UNIVERSITI PUTRA MALAYSIA

PERFORMANCE OF AN INFILTRATION BASIN

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BY

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ABSTRACT

Infiltration basin is constructed to capture and store the excess water while it infiltrates through the basin's floor and sides. The infiltration basins are storm water control measures (SCMs) widely employed for urban storm water management. For this study performance of Infiltration Basin, the dimension of infiltration basin constructed is 1m width and 1m long (1m×1m). The infiltration basin is enclosed with the Perspex to ensure the area is undisturbed. Infiltration can be defined as the rate of water entering into the soil because of the act of the gravity and capillary action. The unit used to measure the infiltration rate is cm/hr. The method to determine the infiltration rate are by using double ring infiltrometer and by direct method. The location has been selected as the study area is near the Hydraulic Laboratory Faculty of Engineering UPM. Before starting the infiltration rate test, soil samples have been gathered and analysed in laboratory using the sieve analysis test. The type of soil sample underlying play very important part in the performance of infiltration rate. The infiltration rate test is tested under two condition which is under natural soil condition and under modified soil condition with and without surface cover. Under modified soil condition, the natural soil is remove and fill with the three types of soil composition which is gravel, filler and natural soil in a certain depth. The analysis indicated that, the rate of infiltration is high at the beginning. Then, it decreases rapidly in the initial stages and slowly till it approaches a nearly constant rate depending upon the type of the soil. The rate of infiltration with the surface cover is higher compare with the rate of infiltration without surface cover. Besides that, the rate of infiltration under modified soil condition is higher compared to rate of infiltration under natural soil composition.

ABSTRAK

Infiltrasi basin dibina untuk menangkap dan menyimpan air yang berlebihan semasa ia menyusup melalui bawah dan sisi lembangan ini. Infiltrasi basin adalah langkah kawalan air digunakan secara meluas untuk pengurusan air di bandar. Untuk prestasi kajian infiltrasi basin, dimensi infiltrasi basin yang dibina adalah 1m×1m. Infiltrasi basin dikelilingi dengan Perspex untuk memastikan kawasan infiltrasi basin tidak terganggu. Penyusupan boleh ditakrifkan sebagai kadar kemasukan air ke dalam tanah kerana tindakan tindakan graviti dan kapilari. Unit yang digunakan untuk mengukur kadar penyusupan adalah cm/jam. Kaedah untuk menentukan kadar penyusupan adalah dengan menggunakan double ring infiltrometer dan dengan kaedah langsung. Lokasi kawasan kajian adalah berdekatan Makmal Hidraulik, Fakulti Kejuruteraan UPM. Sebelum memulakan ujian kadar penyusupan, sampel tanah telah dikumpulkan dan dianalisis di makmal menggunakan analisis ayak. Jenis sampel tanah memainkan peranan yang penting dalam menentukan kadar penyusupan. Ujian kadar penyusupan diuji dalam dua keadaan iaitu dalam keadaan tanah semula jadi dan dalam keadaan tanah diubah suai dengan dan tanpa perlindungan permukaan. Dalam keadaan tanah diubah suai, tanah semula jadi telah dikorek dan diisi dengan tiga jenis komposisi tanah iaitu batu, pengisi, dan tanah semula jadi disetiap kedalaman yang ditentukan. Analisis menunjukkan bahawa, kadar penyusupan tinggi pada awal permulaan. Kemudian, ia berkurangan dengan cepat pada peringkat awal dan perlahan-lahan sehingga ia menghampiri kadar yang sama bergantung kepada jenis tanah. Kadar penyusupan dengan penutup permukaan adalah lebih tinggi berbanding dengan tanpa perlindungan permukaan. Selain itu, kadar penyusupan di bawah keadaan tanah yang diubahsuai adalah lebih tinggi berbanding dengan di bawah komposisi tanah semula jadi.

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D_{10}=Effective size

C_U=Uniformity coefficient

D_{60}=diameter corresponding to 60% finer

C_C=Coefficient of gradation

t=time

cm/hr= centimetre per hour

qm=micrometre

mm=millimetre

cm=centimetre

CHAPTER ONE

INTRODUCTION

1.1 Background

An infiltration basin is a vegetated, open impoundment where incoming stormwater runoff is stored until it gradually infiltrates into the soil strata. Infiltration basins are stormwater control measures (SCMs) widely employed for urban stormwater management. Stormwater control measures (SCMs) have been widely implemented to control the non-point pollution contributed by urban stormwater runoff and reduce runoff volume. Infiltration basins are SCMs that capture, temporarily store, and gradually infiltrate runoff into the ground, thereby reducing the net volume of runoff leaving the site, and can provide moderate to high removal of some pollutants in runoff.

Infiltration basin is a shallow impoundment that stores and infiltrates runoff over a level, un compacted, (preferably undisturbed area) with relatively permeable soils which designed to temporarily store and infiltrate stormwater runoff. Infiltration Basins use the existing soil mantle to reduce the volume of stormwater runoff by infiltration and evapotranspiration. If the soil and infiltration capacity of grassed area is determined to be sufficient, the area can be enclosed through creation of a berm and runoff can be directed to it without excavation.

Infiltration basin is capable of advancing a broad range of water resources and environmental purposes encompassing water purity, ground and surface water reserves, flood prevention, stream channel stability, ecosystem health and the scenic beauty of the stream alleys. Infiltration basin is effective in controlling urban flooding and drainage problem. The condition and infiltration performance of infiltration basins can progressively decline due to sediment deposition, irregular maintenance, improper siting, and poor design. Infiltration basins may be used where the subsoil is sufficiently permeable to provide a reasonable infiltration rate and where the water table is low enough to prevent pollution of groundwater. The framework employs hydrology, soil, and vegetation as primary indices of functionality.

Infiltration is the method of stormwater management capable of maintaining or restoring soil moisture and groundwater reservoirs and consequently supporting downstream base flow. In long-term water balance modelling, the amount of water that passes through subsurface process is indicated by the base flow. Base flow is water that has infiltrated, passes through subsurface storage and transmission process and later re-emerged at the surface. Infiltration performance was found to be related more to site design, environmental factors and material choice.

The rate of infiltration is affected by the permeability rate of the underlying soil, the distance separating the lowest basin elevation from the seasonal high water table (SHWT) and the area of the basin bottom. Additionally, infiltration basins may only be used on these types of sites provided the location of the infiltration basin is not inconsistent with a remedial action work plan or landfill closure plan.

