ESTIMATION OF SOIL COMPACTION PARAMETERS BASED ON ATTERBERG LIMITS

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For my lovely parents, husband and son.

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ABSTRACT

In civil engineering works, soils are commonly used as construction materials. Compaction of soils is carried out to improve the strength of the soils. However, compaction tests are time-consuming and relatively expensive especially when many samples are to be tested. In this study, an alternative method is proposed. The relationships of liquid limit, (LL), plastic limit, (PL), and plasticity index, (PI) to modified maximum dry density, (MDD), and optimum moisture content, (OMC), were determined. The parameters can therefore be correlated by graphical and empirical analysis. Using curve fitting techniques, empirical equations were obtained and charts were prepared. From these, it is possible to estimate the potential optimum moisture content and maximum dry density for the Modified and Standard Proctor compaction tests from the information of Atterberg limits only. Determination of Atterberg Limits is easier and the tools for the test are not complex, it therefore will save time and cost. The collected data for the study were obtained from government agencies and private sectors. The collected data then were used to produce the regression equations. While, the results of the laboratory test programme were used to compare with the results of the regression equations for the compiled data. In the study, the types of soil were limited for clay and silt only, i.e., cohesive soils. From the study, the results show that the multiple-parameter relationships are better than the single-parameter relationship because of its higher regression factor in the statistical analysis and lower percentages of differences in comparison with the laboratory results and the charts. The results also show that the R squared values obtained for the correlations between maximum dry density and the Atterberg limits are higher than that of for the correlations between the optimum moisture content and the Atterberg limits. Hence, optimum moisture content is not a good indicator

compared to the maximum dry density parameter, for the estimation of the soil compaction parameters based on Atterberg limits.

ABSTRAK

Dalam kerja-kerja kejuteraan awam, tanah biasanya digunakan untuk bahan pembinaan. Pemadatan tanah dilakukan untuk menambahkan kekuatan tanah. Walau bagaimanapun, ujian pemadatan ini memakan masa yag panjang dan memerlukan kos yang besar terutama apabila banyak sampel tanah perlu diuji.. Dalam kajian ini, kaedah lain dicadangkan. Hubungan antara had cecair , had plastik dan plastik indeks dengan ketumpatan kering maksimum dan kandungan kelembapan optimum (*Modified* dan *Standard Proctor*) dicari. Parameter-parameter ini boleh dihubungkaitkan dengan menggunakan analisis grafik dan empirikal. Dengan menggunakan kaedah *fitting* lengkung, akan menghasilkan persamaan empirikal dan carta boleh dihasilkan. Dengan teknik ini, kandungan kelembapan optimum dan ketumpatan kering maksimum bagi ujian pemadatan *Modified* dan *Standard Proctor* boleh dianggarkan berdasarkan maklumat daripada had Atterberg sahaja. Had Atterberg boleh diperolehi dengan mudah tanpa menggunakan peralatan yang kompleks maka ini menjimatkan menjimatkan masa dan kos. Data terkumpul bagi kajian ini telah diperolehi daripada agensi kerajaan dan swasta. Sementara itu, data hasil ujian makmal digunakan untuk membuat perbandingan dengan keputusan persamaan regresi data terkumpul. Dalam kajian ini, jenis tanah adalah terhad untuk tanah liat dan kelodak, iaitu tanah berjelekit. Hasil daripada kajian, keputusan menunjukkan hubungan parameter berganda adalah lebih baik daripada hubungan satu parameter kerana faktor regresi dalam analisis statistik bagi hubungan parameter berganda adalah tinggi dan peratus perbezaannya dengan keputusan makmal dan carta juga rendah. Keputusan juga menunjukkan nilai R^2 yang diperolehi daripada korelasi antara ketumpatan kering maksimum dan had Atterberg adalah tinggi berbanding R^2 bagi korelasi antara kandungan kelembapan optimum dan had Atterberg. Oleh itu, bagi anggaran parameter kepadatan tanah berdasarkan had

Atterberg, kandungan kelembapan optimum bukanlah penunjuk yang baik berbanding dengan parameter ketumpatan kering maksimum.

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SYMBOL	DEFINITION
A_v	Air void content
β_1	Slope
β	Constant
E	Compaction energy (unknown) (kJ/m^3)
E_k	Compaction energy (known) (kJ/m^3)
e	Porosity
ε	Random deviation
G_s	Specific gravity of soil particles
LL	Liquid limit
m	Moisture content
MDD	Maximum dry density (Mg/m^3)
M_s	Mass of soil
OMC	Optimum moisture content (%)
PI	Plasticity index
PL	Plastic limit
R^2	Coefficient of determination
ρ_b, γ_b	Bulk density (kN/m³)
ρ_d, γ_d	Dry density (kN/m³)
ρ_w	Density of water (kN/m³)
ρ_{dmax}	Maximum dry density (Mg/m^3)
S_r	Degree of saturation
V	Mold volume

V_a	Percentage air voids
V_v	Volume of voids
V_s	Volume of solids
w	water content
w_{opt}	Optimum moisture content (%)
w_L	Liquid limit
w_P	Plastic limit

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CHAPTER ONE

INTRODUCTION

1.1 Background Of The Problem

The development of land for the construction industry requires considerable quantities of embankment fill, of all which must be compacted to an acceptable standard. Present practice involves obtaining the fill material from randomly selected borrow areas and using this for compaction without prior knowledge of whether it can satisfy the specifications for appropriate dry densities.

