premier study attempting to associate deterministic and reliability method in the analysis of axial pile capacity.

A large portion of this study will concentrate on the prediction of pile axial capacity. Demand for economic and fast track construction makes the prediction of pile capacity and performance before piles are constructed a very attractive alternative (Thurman & D'Applonia, 1965). Capacity prediction has come a long way since Mr. Wellington in 1888, who claimed that the Engineering News (EN) formula which is based on dynamic equation, to be the safest and none the better (..."no better or safer formula than this for the safe working load for piles under all ordinary conditions"...) than this formula (Komornik, 1971). However, it is well known that since the EN formula, there have been many computational methods developed for the determination of pile capacity. This is mainly contributed by the increased knowledge on the pile soil behavior and the increased usage of computers. As stated by Terzaghi in 1960 "...our theories will be superseded by better ones..."