STATISTICAL CORRELATIONS BETWEEN STANDARD PENETRATION TEST N VALUE AND PRESSUREMETER MODULUS FOR KALLANG AND OLD ALLUVIUM FORMATION

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DEDICATION

This thesis is dedicated to my father, who taught me that the best kind of knowledge to have is that which is learned for its own sake. It is also dedicated to my mother, who taught me that even the largest task can be accomplished if it is done one step at a time.

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ABSTRACT

This paper presents a correlation between the Standard Penetration Test N value and Pressuremeter modulus (E_{PMT}) for Clayey (cohesive) and Sandy (cohesionless soil) in Ang Mo Kio area, Singapore. This study is based on the result of a comprehensive site investigation for future MRT in Singapore. The latest edition of the Singapore Geological Map (DSTA, 2009) indicates that the main Geological Formations at the site is the Kallang Formation and the Old Alluvium. Thus, this study focused on the statistical correlations between SPT- N value and E_{PMT} for Kallang Formation and Old Alluvium with different soil type, such as Sandy Silt, Sandy Clay, Silty Sand, Clayey Sand and Gravelly Sand. The literature review shows that there is very limited or no information available about correlations between Standard Penetration Test N value and Pressuremeter Modulus (E_{PMT}) for Kallang Formation and Old Alluvium. Hence, the relationship between and Pressuremeter Modulus (E_{PMT}) is identified in this study, all the results show a significant linear relationship between SPT-N and E_{PMT}. The results show the increase in the measured SPT-N and E_{PMT} values with greater depth in the soil. The empirical equations between SPT-N value and E_{PMT} are suggested and proposed. In order to verify the empirical equations, the empirical equations obtain from regression analysis in this study have been compared with similar equations and soil type with other researchers. The comparisons indicated that there is a similar linear relationship between researches but the slope (gradient) of linear regression is different. Lastly, comparative study of difference type of pressuremeter system (diameter measuring system and volume measuring system) are carried out. Both measuring systems have more consistency result in Clayey (Cohesive) soil and less consistency result in Sandy (Cohesive) soil. The diameter measuring system has a higher consistency in Sandy (Non-cohesive) Soil whereas Volume measuring system has a less scattered result and higher R^2 value in Clayey (Non-cohesive) Soil.

ABSTRAK

Tesis ini membentangkan hubung kait antara nilai Ujian Penembusan Standard N dan modulus Pressuremeter (EPMT) untuk Clayey (kohesif) dan Sandy (tanah tanpa kohesi) di kawasan Ang Mo Kio, Singapura. Kajian ini adalah berdasarkan hasil penyiasatan tapak yang komprehensif untuk MRT masa depan di Singapura. Edisi terbaru Peta Geologi Singapura (DSTA, 2009) menunjukkan bahawa Formasi Geologi utama di tapak adalah Formasi Kallang dan Alluvium Lama. Oleh itu, kajian ini memberi tumpuan kepada korelasi statistik antara nilai SPT-N dan EPMT untuk Formasi Kallang dan Alluvium Lama dengan jenis tanah yang berbeza, seperti Sandy Silt, Sandy Clay, Silty Sand, Clayey Sand dan Gravelly Sand. Kajian kesusasteraan menunjukkan bahawa terdapat sangat terhad atau tiada maklumat mengenai korelasi antara nilai Ujian Penembusan Standard N dan Modulus Pressuremeter (EPMT) untuk Formasi Kallang dan Old Alluvium. Justeru, hubungan antara dan Pressuremeter Modulus (EPMT) dikenal pasti dalam kajian ini, semua hasilnya menunjukkan hubungan linear yang signifikan antara SPT-N dan EPMT. Keputusan menunjukkan peningkatan nilai SPT-N dan EPMT yang diukur dengan kedalaman yang lebih tinggi di dalam tanah. Persamaan empirikal antara nilai SPT-N dan EPMT dicadangkan. Untuk mengesahkan persamaan empirikal, persamaan empirikal yang diperolehi daripada analisis regresi dalam kajian ini telah dibandingkan dengan persamaan yang sama dan jenis tanah dengan penyelidik lain. Perbandingan menunjukkan bahawa terdapat hubungan linear yang sama antara penyelidikan tetapi cerun (kecerurunan) regresi linear adalah berbeza. Akhir sekali, kajian perbandingan sistem perbezaan pressuremeter system (sistem pengukuran diameter dan sistem pengukur isipadu) dijalankan. Kedua-dua sistem pengukuran mempunyai hasil yang lebih konsisten di tanah Clayey (kohesif) dan kurang hasil konsistensi di tanah Sandy (tanpa kohesif). Sistem pengukuran diameter mempunyai konsistensi yang lebih tinggi di Tanah Sandy (tanah tanpa kohesi) sedangkan sistem pengukuran isipadu mempunyai hasil yang kurang tersebar dan nilai R^2 yang lebih tinggi di Tanah Clayey (tanpa kohesi).

