CORRELATION BETWEEN CONE PENETRATION TEST AND BEARING CAPACITY FOR SHALLOW FOUNDATION

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DEDICATION

To my beloved mother, wife and daughters,
Thank you very much for your love, patience and support.

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ABSTRACT

The Cone Penetration Test (CPT) is a simple and versatile test that is becoming more popular in Malaysia for soft clay and fine to medium coarse sand. It can be used as a direct method to determine the soil bearing capacity for a foundation. Analyses were carried out on the CPT data from local project site based on the published correlation and. Data were grouped into cohesive and non cohesive. Based on the results, it is observed that the current published correlations are not suitable to be used in Malaysia. Meyerhof's Bearing Capacity and Schmertmann's equations were used to obtain the estimated bearing capacity. These figures were then plotted on the graphs and the best fit lines are obtained. Two correlations had been evaluated and presented. These correlations represent cohesive and non cohesive soil respectively. From the two correlations, it can be concluded that Schmertmann's correlation gives a much higher value compared with bearing capacity calculated using Meyerhof's. However it shall be noted that the lack of data prevents a better correlation from being produced. A correlation had been proposed in the study to predict the soil bearing capacity value based on the tip resistance. However these correlations are not to be used in practice due to its limitation of data. The published correlations are not suitable to estimate the soil bearing capacity for shallow foundation for soil under study Bearing Capacity correlation for cohesive and non cohesive soils proposed by Schmertmann is likely to overestimate the actual bearing capacity values. The correlation is not appropriate to be used in Malaysia.

ABSTRAK

Ujian Penusukan Kon (CPT) merupakan ujian yang mudah dan seba boleh di mana ia lebih popular di Malaysia bagi tanah liat lembut dan pasir halus hingga sederhana. Ia boleh digunakan sebagai kaedah langsung untuk memperolehi keupayaan galas tanah bagi rekabentuk asas. Analisis dilakukan daripada data CPT daripada tapak projek tempatan berdasarkan hubungan terbitan. Data diketegorikan kepada jelekit dan tidak jeleket. Berdasarkan kepada keputusan yang diperolehi, dapat dilihat bahawa hubungan terbitan sekarang tidak sesuai digunakan di Malaysia. Persamaan keupayaan galas Meyerhof dan Schmertmann digunakan untuk mendapatkan anggaran keupayaan galas. Nilai yang diperolehi kemudiannya diplot ke dalam graf dan seterusnya untuk garis terbaik diperolehi. Dua hubungan akan dinilai dan dipaparkan. Hubungan yang diperolehi ini mewakili tanah jeleket dan tidak jeleket. Daripada dua perhubungan ini, ia boleh disimpulkan bahawa hubungan Schmertmann memberi nilai yang lebih tinggi berbanding nilai keupayaan galas yang dikira menggunakan hubungan Meyerhof. Walau bagaimanapun, perlu diketahui bahawa kekurangan data menghalang hubungan yang lebih baik dihasilkan. Suatu hubungan akan dicadangkan dalam kajian ini bagi meramalkan nilai keupayaan galas tanah berdasarkan rintangan yang diberi. Bagaimanpun, tidak digunakan sebagai a,alan disebabkan data yang terhad. Hubungan terbitan tidak sesuai untuk menganggar keupayaan galas tanah bagi asas cetek. Untuk tanah di bawah kajian hubungan keupayaan galas untuk tanah jeleket dan tidak jeleket yang dicadangkan oleh Schmertmann seperti terlebih anggaran daripada nilai keupayaan galas sebenar. Hubungan ini tidak sesuai untuk digunakan di Malaysia.

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LIST OF SYMBOLS

CPT	-	Cone Penetration Test
SPT	-	Standard Penetration Test
EFCS	-	Extended Field Computer System
Q_c	-	The total force acting on the cone
A_c	-	Projected area of then cone
q_c	-	Cone resistance
F_s	-	Total force acting on the friction sleeve
f_s	-	Sleeve friction
q_u	-	Ultimate Bearing Capacity
n.a.	-	not applicable
o.m.	-	organic material
o.r.	-	out of range
s.f.g	-	sensitive fine grained

CHAPTER 1

INTRODUCTION

1.1 Introduction

The design and construction of foundations require a good knowledge of the mechanical behaviour of soils and of their spatial variability. Such information can be best obtained from a properly planned programme of both laboratory and in situ tests. Among the vast number of in situ devices, the static penetrometer or Cone Penetration Test (CPT) represents the most versatile tool currently available for soil exploration.

