DETERMINING THE PERMEABILITY OF SOIL AT UNVERSITI MALAYSIA PAHANG, GAMBANG CAMPUS USING GUELPH PERMEAMETER KIT

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This thesis is submitted in fullfilment of the requirements for the award of the degree of Bachelor of Civil Engineering

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NOVEMBER 2010

ABSTRACT

The measure of the soil's ability to permit water to flow through its pores or voids is termed as permeability. Different types of soil give different value of permeability because their abilities to permit water to flow through their pores are different. Several factors that affect the permeability of the soil are type of soil, vegetation management, surface moisture, soil compaction, rainfall intensity and temperature. This study was carried out to determine the permeability of the soil and identify the soil classification for ten locations in the compound of Universiti Malaysia Pahang, Gambang Campus. Guelph Permeameter test was used to determine the permeability of soil of each location. The lowest permeability of soil is at Guard house and construction site 2 with the rate of 0 cm/sec while the highest is at sport complex with the rate of 2.19×10^{-4} cm/sec. The results indicated the slow permeability at the ten locations were due to less voids in the soil structures.

ABSTRAK

Saiz kemampuan tanah untuk membenarkan air mengalir melalui pori-pori atau rongga disebut sebagai ketelapan. Berbagai jenis tanah memberikan nilai kebolehtelapan yang berbeza kerana kemampuan mereka untuk membolehkan air mengalir melalui pori-pori yang berbeza. Beberapa faktor yang mempengaruhi kebolehtelapan tanah adalah jenis tanah, pengurusan tumbuhan, kelembapan permukaan, pemadatan tanah, kekuatan curah hujan dan suhu. Kajian ini dilakukan untuk menentukan ketelapan tanah dan mengenalpasti klasifikasi tanah untuk sepuluh lokasi di Kampus Gambang Universiti Malaysia Pahang. "Guelph Permeameter" digunakan untuk menentukan ketelapan tanah di lokasi yang dipilih. Ketelapan terendah tanah adalah di Rumah Jaga dan Laman Pembinaan 2 dengan tahap 0 cm / saat dan ketelapan tertinggi adalah di Kompleks Sukan dengan tahap 2.19×10^{-4} cm / saat. Kajian mendapati ketelapan rendah di sepuluh lokasi yang dipilih. Ini adalah disebabkan oleh kurang rongga dalam struktur tanah tersebut.

TABLE OF CONTENTS

4 ANALYSIS AND DISCUSSION

LIST OF TABLE

LIST OF FIGURES

LIST OF SYMBOL

Q	-	The quantity of water per unit of time
K_{sat}	-	Saturated hydraulic conductivity
A	-	The cross-sectional area of the column
L	-	The length of the column
ΔP	-	Hydrostatic pressure
Q	-	Rate of water flow (volume per time)
K	-	Hydraulic conductivity
A	-	Column cross sectional area
dh/dl	-	Hydraulic gradient
K_{fs}	-	The field-saturated hydraulic conductivity, ($m\ s^{-1}$)
H	-	The ponded depth, (m)
a	-	The radius of the well, (m)
C	-	The matric potential as well as the H/a ratio
Φ_m	-	Matric flux potential
R	-	Rate of water level change

%	-	Percent
cm/min	-	Centimeter per minute
cm	-	Centimeter

CHAPTER 1

INTRODUCTION

1.1 Background

The study of permeability of soil is important for flood or flash flood. Soil permeability is the property of the soil pore system that allows fluid to flow. It is generally the pore sizes and their connectivity which determines whether soil has high or low permeability. Water will flow easily through soil with large pores with good connectivity between them and it is high permeability. Small pores with the poor connectivity between them which would have lower permeability, because water would flow through the soil more slowly. It is possible to have zero permeability which is no flow with high porosity soil if the pores are isolated (not connected). It is also to have zero permeability if the pores are very small, such as in clay (Roy David Nurmi, 2009).

