FITTING SOIL-WATER CHARACTERISTIC CURVE BY USING UNIMODAL AND BBIMODAL SOIL PHYSICAL PROPERTIES

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To my beloved mother and father

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ABSTRACT

The soil-water characteristic curve (SWCC) is the relationship between the volumetric water content, θ and the matric suction, S (= U_a - U_W). The SWCC is requested by many researchers in order to determine the behaviour of soil for further analysis in engineering purposes, for example, shear strength. In the past decade, few fitting methods have been developed to describe the SWCC for a particular soil, for example, Fredlund and Xing (1994). These fitting functions fit the experimental SWCC raw data from laboratory test, to form a curve for further prediction and analyse which costly and time consuming. Thus, Zapata (1994) introduced correlation formulae to D_{60} from soil physical property and SWCC fitting parameters in order to achieve time and cost saving instead of doing grain size distribution analysis, sieve analysis and hydrometer test. Two set of data were selected, clayed sand and silt. By plotting the grain size distribution (GSD) curves from laboratory and fitted GSD curves were calculated and plotted. From the fitted GSD, found the bmodal fitting equation has better fitting results (R^2 = 0.97 (clayed sand) and R^2 = 0.98 (silt)) and the soil physical properties, D_{60}, was determined for further analysis in Zapata (1999) equations as fitting parameters (a_f, n_f, and m_f) in Fredlund and Xing (1994) model. The results were compared to the Fredlund and Xing (1994) model without employing Zapata (1999) equations and found that the behaviour of SWCC with Zapata (1999) equations can produce similar smooth curves.

ABSTRAK

Soil-water characteristic curve (SWCC) adalah hubungan kandungan air volumetric, θ dan sedutan matrik, S (= U_a - U_W) dalam tanah. SWCC telah dimintakan secara luas sebagai analisis tanah dalam Geoteknik Kejuruteraan, seperti kekuatan ricih. Dalam dekad yang lalu, beberapa kaedah pemasangan telah dibangunkan untuk menggambarkan SWCC untuk tanah yang tertentu, contohnya Fredlund dan Xing (1994). Fungsi-fungsi SWCC ini sesuai untuk melibatkan eksperimen data SWCC daripada ujian makmal, untuk membentuk keluk sebagai ramalan selanjutnya dan mengantikan analisis makmal yang mahal dan memakan masa. Oleh itu, Zapata (1994) memperkenalkan formula korelasi untuk D_{60} dari harta fizikal tanah dan SWCC parameter sesuai bagi mencapai masa dan kos penjimatan daripada melakukan analisis taburan saiz butiran, analisis ayak dan ujian hidrometer. Dua set data dipilihkan iaitu kelodak dan tanah liat-pasir. Dengan memplot taburan saiz butiran (GSD) lengkuk makmal dan keluk GSD dipasang telah dikira dan diplot. Dari GSD dipasang, terdapat persamaan yang sesuai bmodal mempunyai keputusan yang lebih baik sesuai (R^2 = 0.97 (tanah liat-pasir) dan R^2 = 0.98 (kelodak)) dan sifat fizikal tanah, D_{60}, telah ditentukan untuk analisis lanjut di Zapata (1999) sebagai persamaan parameter yang sesuai (a_f, n_f dan m_f) dalam Fredlund dan Xing (1994) model. Keputusan telah berbanding dengan Fredlund dan Xing (1994) model tanpa menggunakan Zapata (1999) persamaan dan mendapati bahawa SWCC dengan Zapata (1999) persamaan boleh menghasilkan keluk lancar sama.

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LIST OF ABBREVIATIONS

GSD	–	Grain Size Distribution
SWCC	–	Soil-Water Characteristic Curve
ASTM	–	American Society For Testing and Materials
USCS	–	Unified Soil Classification System

LIST OF SYMBOLS

θ_w	–	Volumetric water content
ψ	–	matric suction
$P_p(d)$	–	percentage by mass of particles passing a particular particle size
a_{gr}	–	parameter designating the inflection point on the grain-size distribution curve and is related to the initial breaking point near the coarser particle sizes
n_{gr}	–	parameter related to the steepest slope on the grain-size distribution curve
d_r	–	parameter related to the particle size in the fine-grained region and is referred to as the residual particle size
d	–	diameter of any particle size under consideration
d_m	–	diameter of the minimum allowable size particle
w_i	–	Millimeter per Day
P	–	cumulative grain-size distribution of soi
S_d	–	Parameter representing the geometric standard deviation of GSD curve
V	–	velocity of fall of the spheres (cm/s)
G_S	–	specific gravity of the sphere
G_f	–	specific gravity of fluid (various with temperature)
η	–	absolute, or dynamic, viscosity of the fluid (g/cms)
e	–	Irrational constant equal to 2.71828, used when taking the natural logarithm
a_f	–	fitting parameter indicating the inflection point that bears a relationship to and is greater than the air-entry value
n_f	–	fitting parameter related to the rate of desaturation
m_f	–	fitting parameter related to the curvature near residual conditions

CHAPTER 1

INTRODUCTION

1.1 Research Background

The soil-water characteristic curve (SWCC) is the relationship between the volumetric water content, θw and the matric suction, S (= U_a - U_W). It has to be reminded that SWCC is only available in unsaturated soil mechanics.