Discharge from infiltration basins of the smaller storm events occurs through the subsoil. Therefore, they may not be used where their installation would create a significant risk of adverse hydraulic impacts. These impacts may include exacerbating a naturally or seasonally high water table so as to cause surficial ponding, flooding of basements, or interference with the proper operation of a subsurface sewage disposal system or other subsurface structure, or where their construction will compact the subsoil. Hydraulic impacts on the groundwater table must be assessed.

A basin excavated in the earth holds the runoff that reaches it until it soaks in. An infiltration basin has no regular surface outlet. When basin eliminate runoff near its source and basin is sized to hold a design storm as well as all background flows, the expense of culvert and swales to convey runoff downstream is eliminated. An infiltration basin can be used in a development where there is sufficient open space and a level area of earth or grass would be seen as a multiple purpose amenity.

There are two main problems encountered which are clogging, which compromise the hydraulic capacity of the basin and possible contamination of underlying soil and groundwater. Clogging is characterized by the hydraulic resistance. Soil samples were collected at different depths in each basin and analysed for different pollution parameters (metals, hydrocarbons, pH, and particle size distribution). Pollutant concentration decrease rapidly with depth whereas pH and grain size increase.

1.2 Problem Statement

The design of infiltration basin requires the knowledge of infiltration capability of soil forming the basin. In this performance of infiltration basin study, it is necessary to determine the infiltration rate at the proposed location of the infiltration basin, which is an area near the Hydraulic Laboratory in Faculty of Engineering UPM. Besides the infiltration rate, the soil properties of the area also need to be determined because the soil properties are among the factors that affect the rate of infiltration.

1.3 Objective

The main aim of this project is:

To construct and test the performance of an infiltration basin with regard to its ability to allow the infiltration process.

The specific objective of this project are:

1. To determine the rate of infiltration of the infiltration basin with different surface cover.
2. To determine the rate of the infiltration of the infiltration basin with different underlying soil layers.

1.4 Scope of Study

This study of the performance of the infiltration basin is carried using field test experiment by using Double Ring Infiltrometre and by using direct method. The location of this study is at the field area behind the Hydraulics laboratory in Faculty of Engineering UPM. The groundwater table level and the underlying soil composition at this infiltration basin area need to be determined first before carry out the analysis. Surface water runoff infiltrate into the ground and percolates down until it reaches a depth of water table zone.

In this study of performance of infiltration basin, the infiltration basin will be constructed under its natural condition with grass cover and without grass cover and this infiltration basin also will be constructed under modified condition with grass cover and without grass cover.

Based on the standard of Manual Saliran Mesra Alam Malaysia(MSMA), there is no limitation on soil infiltration rate but minimum of 1.3cm/hr is recommended and the soils with 30% or greater clay content or 40% greater silt/clay content should not be used. Besides that, the bottom of infiltration basin shall be located at least 1.5m above seasonal high ground water level. The aggregate material shall consist of a clean aggregate with minimum diameter of 30mm and maximum diameter of 70mm.

CHAPTER TWO

LITERATURE REVIEW

2.1 Infiltration

Gregory et. al (2005) expressed that infiltration is the methodology by which water moves descending at the soil surface pass in the soil. This system influences surface runoff, soil erosion, and groundwater recharge. In numerous orders the surface invasion rate is important to measure. The double-ring infiltrometer is regularly utilized for measuring invasion rates. The utilization of more modest diameter inner and outer rings (15 and 30 cm, separately) with a constant head gave comes about that were factually higher than the ASTM standard test and the falling head test with little rings.

The importance of infiltration comes from the role of the subsurface water in the hydrologic balance. The defining process of the infiltration is to transfer surface water to the subsurface. By returning runoff to the earth, it eliminates pollutant discharge, eradicates flood and restores aquatic habitats. Hillel (1980) found that infiltration rate is how fast water enters the soil. Infiltration rate is measured in units of cm/h. Infiltration rate depends on the soil texture and on soil structure. When the rate of delivery of water to the surface is smaller than the soil's ability to take it in, water infiltrates as fast as it arrives. The infiltration rate rises when water is ponded over the surface, increasing the head.

Every earth material contains some amount of pore space inherent in the type of materials. When water infiltrates into the soil, it displaces some of the air and fills a greater proportion of the pore space. Pore space is generally greatest near the earth's surface and less abundant at greater depths. Water seeping down from a rain-soaked surface collects above the impermeable layer, filling all the pores of the permeable portion until it overflows into the stream and ocean. Horton (1940) hypothesized that the potential infiltration rate is controlled at the soil surface and also might be affected by conditions deep within the profile.

Brady (1974), Jury et al. (1991) found that the forces acting upon water in porous underlying earth material include the earth's gravity, the attraction of water molecules to each other and to surrounding solid surface, the weight of overlying water, the attractive force of ions dissolved in water and the weight of any overlying unconstrained soil particles. The runoff infiltrating into the soil moves downward through larger soil pore under the force of gravity. The smaller surface pores take in water by capillarity. The downward moving water is also sucked in by capillary pores. The gravitational water moves towards the ground water following the path of least resistance.

When the capillary pores at the surface are filled and intake capacity reduced, infiltration rate will decrease. As a trend the rate of infiltration is high at the beginning. It decreases rapidly in the initial stages and the slowly till it approaches a nearly constant rate depending upon the type of soil. The trend of infiltration process is observed not only because of filling up surface capillary pores with water but also due to changes in the soil such as dispersion of aggregates, puddling of the surface layer, impact of the rain drops, swelling of colloids, closing of soil cracks and type of vegetal cover.

2.1.1 Factor affecting Infiltration rate

The principles of infiltration and the factors affecting the process are imperfectly understood even after many years of investigation. Early studies by Muntz (1908) were followed by the evaluations studies by many investigators among which were Kohnke (1938), Free,Browning and Musgrave (1940), Nelson and Muckenhirn (1941) and Klute (1952). The most recent general research on the subject of infiltration is the study by Robinson and Rohwer (1957) under field conditions and by Aronovici (1955) under laboratory conditions.

2.1.1.1 Permeability

Permeability is the ability of a material to allow water to pass through it. The rate of infiltration is affected greatly by the permeability of the sediments. Larger particles will increase permeability because pore space is larger. Impermeable may be due to tight packing or cementing particles which seals off the pores from one another. The U.S Salinity Laboratory Staff (1954) pointed out that the effect of divergent flow increases as infiltration area decrease while the permeability decrease with the depth. Permeability is important in evaluating the amount of seepage through and into water wells. On the first application of water in the infiltration test, the rate is generally great. As water application continues and the uppermost sediments become saturated, the infiltration rate gradually decrease and reaches a nearly constant rate, generally within a few hours. The permeability of soil as refer to the table 2.1.