The measurement of the soil's ability to permit water to flow through its pores or voids are termed as permeability. In other words, permeability is a measurement of a material's ability to transmit liquids. Material which contain continuous void is easily permeable. Different types of soil will have different value of permeability because their ability to permit water to flow through its pores is different. A low and high permeability means the water flows through the soil is slow, and fast respectively.

Many factors controlling the proportion of precipitation that is converted to runoff in a given landscape, and the time it takes for runoff to enter a stream. Human changes to these landscape features can greatly influence runoff. Where soil is absent and little-fractured bedrock is exposed, water cannot soak in and will run off rapidly. If soil is present, but is very fine-grained and clay-rich, the pore spaces that water must pass through are extremely small; hence, water will infiltrate very slowly compared to sandy soils that readily soak up water. Some finer-grained soils have vertical cracks that form when the soil shrinks as it dries. These cracks allow water to enter more readily, but may close up after the soil is wetted (Dingman, S. Lawrence, 1994).

Besides that, compaction of soils reduces the size of pore spaces and the infiltration rate. This will affect the runoff. Water commonly runs off areas that were compacted through repeated passage of people, large animals, or heavy machinery. Raindrops falling on bare soil also can compact the soil surface in plowed fields, leading to increased runoff and erosion of farmland (Dingman, S. Lawrence, 1994).

Weathering also will affect the permeability of soil. During the wet weather, moisture content of the soil is higher compare to that of hot weather. Rain water cannot infiltrate through the soil. It causes surface runoff during rainfall. For dry weather, porosity and moisture content of the soil will decreased. High volume of rain water can transmit to the ground.

Several others factors that affect the permeability of soil, for example, vegetation management, initial soil condition, surface moisture, soil compaction, rainfall intensity and temperature. The rate at which water is transmit through surface level of the ground is normally depends on the condition of the surface. This is because some fine materials may block or seal the surface so it affect infiltration rate even though underlying soils are high permeable. Infiltration rate is affected also by the volume of storage available below the ground. In this case, flash flood or flood might take place.

1.2 Problem statements

During heavy rain period, flash flood occurred at the roadside and this is not only affect cars and motorcyclists but also students' movement along the roadside in Universiti Malaysia Pahang. These are the problems which allow flash flood to occur:

1. Around 50% of areas in UMP are occupied with building. (Figure 1.0)
2. Drains are always over flow during heavy rain.
3. Around 20% of area around the Gambang Campus are paved area.

