UNIVERSITI PUTRA MALAYSIA

DETERMINATION OF SOIL MOISTURE CONTENT USING PULSE INFRARED RADIATION

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By

SUZILASAHIBATUL AKHMAR BT AHMAD

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of Requirement for the Degree of Master of Science

Mei 2002

Specially Dedicated to My Beloved

Late Mother

Late Father

Late Brother

Salmi Ahmad

Sarimah Ahmad

Suria Ahmad

Za Asmadi Ahmad

Shileey Lizam Ahmad

Zaizul Harby Ahmad

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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Mei 2002

Chairman : Dr. Rosely Ab Malik, Ph.D.

Faculty : Engineering

Moisture content determination is a routine laboratory test to determine the amount of water present in a quantity of soil sample. It is normally being expressed in terms of the dry mass of soil. The standard practice for moisture content determination of soil can be determined, e.g., using electrical oven (ASTM D 2216) or microwave oven (ASTM D 4643). This study presents a unique equipment developed for the determination of soil moisture content using far infrared radiation (FIR). The pulse infrared radiation is generated by passing the conventional electric heater tube through a thin film of specific powdered ceramic radicals.

By applying experimental design matrix to minimise the number of test and using SPSS Programme to analyse the linear regression, the formula of time for complete drying is compared to the time measured in experiment. The correlation of time by formula and time measured proved the reliability of the formula developed in this study.

Throughout the study, the results of time in moisture content determination using the application of FIR ranges from 20 minutes (0.33 hour) to 180 minutes (3 hour). The developed equipment can also be used for rapid moisture content determination. This is particularly useful for high volume repeated testing such as in highway construction.

Abstrak tesis yang dikemukan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Master Sains

PENENTUAN KANDUNGAN AIR DALAM TANAH MENGGUNAKAN RADIASI INFRA MERAH

Oleh

SUZILASAHIBATUL AKHMAR BT AHMAD

Mei 2002

Pengerusi : Dr. Rosely Ab Malik, Ph.D.

Fakuti : Kejuruteraan

Purata kandungan air dalam tanah adalah salah satu daripada ujian makmal yang penting. Ia biasanya diuji berdasarkan kepada berat kering tanah. Berdasarkan amali piawai untuk menentukan kandungan air tanah, penggunaan oven elektrik (ASTM D2216) dan juga oven gelombang mikro (ASTM D4643) digunakan sebagai alat pengering. Di dalam kajian ini satu kaedah unik digunakan untuk proses pengeringan, iaitu dengan menggunakan radiasi infra merah jauh. Dengan menyadurkan lapisan nipis serbuk seramik khas di permukaan tiub pemanas elektrik yang digunakan, gelombang infra merah jauh akan dipancarkan.

Daripada aplikasi matrik rekabentuk pengujian, yang mana dapat meminimakan jumlah ujian yang terlibat dan menggunakan perisian SPSS untuk menganalisa regrasi lurus, rumus yang diperolehi kemudiannya diuji dengan membandingkan

dengan masa yang diperolehi dalam ujian makmal. Berdasarkan perbandingan dan kaitan nilai antara masa yang diperolehi di dalam makmal dan masa yang diperolehi berdasarkan rumus, terbukti bahawa rumus yang dibina adalah boleh dipercayai.

Berdasarkan keputusan daripada kajian ini, masa yang digunakan untuk menentukan kandungan air tanah adalah di antara 20 minit (0.33 jam) hingga 180 minit (3.00 jam). Rekaan alat pengeringan di dalam kajian ini boleh digunakan untuk memendekkan masa yang digunakan dalam penentuan kandungan air dalam tanah. Ianya sangat berguna untuk ujikaji yang dilakukan dalam kekerapan yang tinggi seperti didalam pembinaan lebuhraya.