Compaction is a process of increasing soil density by packing soil grains closer together and removing air. This is usually done by mechanical means, e.g., rolling, tamping or vibrating. Compaction is intended to improve the strength and stiffness of soil. Consequential (or accidental) compaction, causing settlement, can occur due to vibration (piling, traffic, etc.) or from the self-weight of loose fill.

1.2 Problem Statement

Soil compaction consists of closely packing the soil particles together by mechanical means, thus increasing the soil dry unit weight. As illustrated in Figure l.1, soil compaction occurs when soil particles are pressed together, reducing pore spaces between them. Soils are made of solid grains with voids filled with air and water but compaction only reduces the air fraction. It barely changes the water content and has no effect on the solid volume. In theory, the most efficient compaction process should remove the air fraction completely. However, in practice, compaction cannot completely eliminate the air fraction, but only reduces it to a minimum, provided that appropriate techniques are used.

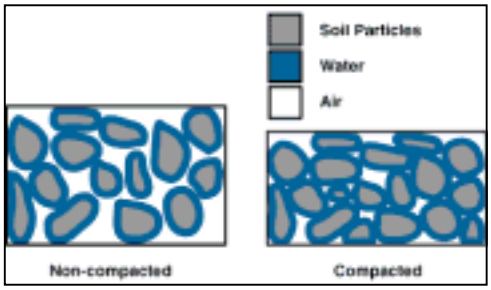

Figure 1.1 Effects of compaction on pore space

There are always confusions between compaction and consolidation. Consolidation corresponds to the drainage of water from soils subjected to continuous loading. On the other hand, compaction is too rapid to allow time for drainage.

That's why it is important to know the water content in soil, by indication of degree of saturation (S_r) of soil usually through the graph. This is because:

($S_r = 1$) ……. Saturated soil

($1 < S_r < 0$)……Partially Saturated soil

($S_r = 0$) ……..Dry soil

The compaction test results are interpreted by using two main parameters, i.e. maximum dry density and optimum moisture content. These parameters are used for estimation of the shear strength and the bearing capacity of the to-be-built platform on subgrades or sub-bases.

1.3 Objectives Of The Project

The main objective in the project is to determine the relationship between the Atterberg limits and parameters of compaction test. Hence, the specific objectives for the project are:

1) To determine relationship between optimum moisture content (OMC) to liquid limit and plastic limit.
2) To determine relationship between maximum dry density (MDD) to liquid limit and plastic limit.
3) To determine the relationship of each compaction parameters; maximum dry density (MDD) and optimum moisture content (OMC) to plasticity index (PI).
4) To determine range of degree of saturation, S_r for compacted soils.

1.4 Scope Of The Project

The data were obtained from related government agencies and private sector, such as Public Work Department (JKR), IKRAM Services Sdn. Bhd. (Central and South Branches), Soiltech Engineering Laboratory Sdn. Bhd. and Master Testing Services Sdn. Bhd. (North South Expressway Project). The data were chosen as random data, which mean no specific area is specified.

The data collected also were obtained from previous theses, Ibrahim bin Husaini *(Kajian Trend Nilai Darjah Ketepuan pada Ketumpatan Maksimum Bagi Ujian Pemadatan, UTM, 2002),* Freddy Teo, *(Hubungan antara Kandungan Lembapan Optimum dan Ketumpatan Kering Maksimum bagi Ujian Pemadatan dengan Had Atterberg, UTM, 2002),* Redzuan Md Yunus *(Korelasi antara Hasil Ujian Pemadatan dan Had Atterberg, UTM, 2003)* and Khainoriyani bt. Khalid *(Korelasi antara Data Ujian Pemadatan dan Had Atterberg, UTM, 2003).*

The Modified Proctor and Standard Proctor compaction tests and the Atterberg limit tests were done to compare with the results of collected data obtained. This is to prove the relationship proposed. The parameters considered from the collected data are optimum moisture content, maximum dry density liquid limit, plastic limit and plasticity index.

1.5 Significance Of The Project

The project produced the correlation charts between the parameters of the compacted soils and the Atterberg limits. The charts will help to estimate values of maximum dry density and optimum water content based on Atterberg Limits' values.

This is very useful during the construction works because it will reduce time to find the maximum dry density (ρ_{dmax}) and optimum moisture content (w_{opt}) and minimize the number of compaction tests, which are relatively high cost.

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