In the Cone Penetration Test, a cone on the end of a series of rod is pushed into the ground at a constant rate and continuous or intermittent measurements are made of the resistance (cone / tip resistance and sleeve friction) to penetration of the cone. The penetration resistance which is digitized permits detail inferences about sratigraphy and lithology. CPT is a reliable and efficient method of obtaining soil-engineering parameters for geotechnical design.

Cone Penetration Tests are conducted to obtain the cone resistance, the side friction and, if there is a piezocone, the pore pressure. The soil type can be determined by analyzing these results, the values can also be used in the design of shallow foundations through the estimation of stiffness and shear strength of cohesive soils.

The total force acting on the cone, Q_c, divided by the projected area of the cone, A_c, produces the cone resistance, q_c. The total force acting on the friction sleeve, F_s, divided by the surface area of the friction sleeve A_s, produces the sleeve friction, f_s. In the piezocone penetrometer, pore pressure is measured typically at one, two or three locations as shown in Figure 1.1. These pore pressures are known as: on the cone (u_1), behind the cone (u_2) and behind the friction sleeve (u_3).

A 60° cone with face area 10cm^2 and 150cm^2 'friction sleeve' is hydraulically pushed into the ground at a constant speed (ranging form 1.5 to 2.5 cm/s). The force required in maintaining this penetration rate and the shear force acting on the friction sleeve are recorded. The friction ratio (cone resistance / side friction) gives an indication of the soil type.

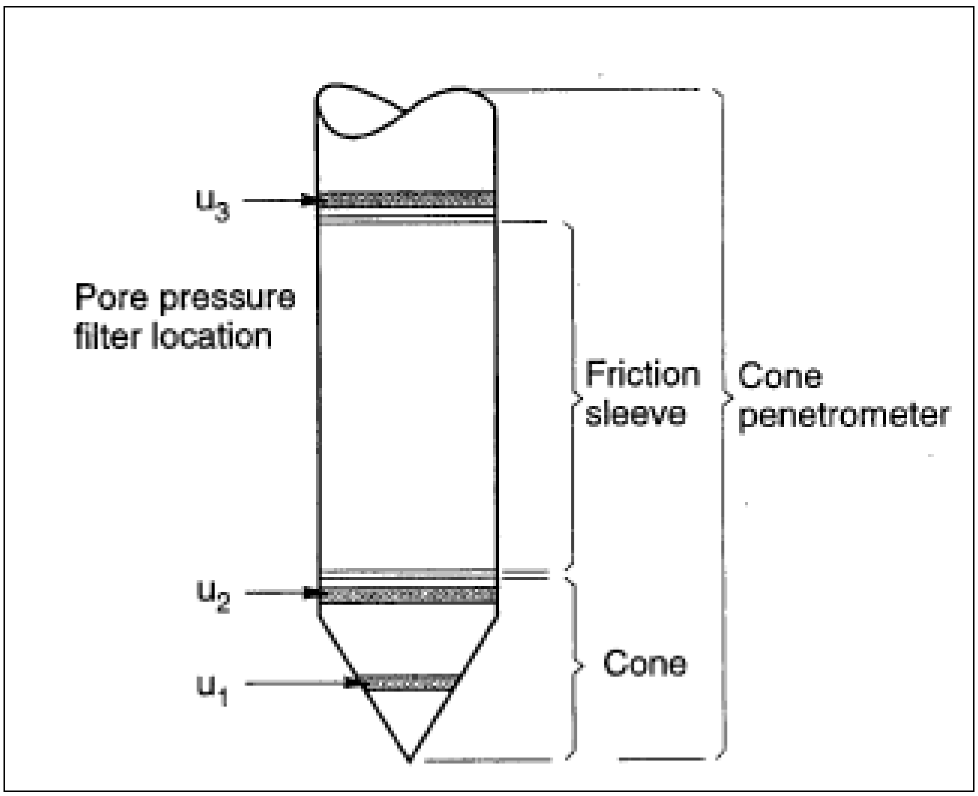

Figure 1.1: Terminology for cone penetrometers.

Probing with rods through weak ground to locate a firmer stratum has been presented since 1917. It was in the Netherlands in 1932 that CPT was introduced in a form recognizable today.

A cone penetrometer with a $10cm^2$ base area cone with an apex angle of 60^o is accepted as the reference and has been specified in the International Reference Test Procedure (ISSMFE, 1989)

The cone penetration tests provide continuous sounding capability and good repeatability. The CPT has three main applications in the site investigation process:

i. to determine sub-surface stratigraphy and identify materials present
ii. to estimate geotechnical parameters
iii. to provide results for direct geotechnical design

1.2 The History of CPT

Comprehensive reviews of the history of penetration testing in general have been given by Sanglerat (1972) and Broms and Flodin (1988).

