EXPERIMENTAL STUDY ON INFILTRATION USING DOUBLE-RING INFILTROMETER

MOHAMMAD FARHAN BIN SALLEH

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University College of Engineering and
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ABSTRACT

Kolej Universiti Kejuruteraan & Teknologi Malaysia (KUKTEM) is located in Pahang Darul Makmur. Infiltration can be define as the rate of water soaking into the soil and the unit used to calculate the infiltration rate is mm/hour. The calculation of the infiltration rate entering the soil, a double-ring infiltrometer is used for the experiment. Three locations have been selected as the study area which is nearby the laboratory of Civil and Environmental Faculty, in front of KUKTEM's mosque and KUKTEM's football field. For each location, three points have been chosen based on the distance of the point with distance between 5m-10m as an experimental point. After performing the experiment, soil samples have been gathered and analyzed in the laboratory using the sieve analysis experiment. The calculation that is using in this experiment is Horton's Equation. The analysis indicated that the soil for the three selected areas is sandy soil. The infiltration rate at KUKTEM's football field is lower compared to the other two selected areas.

ABSTRAK

Kolej Universiti Kejuruteraan dan Teknologi Malaysia (KUKTEM) terletak di Pahang Darul Makmur. Penyesapan bermaksud kadar air masuk ke dalam tanah dan unit yang digunakan untuk mengira kadar resapan ialah mm/jam. Pengiraan kadar resapan air ke dalam tanah, alat double-ring infiltrometer digunakan untuk eksperimen. Tiga tempat telah dipilih sebagai kawasan kajian iaitu berdekatan makmal kejuruteraan awam dan sumber alam, depan masjid KUKTEM dan padang bolasepak KUKTEM. Untuk setiap kawasan kajian, tiga tempat dipilih mengikut jarak antara tempat iaitu jarak antara 5m-10m sebagai kawasan eksperimen. Selepas eksperimen, sampel tanah setiap eksperimen diambil dan dianalisis di makmal dengan ekperimen ayakan. Pengiraan yang digunakan dalam eksperimen ini ialah persamaan Horton. Analisis menunjukkan tanah ketiga-tiga kawasan kajian bercirikan pasir. Kadar penyesapan air ke tanah di kawasan padang bolasepak KUKTEM lebih rendah berbanding dengan di dua kawasan kajian yang lain.

TABLE OF CONTENTS

CHAPTER III METHODOLOGY

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

D_{10} = Effective size

C_u = Uniformity coefficient

D_{60} = diameter corresponding to 60% finer.

C_c = Coefficient of gradation

S_0 = Sorting coefficient

t_p = ponding time

t = time

f_p = infiltration capacity, (mm/hr)

f_f = final infiltration capacity, (mm/hr)

f_0 = initial infiltration capacity, (mm/hr)

k = exponential decay constant, (hr^{-1})

t = time from beginning of rainfall. (hr)

K = hydraulic conductivity

H_o = depth of flow ponded at the surface

S_w = effective suction at the wetting front

L = depth from the surface to the wetting front

f = infiltration rate

F = accumulative infiltration

A = parameter

B = parameter

a = he infiltration capacity [(in./hr)/in.$^{1.4}$] of the available storage (index of surface-connected porosity)

S_a = available storage in the surface layer (A-horizon in agricultural soils, that is about the first six in.) (in. of water equivalent)

mm/hr = millimeter/hour

mm = millimeter

hr = hour

LIST OF APPENDICES

CHAPTER I

INTRODUCTION

1.1 General

Infiltration is the process when the water soaking into the soil. Infiltration rate is simply how fast water enters the soil and is usually measured in inches or millimeters per hour. This rate depends on soil texture (amount of sand, silt, and clay) and soil structure. Soils in good condition have well developed structure and continuous pores to the surface. As a result, water from rainfall or snowmelt readily enters these soils.