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LIST OF ABBREVIATIONS

SPT	-	Standard penetration test
PMT	-	Pressuremeter test
E_{PMT}	-	Pressuremeter modulus
E_M	-	Pressuremeter modulus
PL	-	Limit Pressure
SPT-N	-	Number of blow counts of Standard penetration test
SPT-N60	-	Corrected measured Standard penetration test N value
N60	-	Corrected measured Standard penetration test N value
R^2	-	Coefficient of determination
R	-	Coefficient of correlation
MSE	-	Mean Squared Error
SSE	-	Sum of Squares Error
SSR	-	Sum of Squares Regression
SST	-	Sum of Squares Total

LIST OF SYMBOLS

γ	-	Poisson's ratio, which is assumed to be 0.3
R_p	-	Radius of probe in uninflated condition, mm
ΔR_m	-	Increase in radius of probe up to corresponding point to pressure where E_p is measured, mm
$d\Delta R$	-	Increase in radius of probe corresponding to ΔP pressure increase, mm
ΔR	-	Increase in probe radius, mm
p_o	-	Initial pressure
p_f	-	Creep pressure
p_L	-	Limit pressure
υ	-	Poisson's ratio, which is assumed to be 0.3
v_o	-	Initial volume of the probe which is 837 cm^3
v_m	-	Volume at $(p_o + p_f)/2$
$\delta p/ \delta v$	-	Gradients of the straight-line portion curve (P-V curve

CHAPTER 1

INTRODUCTION

1.1 Background of Study

In Soil investigation, there are two main method to determine engineering soil parameters, which is Insitu and laboratory tests. In situ test are usually more preferred compare to Lab test due to lower level of sample disturbance and unchanged soil stress condition. Furthermore, simple laboratory tests may not be reliable in most cases while more sophisticated laboratory testing can be time consuming and costly (Mair and Wood, 1987), Thus, in situ test is vital in geotechnical engineering.

Several in situ testing methods have been introduced to determine soil properties. Such as Vane shear test (VST), Field Permeability Test, Cone penetration test (CPT) etc. Standard penetration test (SPT) and Pressuremeter Test (PMT) are also among those in-situ techniques. SPT is broadly used for determining different soil properties like bearing capacity, elastic modulus, shear modulus, settlements and etc. Wide research has been conducted on SPT, and numerous correlations have been developed. The relationship of the SPT blows to the relative density, friction angle, bearing capacity, elastic modulus, constraint modulus and undrained shear strength were examined. However, the SPT blows must be normalized for apparatus and overburden corrections. The SPT blows obtained in the field were converted to N60 (Bowles, 1997).

The pressuremeter, introduced in its present form in 1950s, has gained substantial acceptance in the world. The pre-bore PMT was developed by Louis Menard, who is also known as the father of the Pressuremeter, established the prebored PMT equipment and considered it to be one of the most precise testing methods available for almost any type of soil (Menard 1965). Typical testing procedures have

for the most part not changed since the meter's introduction, but changes are being recommended by researchers to accommodate test evaluations in sand soils. In current, there are two types of pressuremeter widely used in Singapore Soil investigate works, which are OYO Elastmeter-2 Sonde (pressuremeter system measuring probe diameter) and Menard Pressuremeter (pressuremeter system measuring volume changes).