Table 2.1:Permeability of different soil types

Types of soil	Phase
Sand and Gravel	Very permeable
Clay and Loam	Impermeable
Mixed soil	Semi permeable

2.1.1.2 Capillarity

Capillarity is the process by which water is drawn into openings due to the attractive force between water molecules and the surrounding earth materials. The water infiltrating into the soil moves downward through larger soil pores under the force of gravity. The smaller surface pores take in water by capillarity. The downward moving water is also sucked in by capillary pores. The gravitational water moves towards the ground water following the path of least resistance. When the capillary pores at the surface are filled and intake capacity reduced infiltration rate decreases.

As a trend the rate of infiltration is high in the beginning. It decreases rapidly in the initial stages and then slowly till it approaches a nearly constant rate in about 30 to 90 minutes depending upon the type of soil. Free, Browning and Musgrave (1940), found that the infiltration rate decreases with increasing clay content and increases with increasing non capillary porosity (approximately equivalent to specific yield).

The continuity of non-capillary or large pores provides easy paths for percolating water. If the subsoil formation has coarse texture the water may infiltrate into the soil so quickly that no water will be left for runoff even if rainfall is quite heavy. On the contrary clayey soils after soaking some water in the initial stages of the rainfall may swell considerably. It makes the soil almost watertight and infiltration may get reduced to practically negligible extent.

2.1.1.3 Soil saturation

The infiltration rate will decrease if the underground soil is already saturated. Water infiltrates into the ground until its meets the interface between the zone of aeration. This interface is the water table. The depth of the water table below the surface varies with the amount of infiltration. For a given soil, initial infiltration rates may vary considerably, depending on the initial soil moisture level. Dry soil has a higher initial rate than wet soil because there is more empty pore space for water to enter.

The short term decrease in infiltration rate is primarily due to the change in soil structure and the filling of large pores as clay particles absorb water and swell. Thus, adequate time must be allowed when running field tests to achieve a steady intake rate. The conductivity of soil varies dramatically ss the water content is reduced below saturation.

Lewis (1937) and Musgrave and Free (1937) conclude that an increase in initial moisture content in the tested sediments correlated with a decrease in infiltration rate. They stated that is probably due to the unavailability of the smallest interstitial spaces for the percolation of water after the initial supply is received. The studies of saturated and unsaturated flow of water through the soils have been made by Colman and Bodman (1944), Kirkham and Feng (1949), Marshall and Stirk (1949), and Miller and Richard (1952).

2.1.1.4 Vegetative Cover

Vegetative cover affects surface entry of water significantly. The vegetation or mulches protect the soil surface from impact of rain drops. The lengthy and extensive root system penetrate the soil and increases its porosity. Organic matter from crops promotes a crumbly by structure and improves soil permeability.

Vegetation allows greater infiltration because of the roots in the plants absorbing all of the excessive water. As the roots absorb the excessive water, the overflow is decreased. The absorption rate depends on the moistness of the soil and roots. But, the infiltration rate is least effect by the vegetation.

2.2 Soil Characteristic

Infiltration basins are commonly utilized to reduce or eliminate storm water runoff and are commonly located on coarse soils due to relatively high infiltration rates. Besides that, a soil boring is collected from the site for analyses, including soil texture, bulk density, and organic matter content. Infiltration basins are facilities constructed within highly permeable soils that provide temporary storage of storm water runoff.

An infiltration basin does not normally have a structural outlet to discharge runoff from a specific design storm. Instead, outflow from an infiltration basin is through the surrounding soil. Soil regulates and partitions rainfall. Soil also regulates flow and storage of water and solutes, including nitrogen, phosphorus, pesticides and other nutrients and compounds that are in dissolved water. Soil stores, moderates the release of, and cycles plant nutrients and other elements. Soil acts as a living filter. Changes in the capacity of a soil to function are reflected in soil properties that change in response to management or climate.

The soil in infiltration basin must be in undisturbed. This because when the soil is disturbed it loses its' natural ability to absorb and infiltrate rainfall making it necessary to collect, channel, store and filter storm water. Management choices affect the amount of soil organic matter, soil structure, soil depth, water and nutrient holding capacity. Soils respond differently to management depending on the inherent properties of the soil and the surrounding landscape.

2.2.1 Particle size of Soil

The grain size analysis is widely used in classification of soils. The data obtained from grain size distribution curves is used in the design of filters for earth dams and to determine suitability of soil. Information obtained from grain size analysis can be used to predict soil water movement although permeability tests are more generally used.

For determining the grain size distribution of soil sample, usually sieve analysis is carried out in which the finer sieve used is 63 micron or the nearer opening. If a soil contains appreciable quantities of fine fractions in (less than 63 micron) wet analysis is done. Soil consists of an assembly of ultimate soil particles (discrete particles) of various shapes and sizes. The object of a particle size analysis is to group these particles into separate ranges of sizes and so determine the relative proportion by weight of each size range. In 1947, Casagrande devise a method to classify soil called "Unified Classification System". In this system, soil sizes are divided into three groups. The particle size based on the types of soil as refer to the table 2.2.

Table 2.2: Particle size based on the types of soil

Particle size	Types of soil
Particle< 0.06mm	Silt and Clay
0.06mm ≤ Particle < 2mm	Sand
Particle ≥ 2mm	Gravel

The particle size of coarse-grained soils (Sand and gravel) is determined by passing a known weight of the soil through a nest of sieves. The mesh in each sieve is a square grid. Each sieve is labelled with a number and the size of the grid. Typically, a stack of sieves will consist of the following from 10mm, 6.3mm, 3.35mm, 2.36mm, 1.18mm, 600ɥm, 300ɥm, 212ɥm, 0.075ɥm and 63ɥm.

When a known mass of the soil is poured on the top of the stack of sieves and then the stack of sieves is vibrated by using sieve shaker. The mass of soil retained on each sieve is determined using a balance and then the percent finer of each sieve is calculated. After that, the results are plotted on a semi-logarithm graph of %finer versus grain size (sieve size opening). The shape of the grain-size curve is indicative of the grain distribution.