The SWCC is requested by many researchers in order to determine the behaviour of soil for further analysis in engineering purposes, for example, shear strength. The behaviour of SWCC is affected by few elements: soil textures, structure and bulk density. Texture of soil which is mainly discussing the ratio of coarse and fine soils, the structural of soil which defines as the component consists in soil for example silt, sand and organic soil, and the bulk density represents the density of each element available in soil condition is different depends on the type of technique used. The techniques which are commonly used such as prefabricated vertical drain, single-stage embankment and multi-stage embankment.

With the capillary theory, many researchers observed that the residual soils show bimodal grains-size distribution result in bimodal soil-water characteristic curve, and vice versa for unimodal soils. Zhang and Chen observed that the bimodal GSD are governed by two pore series in the dual-porosity soil are coarse grains (large pores) and fine grains (small pores).

In the past decade, few fitting methods have been developed to describe the SWCC for a particular soil, for example, van Genuchten and Burdine (1980), van Genuchten (1980), Fredlund and Xing (1994), Gardner (1958), Brooks and Corey (1964) and etc. These fitting functions fit the experimental SWCC raw data from laboratory test, to form a curve for further prediction and analyse. The parameters in these researches' equations are not individually related to shape of the SWCC and also not related to physical properties of the soil. Thus, Zapata (1994) introduced correlation formulae to D_{60} from soil physical property and SWCC fitting parameters.

1.2 Problem Statements

The shape of SWCC shall be reflected from its GSD curve shape. Generally, soil contains two categories according to its pore size distribution, as unimodal soil or bimodal soil. Meanwhile, the SWCC shall also classify into two categories: Unimodal SWCC and Bimodal SWCC.

The laboratory test to obtain soil suction can be obtained either by direct or in direct methods. The direct method measure the negative pore water pressure due to suction directly, whereas the indirect method requires the measurement of other parameters such as relative humidity, resistivity, conductivity or water content and then relate the results to the suction through calibration. The direct method typically requires good contact between the suction sensor and the soil, and measures only matric suctions, however, the indirect method can measure both total and matric suctions. Either direct or indirect method, the laboratory test consumes time (normally from few days to complete a reading). Besides, the equipment to simulate similar condition to real environment is high cost due to the test require high accuracy in result and to simulate some critical condition such as high pressure. Thus, correlated between soil physical properties and SWCC fitting parameters is important to build an effective SWCC according to the soil physical properties.

1.3 Significant Of Study

The research is about to plot the SWCC curve with soil physical parameter, D_{60}, from the fitted GSD curve by using the formula proposed by Zapata (1994). This will save a lot of time during the laboratory stage.

The research requires the knowledge of understanding the SWCC in unsaturated soil mechanic. Besides, understanding of basic soil physical properties such as grain size distribution and pore size distribution is also relatively important. Regression analysis (R^2) to the fitted modal is required to compare the results later.

1.4 Aim

This research study aims to compare the results of SWCC curve (unimodal and bimodal) were developed by using Fredlund and Xing (1994) SWCC fitting method under two difference circumstances: Optimization method and Pre-described formulae.

1.5 Objectives

This study is conducted to accomplish some predefined objectives. Below are the overall objectives of the research:

1. To classify soil type with Unified Soil Classification System (USCS) by conducting soil grain size and plasticity test.
2. To analyse both original and fitted D_{60} value of soil from plotted grain-size distribution (GSD) curve.
3. To compare and discuss soil-water characteristic curve (SWCC) by using both Optimization method and Zapata (1999) fitting parameters formulae into Fredlund and Xing (1994) fitting modal.
4. To examine correlation coefficient (R^2) of unimodal and bimodal GSD curves, the $R^2_{unimodal}$ shall be greater than $R^2_{bimodal}$.

1.6 Scope of Study

The SWCC is the relationship between the volumetric water content, θ and the matric suction, S (= U_a - U_W). It has been introduced by few researchers in the past two decades with several fitting methods to plot a fitting curve according to the laboratory results into a smooth curve to predict the behaviour of soil model under different circumstances of volumetric water content and matric suction, e.g. Fredlund and Xing (1994).

The reason to predict the SWCC with soil physical properties and fitting curve parameters is to save time and cost during laboratory test due to it takes significant time and cost. Moreover, most of the devices cannot achieve high level of matric suction figure. Thus, fitting method can provide required data is necessary during design and analysis with unsaturated soil mechanism.

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