COMPARATIVE SUBSURFACE CHARACTERIZATION OF THE QUATERNARY AND RESIDUAL SITES IN NORTHERN PENINSULAR MALAYSIA BY CUMULATIVE SPT(N) FOR ASSESING CONCRETE PILE FOUNDATION REQUIREMENT

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SCHOOL OF CIVIL ENGINEERING
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ABSTRAK

Kawasan Utara Semenanjung Malaysia kebanyakannya terdiri daripada tanah liat lembut untuk kawasan pantai. Tanah liat lembut meyebabkan cabaran kepada aktiviti-aktiviti pembinaan. Sementara itu, kawasan utara juga terdiri daripada tanah laterit tetapi kurang membangun berbanding kawasan pantai. Dalam kajian ini, suatu kaedah baru bagi menilai kualiti tanah telah diperkenalkan. Secara khususnya, data ujian penembusan (SPT) telah ditukar kepada nilai SPT(N) terkumpul untuk tujuan pembandingan antara tapak. Nilai SPT(N) daripada ujian penembusan yang terdiri daripada tiga tapak tanah liat marin dan tiga tapak laterit telah digunakan dan ditukar kepada nilai SPT(N) terkumpul. Bacaan bagi nilai SPT(N) terpilih adalah daripada kedalaman 1.0m. Kawasan- kawasan dari tanah liat marin akan dibandingkan dengan kawasan- kawasan dari tanah laterit. Dalam kajian ini, setiap tapak dari tanah liat marin akan dibandingkan satu sama lain mengikut kedalaman sebenar daripada data dan jugak kedalaman yang sama untuk kedua- dua tapak (5m). Penilaian berdasarkan kepada julat nilai SPT(N) terkumpul dan bentuk garisan lekungannya dimana tanah liat marin mempunyai lebih kecuraman berbanding tanah laterit. Nilai SPT(N) terkumpul untuk tanah laterit adalah tinggi berbanding tapak tanah liat marin. Oleh itu, penilaian sesuatu tapak berdasarkan nilai SPT(N) terkumpul didapati lebih praktikal untuk digunakan dalam amalan geoteknikal. Kaedah SPT(N) terkumpul juga dijangka mampu membezakan kualiti sesuatu tapak dari segi keperluan asas. Dalam kajian ini, penilaian keupayaan galas cerucuk sesuatu tapak akan melibatkan SPT(N) terkumpul dan juga SPT(N) terkumpul kedua. Suatu korelasi kedalaman dan jumlah keupayaan galas dihasilkan. Panjang penembusan tanah digunakan adalah 5m dan 10m kedalaman dan tanah liat marin dipilih. Korelasi kedalaman dan jumlah keupayaan galas sangat berguna untuk menganggarkan kesesuaian panjang cerucuk yangakan digunakan dalam rekabentuk asas

ABSTRACT

The Northern Peninsular Malaysia area mostly consists of soft marine clays for coastal area. This marine clays are makes it challenging to construction activities. Meanwhile, northern area also consists of laterites soil but less develop compared to coastal sites. In this research, a new method of evaluating the quality of soils was introduced. Specifically, the standard penetration test (SPT) data were converted into the cumulative SPT(N) value curve for comparison between sites which is marine clays and laterites soil. SPT(N) value data obtained from Piezocone test from three marine clays sites and three from laterite sites were used and converted into cumulative SPT(N) value curves. The selected SPT(N) value reading were from the 1m intervals. The sites from marine clays will comparing to the sites from laterite soil. In this study, each marine clay site and laterites will be comparing each other with their actual depth from the data and also same depth for both sites (5m). The evaluation based on the range of cumulative SPT(N) values and shape of the curve which marine clays have steeper line graph compare to laterites. The cumulative SPT(N) value for laterites were higher than for marine clays sites. Thus, the evaluation of a site based on cumulative SPT(N) values was found more practical to be used in geotechnical practice. The cumulative SPT(N) method also expected to be able differentiate quality of sites in terms of foundation required. In this study, the evaluation of pile bearing capacity of a site will be involving the cumulative SPT(N) and also second cumulative SPT(N). A correlation of depth and total bearing capacity are produced. The length of soil penetration used are 5m and 10m under the ground and marine clays sites were chosen. The correlation of depth and total bearing capacity very useful to estimate suitable length of pile to be used in foundation design.