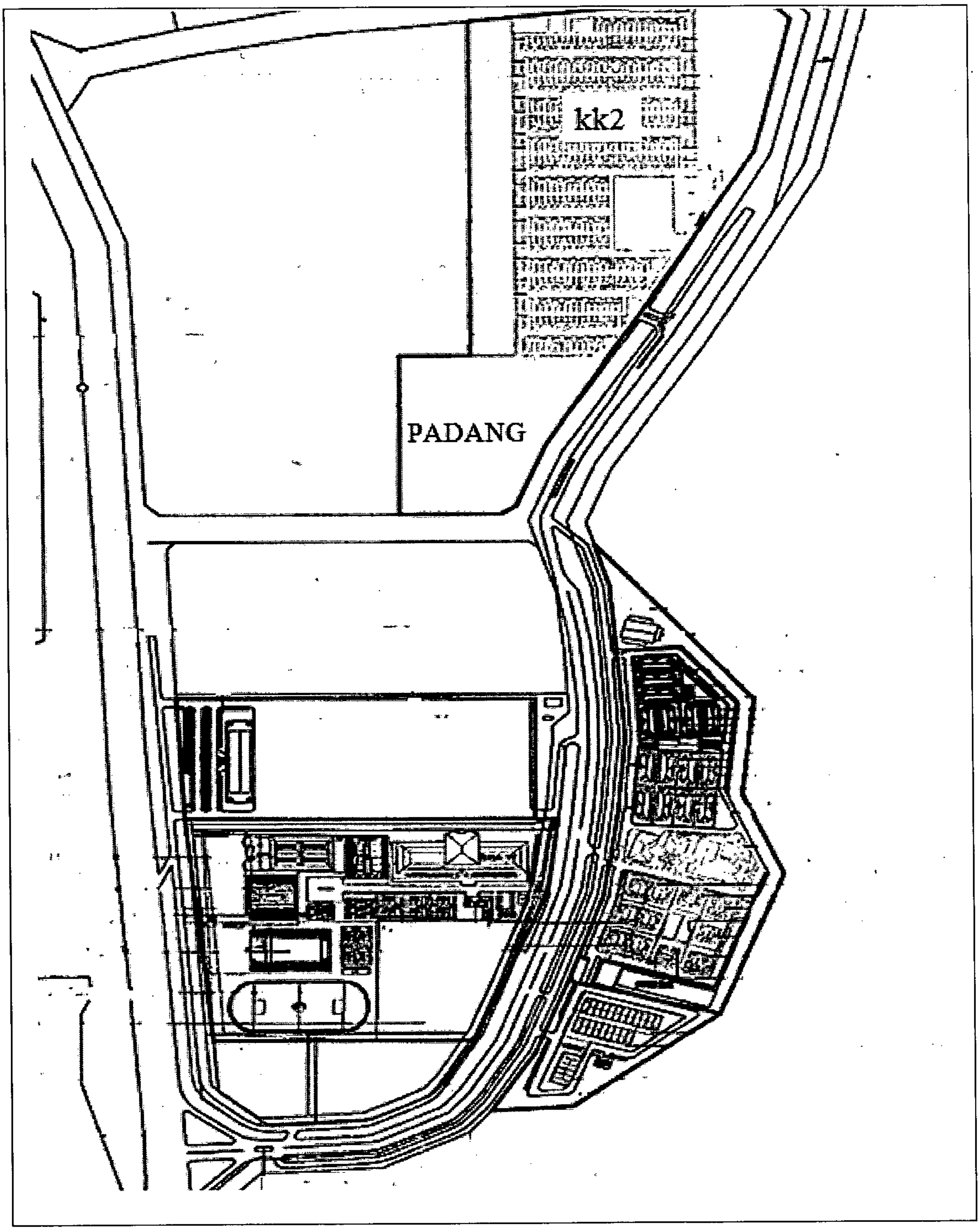

Figure 1.0 Plan for UMP Gambang, Campus

1.3 Research objectives

The objectives of this project are:

1. To determine permeability of the soil by using Guelph Permeameter kit
2. To identify the soil classification in UMP.

1.4 Scope of Study

The studies scopes are as follows:

1. Identify ten locations around UMP Gambang Campus.
2. Use Guelph Permeameter kit to determine permeability of soil in UMP Gambang Campus.
3. Use hand auger to dig and collect the soil samples at the specified location.
4. Determine the type of soil in UMP Gambang Campus.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter covered about the characteristic of the soils, formula for analysis the permeability of soil and method to measure it. Factor affecting the soil permeability was included.

2.2 Soil Properties

Soil can be divided into three major categories which are organic soil, cohesive and cohesionless. Cohesionless soils which the soil particle do not stick together. Cohesion means the act or state of cohering, uniting, or sticking together. While the cohesive soil contains clay minerals and posses plasticity and the particles of soil stick to each other cause by water- particle interaction and attractive force between particles. Organic soils are typically spongy, crumbly and compressible. The most important property of soil related to rainfall induced slope failure is permeability (Cheng and Jack, 2005).

Soil permeability is the property of the soil pore system that allows fluid to flow. It is generally the pore sizes and their connectivity that determine whether a soil has high or low permeability. Water will flow easily through soil with large pores with good connectivity between them. Small pores with the same degree of connectivity would have lower permeability because water would flow through the soil more slowly. It is possible to have zero permeability (no flow) in a high porosity soil if the pores are isolated (not connected). It is also to have zero permeability if the pores are very small, such as in clay (Cheng and Jack, 2005).