Three basic parameters can be determined from these grain size distribution curves which were effective size, Uniformity Coefficient (C_U) and coefficient of curvature(C_C). The diameter in the particle size distribution curve corresponding to 10 %finer is defined as the effective size, D_{10}. The D refers to the size or apparent diameter of the soil particles while the subscript (10,30,60) denotes the percent that is smaller than that diameter. For example, D_{10}=0.1 mm means that 10% of the soil sample grain have diameter smaller than 0.1 mm. while, D60 is the diameter corresponding to 60% finer in the particle distribution. A larger value of C_u indicates a wide grain-size spread between D_{60} and D_{10} grain size.

The uniformity coefficient (C_u) is given by the relation:

$$Cu = \frac{D_{60}}{D_{10}}$$

Coefficient of the curvature(C_C) is defined as a measure of the shape of the curve between D_{60} and D_{10} grain size. Coefficient of gradient is defined as a measure of the shape of the curvature between D_{60} and D_{10} grain sizes. A value of C_C of approximately 1.00 indicates nearly linear variation of the grain-size distribution curve from the D_{60} and D_{10} and the soil is well graded. While, if the C_C is much less or much larger than 1.00, the soil is poorly graded.

The coefficient of the curvature(C_C) is given by the relation:

$$Cc = \frac{D_{30}^2}{D_{10} \times D_{60}}$$

While, for the fine grain soil (silt and clay), the clay mineral and soil moisture(water) content play an important role in influencing the soil behaviour. They will determine the properties and state condition of the soil. Soil volume decrease with decrease in the moisture content. The classification of fine-grained soils also requires the use of the plasticity chart. Each soil is grouped according to the coordinates of the plasticity index and liquid limit.

The original form of Unified Soil Classification 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 y engineers (ASTM Test Designation D-2487).

The Unified Soil Classification System for Coarse grain soil as refer in Table 2.3 and for Fined grain soil is as refer in Table 2.4.

Table 1.3: The Unified Soil Classification System for Coarse grain soil

Description		Group Symbol	Laboratory Criteria		
			Fines (%)	Grading	Plasticity
Coarse grain (>50% larger than BS 63 ųm size sieve)	Gravel (>50% coarse fraction of gravel size)	GW: Gravel -Well graded gravel; Sandy gravel with little or no fines	0-5	CU > 4 1< CC < 3	
		GP: Gravel-poor graded gravel; Sandy gravel with little or no fines	0-5	Not satisfying GW requirements	
		GM: Gravel-silty gravel; Sandy silty gravel	>12		Below 'A line' and PI<4
		GC: Gravel-clayed gravel; Sandy clayed gravel	>12		Above 'A line' and PI>7
	Sand (>50% coarse fraction of sand size)	SW: Sand-well graded sand Gravelly sand with little or no fines	0-5	CU > 6 1< CC < 3	
		SP: sand-poor graded sand ;Gravelly sand with little or no fines	0-5	Not satisfying GW requirements	
		SM: Sand-silty sand	>12		Below 'A line' and PI<4
		SC: Sand-clayed sand	>12		Above 'A line' and PI>7

Table 2.4: The Unified Soil Classification System for Fine grain soil

Description		Group Symbol	Laboratory Criteria		
			Fines (%)	Grading	Plasticity
Fine grain (<50% larger than BS 63 ɥm size sieve)	Silt and Clay (liquid limit <50)	ML: Silt-inorganic silt; Sand-silty fine sand or clayey fine sand, with little plasticity		Refer to plasticity chart	
		CL: Clay-inorganic clay; Silty clay of low plasticity		Refer to plasticity chart	
		OL: Silt-organic silt; Clay-organic silty clay of low plasticity		Refer to plasticity chart	
	Silt and Clay (liquid limit >50)	MH: Silt-inorganic silt of high plasticity		Refer to plasticity chart	
		CH: Inorganic clay of high plasticity		Refer to plasticity chart	
		OH: Organic clay of high plasticity		Refer to plasticity chart	
High organic soil		Pt: Peat and other highly organic soil			

2.3 Example of Infiltration Basin Constructed

2.3.1 Long Island, New York

The Island's infiltration program began in 1935 as part of the Nassau County Sanitation Commission's comprehensive drainage plan. According to that plan, the use of the recharge basins would conserve storm runoff by replenishing the island's ground water, which is its only water source and would avoid expensive public storm sewers by eliminating runoff near the source. The island's housing boom following World War II was accompanied by a large increase in the number of infiltration basin. Long Island's soil is derived from glacial outwash and terminal moraines and are mostly sandy and permeable, particularly on the outwash plains where a large amount of development takes place.

Long Island's basins were inventoried in 1969 (Seaburn and Aronson,1974). At that time the basins ranged in area from 0.4 to 12 ha, averaging between 0.4 to 0.8 ha. Most were excavated 3 to 4.5 m below the land surface; some were as deep as 12m. Most had overflow structures to carry excess water from one basin to another or to a nearby stream. 80% of the basins drained residential areas, 17% drained highways and 3% drained commercial and industrial areas. The average drainage area was 14 ha.

The basin tends to be open, flat-bottomed excavations, usually with steep sides. Some basins include settling areas of different elevations on the basin floor. The lower level collects inflowing coarse sediment and trash, leaving the higher level relatively free to infiltrate without rapid sedimentation. Sizing methods and criteria have evolved empirically (Seaburn and Aronson, 1974).

About 91% of the basins are dry within 5 days after a 2.5cm rainfall (Ku and Simmons,1986). Those that hold water for longer periods intersect the water table, are excavated in soil of low conductivity or are clogged with layers of sediment and debris. In some of water-containing basins, water levels recede rapidly (within a few hours after a storm) to the pre-storm levels (Aronson and Seaburn, 1974). Evapotranspiration losses are negligible when water remains in the basins are only a short time.

In summary, the Long Island, New York demonstrates the effectiveness of artificial recharge in a more urbanized, eastern setting, where climate and water availability are significantly different than in the West. Storm water runoff is recharged into infiltration basins to replenish the ground water withdrawn for use by Long Island residents, thereby also helping to retard seawater intrusion into the aquifers that provide the primary source of drinking water for the area.

2.3.2 Aman Lake, USM Main Campus Malaysia

Aman Lake is one of flood retention ponds located in USM Main Campus, Pulau Pinang, Malaysia. It is constructed as flood mitigation effort to reduce flood problem inside campus area. The Aman lake has an area of about 0.743 ha, storage volume of about 57.627 m^3 and two channel linked to the river as inlet channel and outlet channel. Some study to investigate the effectiveness of Aman Lake in reducing flood events has been conducted. The result from this study show that, Aman Lake is able to reduce the flood level approximately 43cm for 2 years ARI and 82 cm for 10 years.