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LIST OF ABBREVIATIONS

SPT	**S**tandard **P**enetration **T**est
CPT	**C**one **P**enetration **T**est
CPTU	**P**iezocone **P**enetration **T**est
ASTMD	**A**merican **S**tandard **T**est **M**ethod
USM	**U**niversiti **S**ains **M**alaysia
PZ	**P**enetration **P**oint

NOMENCLATURES

s_u	Undrained shear strength
q_c	Cone resistance
f_s	Skin friction
Ø	Friction angle
u	Pore water pressure
$Qult$	Total bear
N	SPT number
D_{50}	Grain size distribution
I_c	Soil behaviour type index
N_{60}	Energy ratio of 60% of N-value
n	Cone tip resistance
T_s	Average ultimate shear stress mobilized along the shaft
α	Empirical factor
q_{tip}	End bearing capacity
c	Cohesion
N_c, N_q, N_Y	Bearing capacity factors
K	Lateral earth pressure
$Tan\ \delta$	Coefficient of friction
σ_h	Lateral pressure
σ_v	Vertical pressure
$Bult$	Total Skin Friction

CHAPTER 1

INTRODUCTION

1.1 Background

The quaternary deposits of western coast of peninsular Malaysia are altogether called the marine clays although they also consist of sand layers. In this dissertation however the marine clays shall refer to the clayey portions of the quaternary deposits. The quaternary deposits were formed during the geological processes that took place within the last 2.6 million years. The 2.6 million years of the Quaternary era represents the time when there has been relatively little change in the distribution of the continents due to plate tectonics, thus the Quaternary deposits of peninsular Malaysia represent the non-deformed stratigraphy defining the soft ground of the area. The Quaternary geological record is therefore preserved in greater detail than those of earlier periods where they might have been distorted by the movements (Chai and Oh, 2006).

Development projects over the Marine clay sites of the western coast of peninsular Malaysia have increased tremendously in recent years. The northern states involving Perlis, Kedah, Pulau Pinang, and Perak has approximately 10000 km^2 of the Quaternary deposit that is generally located along the coast. The presence of this deposits represent a stark contrast to the residual laterite soils of the interior regions which cover three times as much area of the quaternary deposits or about 30000 km^2(Society, 1970).

There are many in-situ testing methods available for determining the characteristics of soils. One of them is the cone penetration test with pore water pressure acquisition capability (CPTU), which is also called the piezocone penetration test. The CPTU is capable of determining soil properties in terms of soil type, relative strength, groundwater pressure, and time-rate consolidation parameter, among others, which can be useful for foundation design. The CPTU is a better site investigation method as compared to the more traditional wash boring method in terms of the non-disruptiveness of the test to the environment and the non-disturbance caused to the soils being tested.

The CPTU also has other advantages over the wash boring method. First is the speed at which a CPTU test can accomplish for a location, second is the repeatability at which tests can be carried out for a location, and third is economy where the CPTU charge is always cheaper than the wash boring method per location. The design processes can also be carried out conveniently based on CPTU results partly due to the interpreted strength parameters and soil types made available by the technology. Thus, for works in the northern states, the CPTU method has been used often in getting the soil parameters to be used in foundation designs over the marine clays and residual laterite soils. The apparatus and parameter of CPTU shows in Figure 1.1.

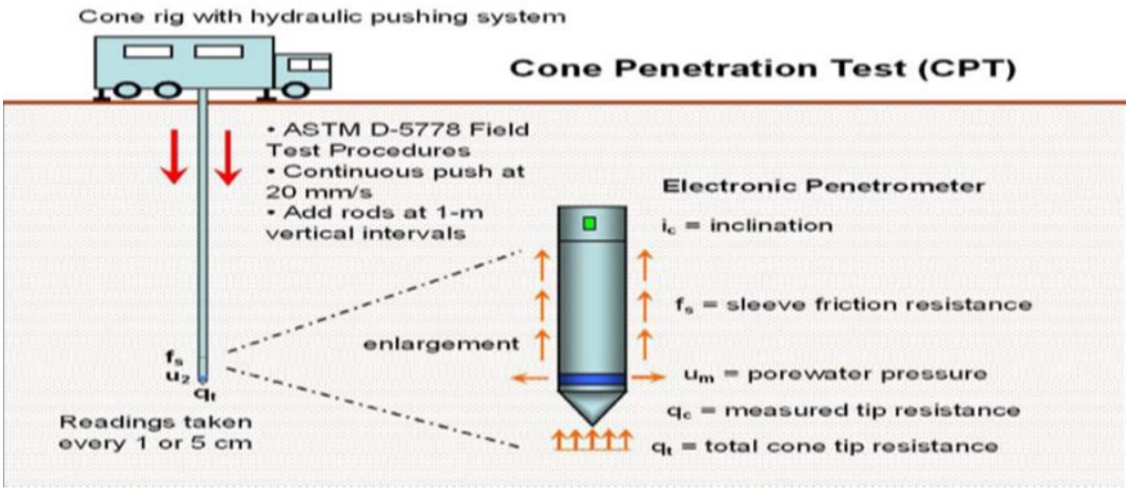

Figure 1.1: The CPTU according to ASTMD 5778 (NCHRP CPT SYNTHESIS, 2007)