Actual water movement is thought of as small, interconnected, irregular conduits. Because the water moves through the voids, it follows that the soils with large voids such as sands are generally more permeable than those with smaller voids such as clays. Additionally, because soils with large voids generally have large void ratios, it may be generalized that permeability tends to increase as the void ratio increase. Because water movement can have profound effects on soil properties and characteristics, it is an important consideration in certain engineering application. Tables 2.1 show the lists of some soil permeabilities (Cheng and Jack, 2005).

Table 2.1 Soil Permeability (Cheng and Jack, 2005)

Soil	**Permeability Coefficient, k (cm/sec)**	**Relative Permeability**
Coarse gravel	$>10^{-1}$	High
Sand, clean	10^{-1} - 10^{-3}	Medium
Sand, dirty	10^{-3} - 10^{-5}	Low
Silt	10^{-5} - 10^{-7}	Very Low
Clay	$< 10^{-7}$	Impervious

There are several factors which influence the permeability of soil such as soil texture, organic content in soil, the density of soil and vegetation. Soil texture refers to the proportions of the sand, silt, clay in soil. Course textured sandy and gravelly have the largest pores and the most rapid permeability. Fine textured clayey soils have tiny pores and very slow permeability rates. Medium textured loams, silt loams and clay loams have intermediate rate of permeability (Cheng and Jack, 2005).

Soil organic matter contributes to soil productivity in several ways, but there is no direct quantitative relationship between soil productivity and total soil organic matter. In fact, it has been the decline in organic matter that has contributed to the productivity of the crop-fallow system. Organic soils often have varying degrees of organic compounds in different states of decomposition. Organic matters help create and stabilize aggregates of the grains of sands, clay and silt. This aggregates or units of soils structure, have relatively large spaces between them, permitting more rapid water movement. Dense, compacted or cemented soil layers have very slow rates of permeability. Roots, burrowing insects and animals create large voids or macropores which can transmit water very rapidly under saturated conditions. Macropores also are common in very coarse textured soils and in soils that crack extensively upon drying (Cheng and Jack, 2005)

2.3 Porosity

Soil porosity refers to that part of a soil volume that is not occupied by soil particles or organic matter. Pore spaces are filled with either air, other gases, or water. Large pores (macropores) allow the ready movement of air and the drainage of water. They are also large enough to accommodate plant roots and the wide range of tiny animals that inhabit the soil. Large pore spaces permit fast infiltration and percolation of water through a soil or soil horizon. Small pores (micropores) exhibit attractive forces strong enough to hold water in the pore. They are the water retention system of the soil which provides water storage for plant roots. During precipitation, macropores conduct water into the soil where it fills the micropores. At field capacity all pores small enough to retain water against the pull of gravity are filled (Brady and Weil, 1999; Munshower, 1994).

Clay soils have numerous micropores and hold large quantities of water, but since they have few macropores they produce very slow infiltration rates. The pores in the clays may be so small and hold water so tenaciously that the water is not available to plants. Sandy soils with numerous macropores but few micropores have higher infiltration and percolation rates but a lower water-holding capacity than other soil textures. A lower water-holding capacity can mean less available water for plant roots. For revegetation purposes, plants perform best in intermediate soil textures (loams) where soils contain mixtures of micro and macropores (Munshower, 1994).

2.4 Hydraulic Conductivity

Water can move through soil as saturated flow, unsaturated flow, or vapor flow. Saturated flow takes place when the soil pores are completely filled (or saturated) with water. Unsaturated flow occurs when the larger pores in the soil are filled with air, leaving only the smaller pores to hold and transmit water. Vapor flow occurs as vapor pressure differences develop in relatively dry soils. Vapor migrates from an area of high vapor pressure to an area of low vapor pressure. Hydraulic conductivity is a soil property that describes the ease with which the soil pores permit water (not vapor) movement. It depends on the type of soil, porosity, and the configuration of the soil pores. In saturated soils, the hydraulic conductivity is represented as K_{sat} and in unsaturated soils, the hydraulic conductivity is represented as K (Ecorestoration.2004).