Soil is a reservoir that stores water for plant growth. The water in soil is replenished by infiltration. The infiltration rate can be restricted by poor management. Under these conditions, the water does not readily enter the soil and it moves down slope as runoff or ponds on the surface, where it evaporates. Thus, less water is stored in the soil for plant growth, and plant production decreases, resulting in less organic matter in the soil and weakened soil structure that can further decrease the infiltration rate.

Another important of infiltration is in construction. The infiltration experiment will be done at any area to definite that the area safe for construction. The results summarize about the texture and porosity of the soils. Good soil structure improves infiltration. Soils with good structure have more pores for the movement of water than soils with poor structure.

Commonly used methods for determining infiltration capacity are hydrograph analyses and infiltrometer studies. Infiltrometers are usually classified as rainfall simulators or flooding devices. In the former, artificial rainfall is simulated over a test plot and the infiltration is calculated from observations of rainfall and runoff, with consideration given to depression storage and surface detention (W. K. Johnson, 1974). Infiltrometers are usually tubes and rings inserted in the ground level of soil.

Water is applied and maintained at a constant level and observations are made of the rate of replenishment required (W.Viessman and Jr.Gary L.Lewis, 2003). Estimates of infiltration based on hydrograph analyses have the advantage over infiltrometers of relating more directly to prevailing conditions of precipitation and field. Several methods have been developed and are in use (Charley, A. Pabst, and J.Peters, 1995).

1.2 Problem Statement

In this infiltration study, the infiltration test will determine the types of soil in KUKTEM area. The result from the experiment will analyze the types of soil and the effects for the development at the surrounding KUKTEM area. This study will determine how fast the water infiltrates into the soil in KUKTEM area. So we will know the properties of soil in the area which the rates of infiltration that can prevent flood from happen and for the future development. For the preventing flood happen, the soil properties must be study before any development will be constructed at KUKTEM area.

1.3 Objective

The objectives of study are;

1. To determine types of soils for study area.
2. To obtain infiltration curve using Horton's Equation.
3. To determine the infiltration parameter using Horton's Equation.
4. To compare the values of infiltration parameter among different locations.

1.4 Scope of study

This study will be used Double-Ring Infiltrometer that is prepared by Faculty of Civil and Environmental Engineering KUKTEM. Three main locations are chosen to collect the data. The locations are nearby the Civil and Environmental Engineering Lab, in front of KUKTEM's mosque and KUKTEM's football field. The calculation for infiltration measurement in this study is using Horton's Equation.

CHAPTER II

LITERATURE REVIEW

2.1 Infiltration

Infiltration process is the largest process of rainfall losses in area. The term infiltration refers to the process by which rainwater passes through the ground surface and fills the pores of the underlying soil (A.Osman Akan and Robert J. Houghtalen, 1992). Surface and subsurface of soil conditions influence the infiltration rates. The surface conditions determine the availability of water, while the subsurface conditions govern the ability of the available water to infiltrate (A.Osman Akan and Robert J. Houghtalen, 1992). The rate of rainfall means the availability of water at the ground surface. The infiltration capacity means as the maximum rate at which water can infiltrate into the soil. Its mean the ability of available water to infiltrate.

Infiltration is the process when the water penetrating or enter into the soil from the ground surface. There are many factors that influence the infiltration rate such as the condition of the soil surface and its vegetative cover, the properties of the soil, such as its porosity and hydraulic conductivity, and the current moisture content of the soil. Soil strata with different physical properties may overlay each other, forming horizons; for example, a silt soil with relatively high relatively high hydraulic conductivity may overlay a clay zone of low conductivity. Also, soils exhibit great spatial variability even within relatively small areas such as a field. As a result of these great spatial variations and the time in soil properties that occur as the soil moisture content changes, infiltration is a very complex process that can be described only approximately with mathematical equations (Ven Te Chow, 1988).

2.2 Factors affect infiltration

The proportion of water from rainfall or snowmelt that enters the soil depends on residence time (how long the water remains on the surface before running off) and the infiltration rate. These are affected by vegetation and many soil properties.