1.2 Problem Statement

The Northern state of Peninsular Malaysia consists of the problematic coastal area and the more stable interior region in terms of foundation requirements. Ironically, the coastal areas which are deposited by the soft marine clays, are much more developed and supporting a large number of structures and constructions. The marine clays are the types of soils with fine grains and are less preferred in terms of their strength. Most sites with soils under this category, when constructed over, would undergo great settlements. Meanwhile, the laterite soils which are the stronger materials in comparison underlain the interior sites which are less developed in comparison to the coastal sites. There is no simpler way to describe the difference between the two types of sites other than saying that one is quaternary or marine clay deposit and the other is residual or made of laterite soils. The contrast simply means that a marine clay site would require more foundation requirements than the laterite soil site would for a similar structure. The marine clays are more problematic in comparison.

Moreover, due to the extensive development over the quaternary, marine clay sites, many foundation designs have become repeats of earlier ones due to similar nature of the profiles. To a lesser extent similar situation applies over certain locations of the residual, laterite sites also where similar ground would lead to similar foundation design for similar structure. Therefore, designing similar foundation but with new calculation and most of the times with new site investigation data acquired would be uneconomical. It is obvious that despite the vast experience gained for the marine clay engineering, engineers are still struggling with every new job given to them.

The traditional way of designing is by evaluating the standard penetration test number SPT(N). However, when examining the soil properties of a site considered for a project, the SPT(N) record would not allow for easy evaluation of the site, hence a new method of evaluation by the cumulative SPTN instead is introduced in this dissertation. Thus the new method of evaluation is by using the cumulative SPT(N) instead of the usual non-cumulative SPT(N). The proposed cumulative SPT(N) method is expected to be able to differentiate a site over another not only in terms of ground strength but also in terms of foundation requirement. It will be shown later that in terms of evaluating the pile bearing capacity of a site, not only the cumulative SPT(N) term is needed, but also the second cumulative SPT(N) term. The cumulative SPT(N) at a depth can be given by $\int_{x=0}^{x=D} N\,dx$ while the second cumulative SPT(N) at a depth can be given by $\int_{x=0}^{x=D} N^2\,dx$ where N is the SPT(N) value and D is the depth at which the cumulative SPT(N) is being considered.

1.3 Objectives

The objectives for this research are as follows:

i. To describe the various shapes of curves resulted from generating the cumulative SPT(N) curves from the ordinary SPT(N) curves for the different types of ground covering the quaternary marine clay sites and the residual laterite sites.

ii. To evaluate correlation between the skin friction capacity and total bearing capacity of a pile to the cumulative SPT(N) and the second cumulative SPT(N).

iii. To tabulate the total bearing capacity with various size of piles at 10m depth of penetration for marine clays sites.

1.4 Scope of Works

This research focused on the comparison of soil strength in describing the different qualities of studied sites based on the cumulative SPT(N) values method. Various sites from the marine clays and laterites backgrounds were brought to comparison against each other. The cumulative SPT(N) values were determined against depth starting from the surface of the ground to the maximum depth the cone could penetrate. From the cumulative SPT(N) curves, the friction capacity of a pile was being determined. Data from several areas in northern region of Peninsular Malaysia such as Pulau Pinang, Perak, Perlis and Kedah were chosen for the cumulative SPT(N) calculation. SPT(N) of quaternary and residual sites were calculated and compared against each other. Their applicability in pile designs over the two types of ground were also calculated and compared against each other.

1.5 Dissertation Outline

This dissertation is in five chapters. Chapter 1 consists of an introduction to the research, problem statements, objectives, and scopes of study. Chapter 2 presents the review of the literatures. Chapter 3 provides methodology and flow of the research study. Chapter 4 contains the results and discussions of the study. Finally, chapter 5 presents the conclusions of the study and recommendations for better investigations in future.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

This chapter presents the literature reviews that have been carried out throughout this study covering the quaternary marine clays, residual laterite soils, wash boring and the CPTU site investigation methods, the SPT(N), and estimation of pile bearing capacities in soft and hard grounds.

2.2 Gravel, Sand, Silt, Clay

Smith (2014) states that there are four types of soils formed respectively due to weathering, temperature, gravity, and the action of frost; these processes are continually forming the particles of various sizes that eventually become the respective soil. Soils are also either transported, residual, or organic. Gravels, sands, silts, and clays of the alluvial soils are transported or transited by water.