1.2.1 Mechanical Cone Penetrometers

The first Dutch cone penetrometer test were made in 1932 by P. Barentsen, an engineer at the Rijkwaterstaat (Department of Public Works) in Holland. A gas pipe of 19 mm inner diameter was used; inside this is a 15 mm steel rod could move freely up and down. A cone tip was attached to the steel rod. Both the outer pipe and the inner rod with the 10 cm^2 cone with a 60^o apex angle were pushed down by hand (Barentsen, 1936). Barentsen corrected the measured cone resistance by subtracting the weight of the inner rod. The maximum penetration depth was 10-12 meters and the penetration resistance was read on the manometer.

Several Dutch and Belgian engineers used the early version of the cone penetration test for evaluating pile bearing capacity (e.g. Buisman, 1935; Huizinga, 1942; de Beer, 1945; Plantema, 1948)

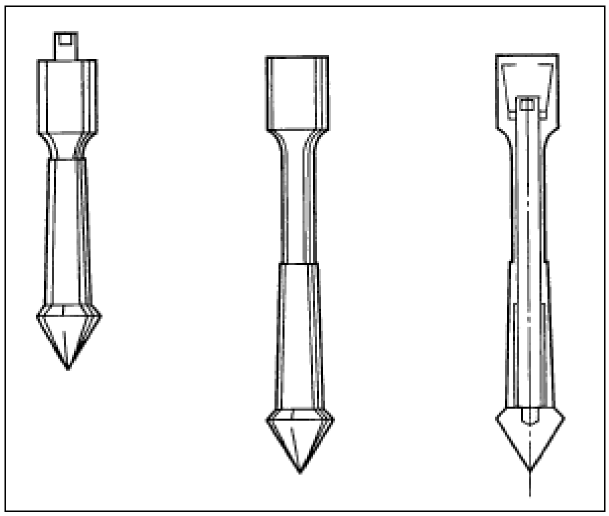

Figure 1.2: Dutch cone with conical mantle (Sanglerat 1972)

Begemann (1953, 1969) significantly improved the Dutch static cone penetration test by adding an “adhesion jacket” behind the cone. Using this new device the local skin friction could be measured in addition to the cone resistance. Measurements were made every 0.2 m and for special purposes the interval could be decreased to 0.1 m. Begemann (1965) was also the first to propose that the friction ratio (sleeve friction/cone resistance) could be used to classify soil layers in terms of soil type.

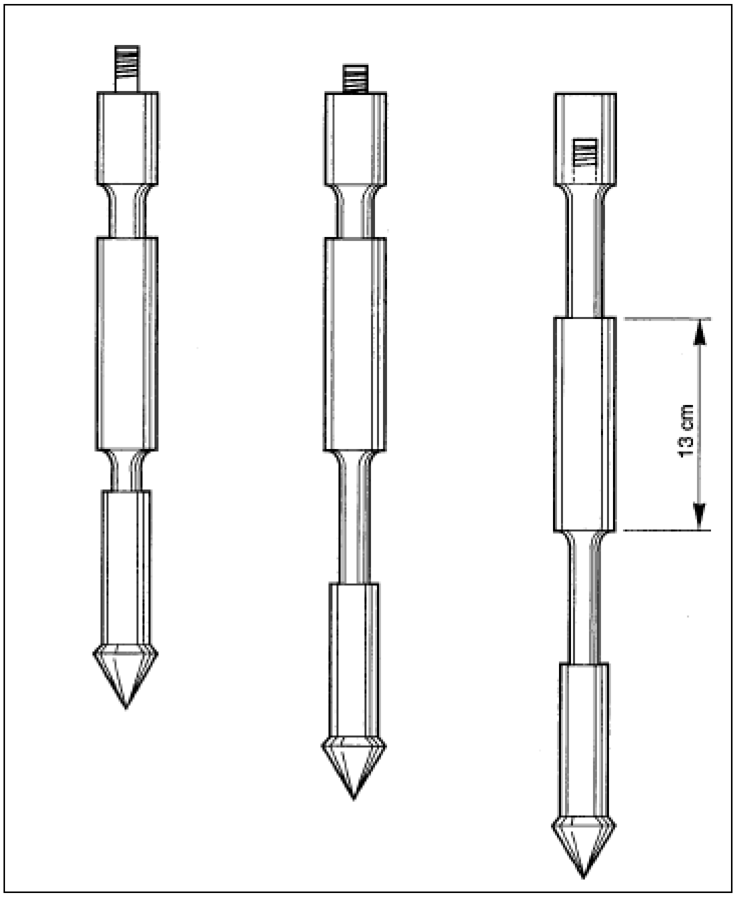

Figure 1.3: Begemann type cone with friction sleeve (Sanglerat 1972)