2.2.1 Soil properties

The properties that affect infiltration and cannot be readily changed by management include:

i. Texture

Water moves more quickly through the large pores and spaces in a sandy soil than it does through the small pores in a clayey soil. Where the content of organic matter is low, texture plays a significant role in the susceptibility of the soil to physical crusting.

ii. Clay mineralogy

Some types of clay develop cracks as they dry. These cracks rapidly conduct water to the subsurface and seal shut once the soil is wet.

iii. Minerals in the soil

High concentrations of sodium tend to inhibit the development of good structure and promote the formation of surface crusts, which reduce the infiltration rate. Calcium improves soil structure.

iv. Soil layers

Subsurface soil, including a subsoil of dense clay, cemented layers, and highly contrasting layers, such as coarse sand over loam, can slow water movement through soil and thus limit infiltration.

v. Depth

Soil depth controls how much water the soil can hold. When soil above an impermeable layer, such as bedrock, becomes saturated, infiltration ceases and runoff increases. The properties that affect infiltration and can be readily changed by management or a shift in vegetation.

vi. Organic matter and soil biota

Increased plant material, dead or alive, generally improves infiltration. As organic matter is broken down by soil organisms, it binds soil particles into stable aggregates that enhance pore space and infiltration.

vii. Aggregation and structure

Good soil structure improves infiltration. Soils with good structure have more pores for the movement of water than soils with poor structure. If aggregates are stable, the structure remains intact throughout a rainstorm.

viii. Physical crusts

Physical crusts form when poorly aggregated soils are subject to the impact of raindrops and/or to ponding. Particles broken from weak aggregates can clog pores and seal the surface, thus limiting water infiltration.

ix. Biological crusts

Biological crusts can either increase or reduce the infiltration rate. Their effect on the infiltration rate depends on many other factors, including soil texture.

x. Pores and channels

Continuous pores connected to the surface convey water. Such organisms as earthworms, ants, and termites increase the number of pores. Termites, however, can decrease the infiltration rate by reducing the amount of litter cover, and some ant species seal the surface around their nests.

xi. Soil density

A compacted zone close to the surface restricts the entry of water into the soil and often results in surface ponding. Increased bulk density reduces pore space and thus the amount of water available for plant growth.

xii. Water-repellent layer

As shrubs and an underlying thick layer of litter burn in a hot fire, very high temperatures can occur directly beneath the shrubs. The heat forces a gas from the burning plant material into the soil. When it cools, the gas forms a water-repellent layer that limits infiltration. This feature is temporary, although it may persist for a number of years. Some soils can be slightly water repellent when dry.

2.2.2 Residence time

The length of time that water remains on the surface depends on the slope, the roughness of the soil surface, and obstructions to overland flow, such as plant bases and litter. Consequently, plant communities with large amounts of basal area cover, such as grasslands, tend to slow runoff more than communities with small amounts of basal cover, such as shrub lands.

2.2.3 Infiltration rate

The infiltration rate is generally highest when the soil is dry. As the soil becomes wet, the infiltration rate slows to the rate at which water moves through the most restrictive layer, such as a compacted layer or a layer of dense clay. Infiltration rates decline as water temperature approaches freezing. Little or no water penetrates the surface of frozen or saturated soils.

2.2.4 Vegetation

A high percentage of plant cover and large amounts of root biomass generally increase the infiltration rate. Different plant species have different effects on infiltration. The species that form a dense root mat can reduce the infiltration rate. In areas of arid and semiarid rangeland, the infiltration -limiting layer commonly is confined to the top few millimeters of the soil, particularly in the open spaces between plant canopies. These areas receive few inputs of organic matter, which build soil structure. Also, the impact of raindrops in these areas can degrade soil structure and form physical crusts.