Figure 2.1: Aman Lake, USM Main Campus Malaysia

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This study of performance of infiltration involves several principle steps which are illustrated in the following Figure 3.1 Problem statement is the first thing to determine because it is very important to ensure the study is follow the requirement of objective and scope of work of the project.

Determine the location to construct the infiltration basin

↓

Determine the groundwater level at this site location

↓

Get the soil sample from the site location

↓

Determine the underlying soil composition

↓

Design and construct the infiltration basin

↓

Determine the infiltration rate

↓

Repeat the experiment with modified underlying soil condition

Figure 3.1: Flowchart of methodology

3.2 Selecting Site Location

The location for this study has been determined. This infiltration basin has been constructed at the area near the Hydraulic Laboratory in Faculty of Engineering UPM as shown in Figure 3.2.

Figure 3.2: Location of infiltration basin

3.3 Determination of Groundwater level

Determination of groundwater level for the performance of infiltration basin is very important because the level represents the potential height to which water will rise. Therefore, the groundwater level need to determine before infiltration rate is carry out. The water table level can be determined by digging a representative hole with an auger. The representative hole is as shown in Figure 3.3. Make sure that the area and the elevation of the hole is representative of the entire field.

The soil layer is dig until water starts entering the hole, or to a maximum depth of 1.2 meter. Allow the hole to settle, and observe if water fills the hole within 1 hour. The level that water began to enter the hole, or the level to which it fills it, is the water table level. Make note of this depth. Multiple holes may be dug for greater accuracy. But for this study of the performance of infiltration basin, only one hole is dig. The removing soil from this test was used to determine the underlying soil composition.

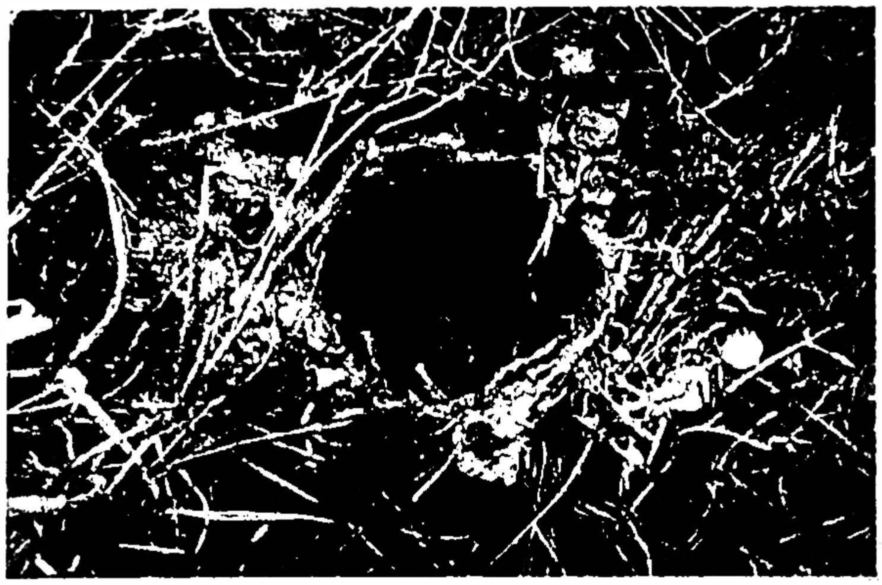

Figure 3.3: The hole by using Auger hole method

After reaching the ground water level, the digging process is stop. Then, construct a standpipe at the auger hole by inserting the PVC pipe at the centre of the hole and fill the surrounding of the hole by fine sand until it reaches the ground surface as shown in Figure 3.4. After that, cement the ground surface around the pipe. The ground surface around the hole is need to cement because to avoid the water from the rainfall to enter the hole. The groundwater level is determining by inserting the water level meter into the standpipe until it sound. that means, it already reaches the ground water level. Ground water level need to be taken every time to conduct the experiment.

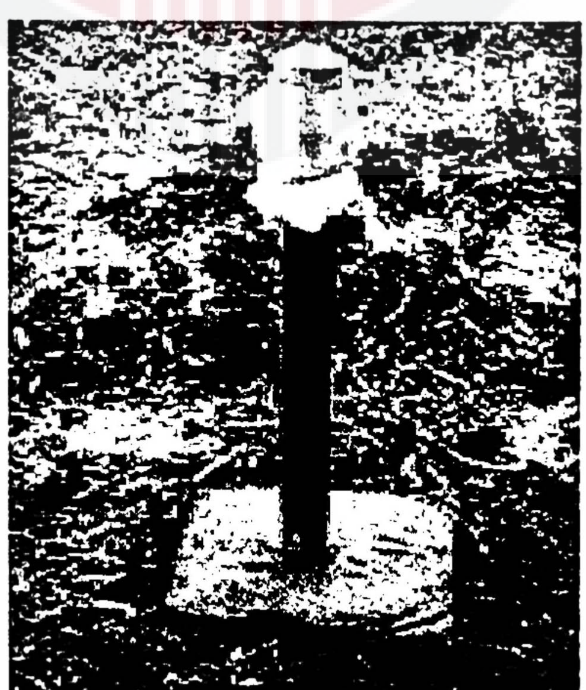

Figure 3.4: Standpipe

3.4 Samples Collection

The soil samples obtained during the site investigations can be divided into two categories, whether disturbed soil sample or undisturbed soil. For the disturbed soil sample, it can be obtained by using test pit or hand auger or boreholes method. while for undisturbed soil sample, a sample tube made of steel is usually used to obtain such sample. The sample tube is sealed with wax at both ends once the sampling process is done to prevent loss of the moisture. This process will help preserve the soil sample as in its original condition.

For this site investigation work to determine the soil composition, disturbed soil sample is obtained. Soil sample is obtained from the removing soil of the auger hole method for determine the groundwater level by using hand auger. The soil sample was collected until it reached the depth of groundwater level. The soil sample collected was kept into the plastic bag. Then the soil sample taken from the field test was brought to the soil laboratory for the further soil analysis. As shown in Figure 3.5, three soil samples are collected and tested in the soil laboratory.

Figure 3.5: Soil Samples

3.5 Determination of Underlying Soil Composition

Soils are the most important consideration for site suitability. In general, County Soil Surveys may be used to obtain necessary soil data for planning and preliminary design of infiltration basins. However, for final design and construction, soil tests are required at the exact location of the proposed basin in order to confirm its ability to function properly without failure. In this study of infiltration rate, sieve analysis test and Liquid Limit and Plastic limit test are carried out to determine the underlying soil composition at this infiltration basin area.