Most mechanical cone penetrometers measure the force needed to press down the inner rod with a manometer at ground level. Mechanical cone penetrometers are still widely used because of their low cost, simplicity and robustness. In rather homogeneous competent soil, without sharp variations in cone resistance, mechanical cone data can be adequate, provided the equipment is properly maintained and the operator has the required experience. Nevertheless, the quality of the data remains somewhat operator dependent. In soft soils, the accuracy of the results can sometimes be inadequate for a quantitative analysis of the soil properties. In highly stratified materials even a satisfactory qualitative interpretation may be impossible.

1.2.2 Electric Cone Penetrometers

According to Broms and Flodin (1988) the very first electric cone penetrometer was probably developed in Berlin during the Second World War.

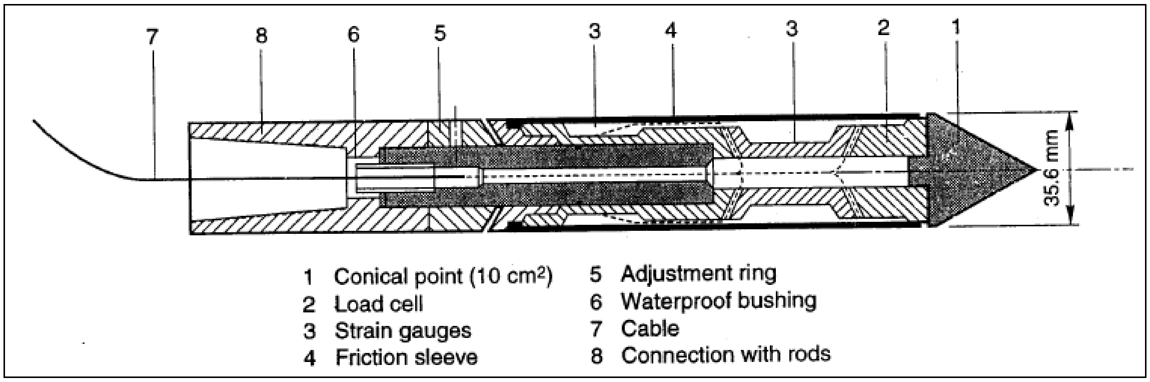

Figure 1.4: The Fugro electrical friction cone

The signals were transmitted to the ground surface through a cable inside the hollow penetrometer rods. Muhs (1978) reviewed the main improvements of the new penetrometer relative to mechanical cone penetrometer namely:

1. The elimination of possible erroneous interpretation test results due to friction between inner rods and outer tubes.
2. A continuous testing with a continuous rate of penetration without the need for alternative movements of different parts of the penetrometer tip and no possibility for undesireable soil movements influencing the cone resistance.
3. The simpler and more reliable electrical measurement of the cone resistance with the possibility for continuous readings and easy recording of the results.

Another reason for using electrical measurement systems is that very sensitive load cells can be used and thereby much more accurate readings can be obtained in very soft sols.

The first electrical cone penetrometer in Holland, called the Rotterdam cone, was developed and patented, in 1948 by the municipal engineer Bakker. A large number of different electric cone penetrometers have been developed in many countries all over the world. However, the mechanical cone penetrometer is still used in some countries.

1.2.3 The Piezocone

A conventional electric piezometer, developed by the Norwegian Geotechnical Institute (NGI), was used by Janbu and Senneset (1974) to measure pore pressures during penetration adjacent to CPT profiles. Schmertmann (1974) also pushed in a piezometer probe and measured penetration pore pressures.