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LIST OF ABBREVIATIONS

w	Water content
M_w	Mass of water present in the soil mass
M_s	Mass of soil solid
λ	Wavelength
v	Frequency
c	Speed of electromagnetic radiation
$\bar{v}$	Wave number
ΔE	Energy of wave
W	Power
T	Temperature
T_E	Absolute temperature
T_S	Absolute surface temperature
I	Intensity of radiation
I_{max}	Maximum intensity of radiation
V	Amount of adsorption water
V_m	The adsorption capability
β	BET constant
H	Relative humidity
S_0	The specific surface area
ε_0	The thickness of a single molecular layer
p	Vapour pressure

p_s Saturated vapour pressure of free water

p_{ice} Saturated vapour pressure of ice

$\alpha\lambda$ Spectral absorptivity

W_L Liquid limit

W_p Plastic limit

P.I. Plasticity index

F_I Flow index

I_p Plasticity index

CHAPTER 1

INTRODUCTION

1.1 General

Moisture content or water content is the amount of water absorbed in the sample under certain constant condition. According to Axtel and Bush (1991) the moisture content of a material can be defined in two ways, on a wet or dry basis. The wet-weight basis moisture content is defined as the weight of water in a sample divided by the total weight of the sample (water plus dry material) While the dry- weight basis expresses the moisture in a material as a percentage of the weight of bone-dry weight (ASTM D2216, ASTM D 4643). At present our routine laboratory test of moisture content has been defined in term of its dry-weight basis.

For determination of moisture content in term of its dry-weight basis, the soil need to be dried at certain temperature so that most of the water present will evaporate, and after some times the mass of soil solid (without water present) and moisture content will be determined. By definition (Bowles, 1992; Okazaki, 1991; Axtel and Bush, 1991; Gardner 1971),

$$\text{Water content, } w = \frac{M_w \times 100}{M_s} \text{ (percent)}$$

Where: M_w = mass of water present in the soil mass

M_s = mass of soil solids

There are many methods of driving the water particles away from the soil. In this study, the use of the long-wave or far infrared radiation (FIR) to drive the water particles for moisture content determination of soil is employed. During the study, 2 types of oven is used, an oven with FIR (IRO) and an oven without FIR (NIRO). The difference between the ovens is the type of electric heater tube installed as for IRO it is coated with special ceramic powder. The NIRO is used as a control, to define the effectiveness of FIR in soil drying process.

Using the application of special ceramic powder to generate FIR from conventional electric heater tube, this study is conducted to define the effectiveness of FIR radiation for drying soil in laboratory.

1.2 Objective

The objective of this research is to study the effectiveness of ceramic powder that generates FIR in drying process for the determination of moisture content of soil. The specific objective of this study will include:

1. To determine the moisture content of soil by using FIR radiation.
2. To determine time consuming for complete drying using IRO.
3. To develop an equation formula of time for complete drying (T) as a function of weight of soil (W), type of soil (C), and power of oven (P).
4. To determine the correlation between IRO and NIRO.

1.3 Scope and Limitations

In order to get a far infrared oven, which is not available in the soil laboratory at present, a prototype model of FIR oven is built. A second oven is uncoated with ceramic powder to serve as a control. Both IRO and NIRO is used to carry out the most effective way of heating equipment in order to find the moisture content of soil. The experiments is carried out through a conventional oven. A correlation with conventional oven is also conducted.

In this study, experimental design matrix is applied. The number of experiments works required to analyse the effectiveness of oven are expected to be lower as this method is very useful to minimise the number of testing, so the time spent is greatly reduced.

Analysis on the effect of independent variable in determining time for complete drying, which is at moisture content equal to zero is made. Three independent variables that been listed in this study are weight of soil (W), soil type (C) and power of oven (P).

1.4 Structure of Thesis

Divided by five chapters, this thesis is structured by beginning with the introduction in chapter one. Literature review from various areas related to this study is presented in chapter two. The structure of methodology for experimental works is stated in chapter 3. Chapter 4 contain all the experimental result along the experimental works and analysis of the result. The last chapter, chapter 5 is the conclusion for the studies been done and recommendations are listed to improve the study.