3.5.1 Sieve Analysis

Sieve analysis is a test that need to conduct in the Laboratory. This test is performed to determine the percentage of different grain sizes contained within a soil. The mechanical or sieve analysis is performed to determine the distribution of the coarser and larger-sized particles. For the sample preparations, the sample is obtained from the infiltration basin soil area. The standard reference for this test is ASTM D 422 - Standard Test Method for Particle-Size Analysis of Soils. The distribution of different grain sizes affects the engineering properties of soil. Grain size analysis provides the grain size distribution, and it is required in classifying the soil.

Before running the test, the weight of each sieve and the pan that will be used is weight and record. While, the soil sample must be dried to a constant weight at temperature not exceeding 110°C and weight. Nest the sieve by arranging the finest sieve above the bottom pan and the coarsest sieve at the top. The dried soil sample is place on the top of the sieve and place the cap over it. After that, place the sieve stack in the sieve shaker and shake for 10 minutes.

After 10 minutes, remove the sieve stack from the sieve shaker and record the weight of each sieve with its retained soil. Not only that, the pan also will weight. The mass of the soil retained on each sieve will be obtain by subtracting the weight of the empty sieve from the mass of the sieve with the retained soil. The mass of soil retained must be recorded on the data sheet. The sum of these retained masses should be approximately equals the initials mass of the soil sample. A loss of more than two percent is unsatisfactory. After that, the percent of the soil retained and the percent of soil passing is calculated and recorded. Thus after complete calculate, the semi-logarithmic is plot of grain size against percent finer.

Figure 3.6: Mechanical sieve shaker equipment

3.5.2 Plastic Limit and Liquid Limit Test

The determination of the Liquid limit and Plastic Limit for fine grained soil is by using Casagrande's method. From the testing of Liquid Limit Test, the semi log graph of soil moisture content against number of blows will be plotted. The value of moisture content that corresponds to 25 blows is taken as soil liquid limit (LL). While for Plastic Limit Test, the average moisture content (w) is considered as the soil plastic limit (PL). After done LL and PL testing, the soil Plasticity Index (PI) can be calculated. Thus, the soil can be classifying according to Unified Classification System.

3.6 Design of an Infiltration basin

In this study of performance of infiltration basin, a square infiltration basin is constructed. The area of the selected infiltration basin is 1.0m^2 which is 1.0m × 1.0m. The infiltration basin is being enclosed with the Perspex of the dimension 1.0m × 1.0m × 0.5m. The infiltration basin constructed as shown in Figure 3.7 and the cross section of soil layer under natural soil composition as shown in Figure 3.8.