The fundamental concept behind the PMT is the expansion of a cylindrical sleeve in the ground at a particular depth in order to monitor the relationship between the pressure and the deformation. The pressuremeter comprises of two major parts: the measuring unit and the probe unit. The measuring unit was located on the ground surface consisting of several gauges that record pressure and volume and the probe unit was inserted into a borehole. When the probe is installed at the desired depth, as the pressure increases in the measuring cell, the borehole walls deform. Two main soil parameters can be determined by the pressuremeter test are the the pressuremeter modulus (E_{PMT}) and limit pressure (PL), pressure corresponding to twice the initial volume (vo). The pressuremeter modulus (E_{PMT}) is obtained by the Equation (1.1).

$$E_p = 2\,(1+\upsilon)\,(v_o + v_m)\,\frac{\delta p}{\delta v} \tag{1.1}$$

The reasons of correlation between Standard penetration test-N (SPT) and pressuremeter modulus (E_{PMT}) is useful are as follows:

- Standard penetration test N value (SPT-N) is relatively low cost, common and easy to carry out in most of the soil investigation work in Singapore. However, pressuremeter test is comparatively in higher cost and expensive (Approximate 25 times higher than SPT). It depends on the nature of the structure, most of the time is not considered to be performed in rather small and involve only simple geotechnical project.
- Phoon and Kulhavi (1999) emphasized that local correlations that are developed within a specific geology setting are generally preferable to generalised global correlations because they are significantly more accurate.

Hence, it is necessary to investigate and provide the empirical relations for different areas.

- This correlation aid geotechnical designer in evaluating, comparing, interpreting or cross-checking the soil parameters obtained from these two important in situ tests (Bozbey and Togrol, 2010).

1.2 Problem Statement

Currently, there is no study of the relationship between Standard Penetration Test (SPT) and Pressuremeter Test (PMT) is available for Kallang formation and Old alluvium formation in Singapore. Also, the pair of readings (SPT-N and E_{PMT}) for Gravelly SAND is not available from these studies.

For prebored Pressuremeter Test (PMT) system that used to carry out the test. There is only one type of PMT system (Menard Pressuremeter, pressuremeter system measuring volume changes) was adopted and carried out by the previous research studies.

For decision making process of managers in project management. There are several challenges which they are encountered during this MRT project as below:

- Determine the appropriate PMT equipment system (Diameter measuring system or Volume measuring system) to be adopted in the investigation area.
- Determine the reasonable soil parameters (SPT-N value or E_{PMT}) to be proposed for geotechnical design

Hence, it's important to study and correlate the relationship between SPT and PMT result obtained during soil investigation in this local area by using both type of PMT measuring system.

1.3 Objective of Study

The objectives of this study are shown in the following:

- Determine the relationship between Depth and Standard Penetration Test N value (N60)
- Determine the relationship between Depth and Pressuremeter Modulus (E_{PMT})
- Determine the relationship between Standard Penetration Test N value (N60) and Pressuremeter Modulus (E_{PMT})
- Determine the correlation between Standard Penetration Test N value (N60) and Pressuremeter Modulus (E_{PMT}) in Kallang Formation and Old alluvium
- Comparative study of result by volume measuring system and diameter measuring system of pressuremeter.

1.4 Scope of Study

The scope of study is to study the relationship between Standard Penetration Test N value (N60) and Pressuremeter Modulus (E_{PMT}) based on the SPT and PMT tests that have been carried out during MRT Project, Cross Island Line, site investigation in Singapore.

The empirical equations are proposed for Clayey (cohesive) and Sandy (cohesionless soil) soil separately. Those equations are compared with equations that have been proposed by other researchers. This is to prove and verify the equations from this study is similar with other researchers. In addition, comparative study of Pressuremeter Modulus (E_{PMT}) result by using volume measuring system and diameter measuring system will be reviews and discussed.

The results adopted in this study were obtained from three (3) exploration boreholes. The fieldworks for this site investigation were conducted in three (3) boreholes. It consists of the field tests such as hole drilling, Standard Penetration Tests (SPT) and Pressuremeter Tests (PMT).

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