The quantity of water per unit of time, Q, that flows through a column of saturated soil can be expressed by Darcy's Law, as follows:

$$Q = \frac{K_{sat} A \Delta P}{L}$$

Where:

Q = the quantity of water per unit of time

K_{sat} = saturated hydraulic conductivity

A = the cross-sectional area of the column

L = the length of the column

ΔP = hydrostatic pressure

Flow through an unsaturated soil is more complicated than flow through continuously saturated pore spaces. Macropores are filled with air, leaving only finer pores to accommodate water movement. The movement of water in unsaturated soils is dictated by differences in matric potential, not gravity. The matric potential gradient is the difference in the matric potential of the moist soil areas (high matric potential) and nearby drier areas (low matric potential) into which the water is moving (Brady and Weil, 1999).

Hydraulic conductivity is an important soil property when determining the potential for widespread groundwater contamination by a contaminating source. Soils with high hydraulic conductivities and large pore spaces are likely candidates for far reaching contamination. The hydraulic conductivity in a saturated soil can be measured by injecting a non-reactive tracer (i.e. bromide) in a monitoring well and measure the time it takes for the tracer to reach a down gradient monitoring well. Remediation of contaminated groundwater can be a likely step in the reclamation process (Ecorestoration.2004).

2.5 Darcy Law

In fluid dynamics, Darcy's law is a phenomologically derived constitutive equation that describes the flow of a fluid through a porous medium. The law was formulated by Henry Darcy based on the results of experiments on the flow of water through beds of sand. Darcy's law is a simple proportional relationship between the instantaneous discharge rate through a porous medium, the viscosity of the fluid and the pressure drop over a given distance. In modern format, using a particular sign convention, Darcy's law is usually written as:

$$Q = -KA\,\frac{dh}{dl}$$

Where:

Q = rate of water flow (volume per time)
K = hydraulic conductivity
A = column cross sectional area
dh/dl = hydraulic gradient, that is, the change in head over the length of interest.

The law is often transformed by dividing through by the cross-sectional area and is then restated as:

$$q = \frac{Q}{A} = -K\,\frac{dh}{dl}$$

where q now has the dimensions of a velocity, and is referred to as the Darcy, or superficial, velocity (James R and Paul A,1992).

2.6 Method to Measure Permeability of Soil

2.6.1 Guelph Permeameter

The permeability can be measured efficiently in situ by using Guelph Permeameter. The Guelph Permeameter is an easy to use instrument for quickly and accurately measuring in-situ permeability of soil. The equipment is portable and friendly use so it can be transported, installed and operated easily by one person. Measurements can be made in half to two hours, depending on soil type, and require only around 2.5 liters of water. Measurements can be made in the range of 15 to 75 cm below the soil surface. Accurate evaluation of soil hydraulic conductivity and matrix flux potential can be made in all types of soils.

The Guelph permeameter, a constant-head well permeameter, regulates the ponded head level, while measuring the flux of water into the soil from a cylindrical Auger hole (Reynolds and Elrick, 1983). Reynolds and Elrick (1985) described the steady flow of water out of a well into the soil in terms of three fluxes. The water flows out of the well by a radial pressure gradient-induced flux and through the base of the well, driven by both vertical pressure and the gravity gradient. The total flux is described by Richard's equation for steady flow out of a cylindrical well:

$$Q = 2\pi H^2 \left[\frac{K_{fs}}{c} + \frac{K_{fs}}{2}\left(\frac{a}{H}\right)^2 C + \frac{\Phi m}{H}\right]$$

Where

K_{fs} = the field-saturated hydraulic conductivity, (m s^{-1})

H = the ponded depth, (m)

A = the radius of the well, (m)

C = the matric potential as well as the H/a ratio

Φ_m = matric flux potential