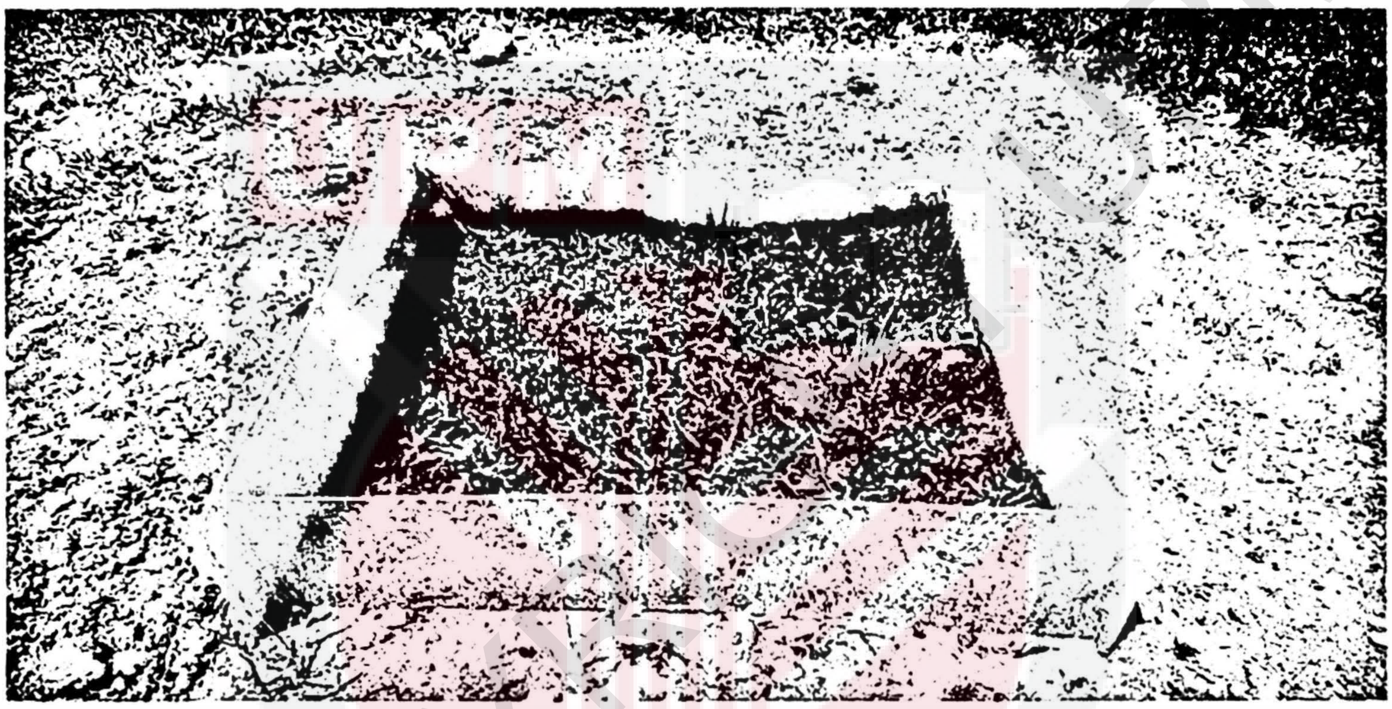

Figure 3.7: Infiltration basin

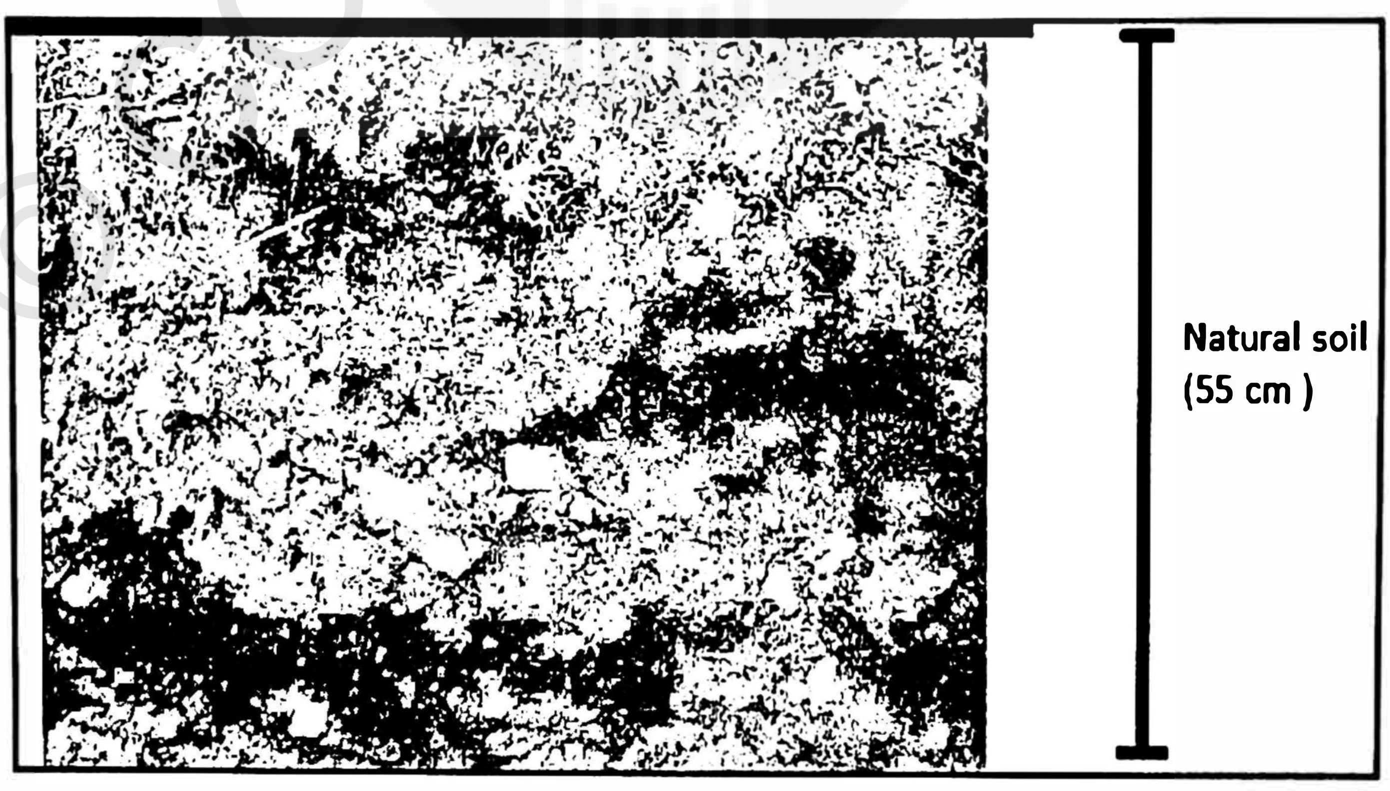

Figure 3.8: cross section of soil layer under natural soil composition

Under natural underlying soil composition, the soil on the infiltration basin must kept remain undisturbed. While, under modified underlying soil composition, the soil is excavated for about 55cm depth with 1m width and 1 m long as shown in Figure 3.9. After that, the infiltration basin is filled with three types of soil composition for a certain depth. At the bottom layer of the infiltration basin is filled with gravel for about 20 cm depth and at the middle of the infiltration basin is filled with filler for about 20 cm depth. While for the top layer, at first experiment it filled with organic soil. But then after the first experiment, the top layer is filled with natural soil there for the next experiment. The infiltration basin under modified soil composition as shown in Figure 3.10 and Figure 3.11.