Seghal (1984) describes a gravel as a rock fragment that has been transported by water away from its original location or source. The shape can be angular, sub-angular, well rounded, rounded, and sub-rounded depending on how far or how extensive the transport has been. Hamzah and Ramli (1992) describes that the water actions are the ones causing the circular appearance in gravel. The main mineral constituent of a gravel is usually quartz.

A sand particle consists of silica and quartz. Normally, course sand is similar in shape to the gravel as it is also formed from the same material as the gravel comes from. The fine sand is usually in angular shape. The structure in a sand body is always open where the pores are always permeable by water thus a sandy soil is always well drained

(Hamzah and Ramli,1992). A sandy soil is also not affected by consolidation process like a clayey soil would be.

Silts is a fine grained soil, and can be designated as organic or inorganic. Inorganic silts have bulky grains while organic silts can be highly compressible and have some amount of cohesion. Silts easy to crumble when squeezed and can be dusted off the hand when dried, feels rough, and can have some plasticity (Seghal, 1984).

Clay is formed from chemical weathering process. A clay expands upon absorbing water. Clay particles are very small in size with properties very much affected by the moisture content and surface characteristics. The permeability value of a clay is too low and it has a very low rate of draining too. Martin and Guggenheim (1995) stated that, clay is a naturally occurring material and composed primarily of fine-grained materials which are plastic at appropriate moisture contents.

2.3 Marine Clays and Laterite Soils

Marine clays or quaternary deposits refer to the clayey soils. As mentioned earlier, a quaternary deposit site can also consist of sand deposits and can also be covered by coastal alluvium deposits. The quaternary deposits were formed within the last 2.5 or 2.6 million years. In the process, fine materials were washed from the inlands and deposited along the coast in a marine environment which created the very flat ground surface seen today. However, segments of the quaternary deposits found in Peninsular Malaysia coastal areas, in addition to the broad stretches of flat lands with only slight variation in ground level, can also be found that are gently undulating (Bosch, 1998). The occurrence of widespread and thick deposits of soft marine clay is due to the Quaternary deposition, where fines settled over a long period of time in relatively stagnant waters.

Rajasekaran and Rao (2002), describes marine clays as quaternary deposits located in many coastal and offshore areas. Marine clay areas of Peninsular Malaysia are bordered by the Straits of Malacca to the west and inland hills to the east. The SPT(N) number for marine clays were found by the present study to range mostly between 0 and 6. These inland hills provide the laterites which are residual soils, formed by the weathering of parent rock which could be igneous or sedimentary rock. The laterites could have a number of SPT(N) greater than 7 as found by the present study, a number significantly higher than the marine clays. Clays are naturally soft due to their high water content and the presence of swelling clay minerals such as chlorite (Bjerrum, 1973). Other than that, the residual soil such as laterites soil formed by chemical weathering under warm, humid tropical condition when rainwater leaches out of soluble rock material leaving behind the insoluble hydroxides of iron and aluminium which giving the red-brown colour to the soil (Seghal, 1984).

Ahmad et al. (2006) states that residual soils are the weathering products of rock and commonly found under unsaturated conditions. The properties of residual soils are a function of the degree of weathering. The residual soils are generally found as capping of hills and therefore provide excellent borrow areas for extensive use in various construction activities (Goswami and Mahnta, 2007). Laterites soil could be used for landfill liner construction because it has low hydraulic conductivity (Anderson and Hee, 2000). The other property that makes it suitable for a landfill liner is the high sorption capability. Nevertheless, none of the studies described above have any mention of the use of cumulative SPT(N) values as a method of quality assessment of the marine clay sites and laterite materials.

2.4 Subsurface Exploration

Subsurface exploration of a site is carried out to determine physical and engineering properties of soils below the ground. The methods normally involve soil sampling, and in-situ and laboratory testing. In-situ testing is important in geotechnical engineering while the laboratory testing could be time consuming and may be less reliable for design other than being costly (Mair and Wood, 1987).

There are two common in-situ testing methods which are the Standard Penetration Test (SPT) and those of the CPTU which also include the SPT equivalent. The SPT has become the industry standard subsurface exploration test. However, for this study, only the SPT equivalent as carried out by the CPTU test was considered. The CPTU is preferred by the industry due to its accuracy, continuous data, and reliability. The CPTU test is also very suitable for use in environmentally sensitive cases and can also be applied in soil harder than the marine clays.

The traditional non-electronic cone penetration test (CPT) has the cone resistance (q_c) and skin friction (f_s) acquisition capabilities without the pore pressure measurement. However, the measurement of sleeve friction is sometimes less accurate and not reliable, especially for the nonhomogeneous soil profiles. Furthermore, one can easily miss thin soil layers in CPT tests, but these could be very important in foundation design. All of these difficulties can be easily overcome by using the new electronic CPTU technology (Cheng-hou et al., 1990).