2.3 Engineering Classification of Soil

Different soils with similar properties may be classified into groups and sub-groups according to their engineering behavior. Classification systems provide a common language to concisely express the general characteristics of soils, which are infinitely varied, without detailed descriptions. Currently, two elaborate classification systems are commonly used by soils engineers. Both systems take into consideration the particle-size distribution and Atterberg limits. They are the American Association of State Highway and Transportation Officials (AASHTO) classification system and the Unified Soil classification system. The AASHTO classification system is used mostly by state and country highway departments. Geotechnical engineers generally prefer the Unified system.(Braja M.Das,2006)

2.4 Particle-Size Distribution Curve

A particle-size distribution curve can be used to determine the following four parameters for a given soil.

1. Effective size (D_{10}): This parameter is the diameter in the particle-size distribution curve corresponding to 10% finer. The effective size of a granular soil is a good measure to estimate the hydraulic conductivity and drainage through soil.

2. Uniformity coefficient (C_u) : This parameter is defined as

$$C_u = \frac{D^{60}}{D_{10}} \tag{2.1}$$

where D_{60} = diameter corresponding to 60% finer.

3. Coefficient of gradation (C_c) : This parameter is defined as

$$C_c = \frac{D^2_{30}}{D_{60} \text{ X } D_{10}} \tag{2.2}$$

4. Sorting coefficient (S_0) : This parameter is another measure of uniformity and is generally encountered in geologic works and expressed as

$$S_0 = \sqrt{\frac{D_{75}}{D_{25}}} \tag{2.3}$$

The sorting coeffiecient is not frequenly used as a parameter by geotechnical engineers. (Braja M. Das, 2006)

2.5 Unified Sil Classification System

The original form of this system was proposed by Casagrande in 1942 for use in the airfield construction works undertaken by the Army Corps of Engineers during World War II. In cooperation with the U.S Bureau of Reclamation, this system was revised in 1952. At present, it is used widely by engineers (ASTM Test Designation D-2487). The Unified Soil Classification System is presented in Table 2.1.

Table 2.1 : Unified Soil Classification (USC) System (from ASTM D 2487), 2003

Unified Soil Classification (USC) System (from ASTM D 2487)				
Major Divisions			**Group Symbol**	
Course-Grained Soils More than 50% retained on the 0.075 mm (No. 200) sieve	**Gravels** 50% or more of course fraction retained on the 4.75 mm (No. 4) sieve	Clean Gravels	GW	Cu > 4 and 1 < Cc < 3c
			GP	Cu < 4 and/or 1 > Cc > 3c
		Gravels with Fines	GM	PI < 4 or plots below "A" line (Figure 2.1)
			GC	PI > 7 and plots on or above "A" line ((Figure 2.1)
	Sands 50% or more of course fraction passes the 4.75 (No. 4) sieve	Clean Sands	SW	Cu > 6 and 1 < Cc < 3c
			SP	Cu < 6 and/or 1 > Cc >3c
		Sands with Fines	SM	PI < 4 or plots below "A" line (Figure 2.1)
			SC	PI > 7 and plots on or above "A" line (Figure 2.1)
Fine-Grained Soils More than 50% passes the 0.075 mm (No. 200) sieve	**Silts and Clays** Liquid Limit 50% or less		CL	PI < 4 or plots on or above "A" line (Figure 2.1)
			ML	PI > 7 and plots below "A" line (Figure 2.1)
			OL	Liquid limit – oven dried ----------------------------- < 0.75 Liquid limit – not dried ; OL zone
	Silts and Clays Liquid Limit greater than 50%		CH	PI plots on or above "A" (Figure 2.1)
			MH	PI plots below "A" line (Figure 2.1)
			OH	Liquid limit = oven dried ----------------------------- < 0.75 Liquid limit – not dried ; OH zone
Highly Organic Soils			PT	Primarily organic matter, dark in colour and organic odor
Prefix: G = Gravel, S = Sand, M = Silt, C = Clay, O = Organic Suffix: W = Well Graded, P = Poorly Graded, M = Silty, L = Clay, LL < 50%, H = Clay, LL > 50%				