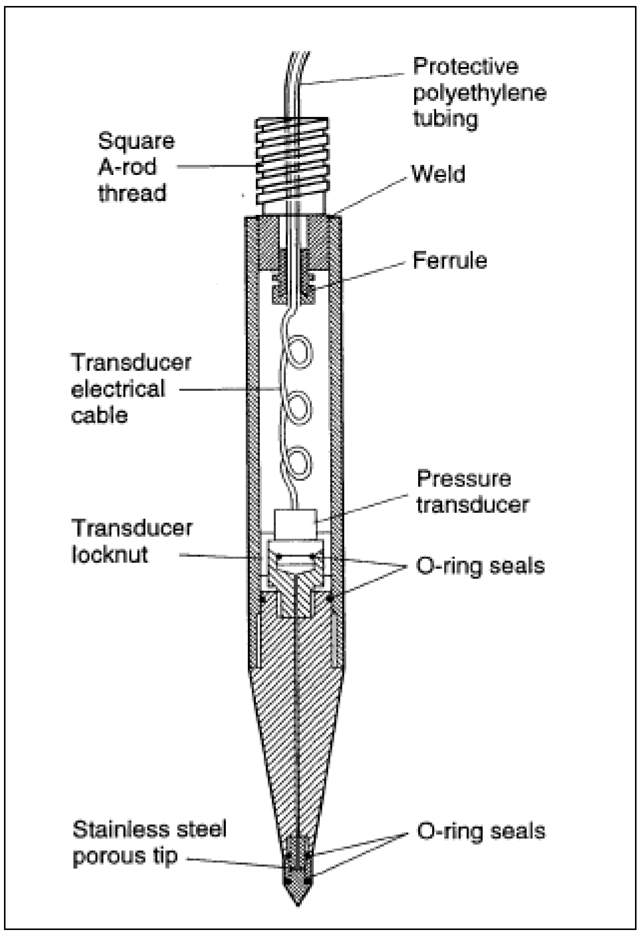

Figure 1.5: The Wissa Pizometer Probe (Wissa et al. 1974)

Schmertmann recognized the importance of pore water pressure measurement for the interpretation of CPT data. Both Janbu and Senneset and Schmertmann showed the results of the changes in pore pressures during a pause in the penetration.

Schmertmann (1978) used the Wissa type piezometer probe and a 60^{o} cone with filter at the tip in a study of the evaluation of liquefaction potential of sands. Baligh et al. (1980) also did test with the Wissa probe in addition to tests with 60^{o} cones with various filter locations. However, each cone recorded only pore water pressure and from only one sensing filter elements. Parallel tests were performed with the electric cone penetrometers. Baligh et al. suggested that the pore water pressure data, when combined with the CPT data, could provide a promising method for soil identification and an estimate of overconsolidation in a clay deposit.

A large number of piezocones have been developed in recent years. For practical projects pore pressures are not normally measured at one location; most frequently behind the cone. For research and special projects, piezocone with two or three filter positions have been developed. Bayne and Tjelta (1987) and Zuidberg et al. (1987) reported the development of the triple element piezocones.

With the measurement of pore water pressures it became apparent that it was necessary to correct cone resistance for pore water pressure effects.

1.3 Problem Statement

CPT is gaining popularity in Malaysia and the data obtained has been used for the design of foundation through empirical correlation. However the correlation used in the design of foundation is based on the foreign soil and still yet to be established for Malaysian soil condition. Thus the application of these correlations for Malaysian soil will lead to an erroneous conclusion.

1.4 Aim and Objectives of Studies

The aim of the study is to find the correlation between CPT values and Soil Bearing Capacity that best suit the type of soils in Malaysia. In order to achieve this aim, three objectives have been identified for the study:

i. To evaluate published correlation for CPT values and the soil bearing capacity.

ii. To tabulate the CPT values obtained from collected soil sample and propose the best fit line with respect to the soil bearing capacity.

iii. To obtain a correlation between CPT values with soil bearing capacity that is best suited for the type of soil in Malaysia. Two (2) correlations will be produced to differentiate cohesive and non cohesive soil.

1.5 Scope of Study

Ninteen (19) numbers of peizocone and eight (8) numbers of boreholes were carried out at the proposed site of “Cadangan Pembinaan Pusat Angkasa Negara Di Atas Lot 2233 Mukim Kelanang, Daerah Kuala Langat, Selangor Darul Ehsan”.

Two sets of equation will be used through out the study;

i. Interpretation of data for soil bearing capacity will be applied through Meyerhof’s (1951) General Bearing Capacity equation. The values for cohesion, soil unit weight and angle of friction are obtained from the lab test carried out to the undisturbed sample of soil retrieved during the deep boring works.

ii. Interpretation of data for soil bearing capacity with respect to the cone resistance will be applied through equation developed by Schmertmann (1978). The values of cone resistance are obtained from the Cone Penetration Test.

iii. Correlation between cone resistance and N values is produced as a matter of comparison to the works which have been carried by other researchers.

1.6 Expected Findings

Cone Penetration Test is one of the available methods apart from SPT to determine the soil strength. It can be directly used in design of foundation but usually is incorporated with correlation based on local conditions. However since they are generalized, the empirical relationship used may not be applicable locally. An empirical correlation for local condition is expected to be derived from the collected data. This correlation will help geotechnical designers to improve the reliable interpretation methods used to estimate the bearing capacity of Malaysian soil using CPT.