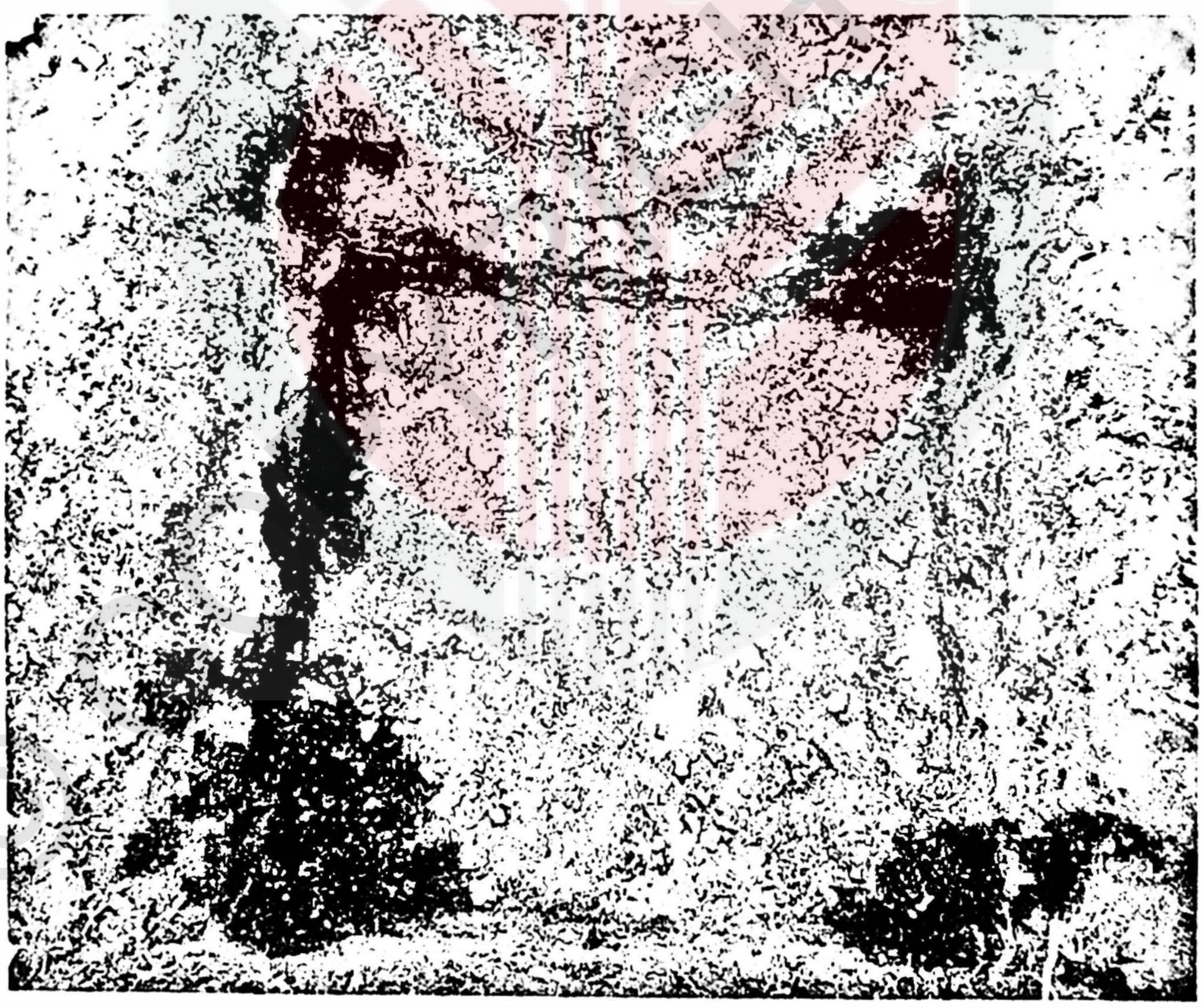

Figure 3.9: Infiltration basin under modified soil composition

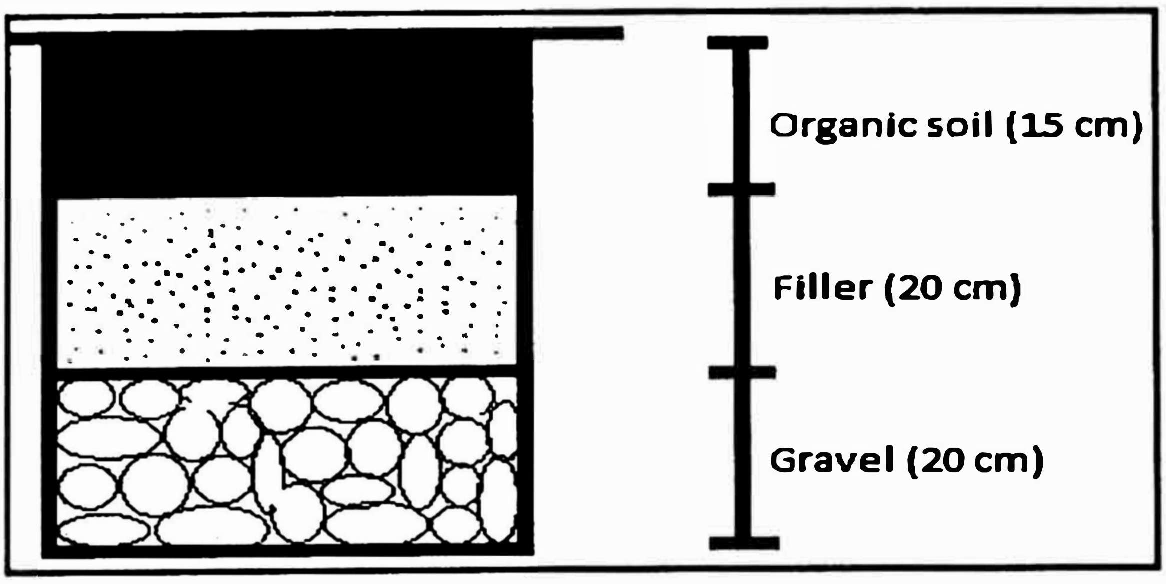

Figure 3.10: Cross section of modified soil layer with organic soil at the top layer

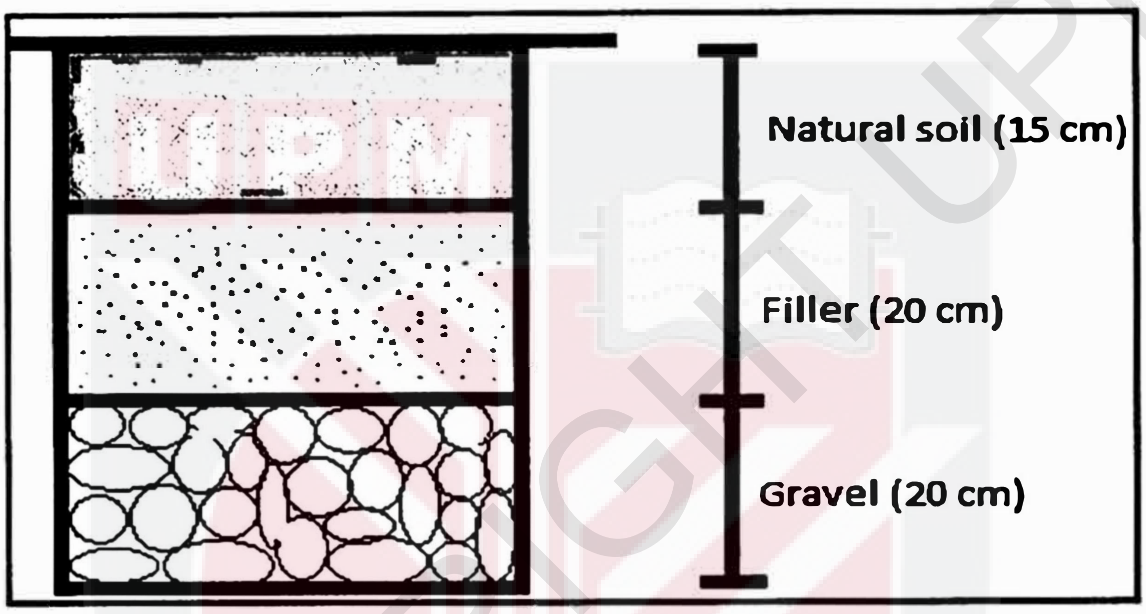

Figure 3.11: Cross section of modified soil layer with natural soil at the top layer

3.7 Determination of Infiltration Rate

Infiltration rate is determined under natural soil composition and under modified soil composition with and without grass. The infiltration rate is determined by using direct method and double ring infiltrometer method. By using direct method, four experiment of infiltration rate is tested which is under natural soil composition without grass(N-WTG), under modified soil composition without grass and with organic soil at the top layer(M-WTG-ORG), under modified soil composition without grass and with natural soil at top layer(M-WTG-NATURAL) and under modified soil composition with grass(M-WG-NATURAL).

While by using double ring infiltrometer method, four experiments of infiltration rates are tested which is under natural soil composition without grass (N-WTG), under natural soil composition with grass(N-WG), under modified soil composition without grass(M-WTG) and under modified soil composition with grass(M-WG).

3.7.1 Double Ring Infiltrometer method

The purpose of the double ring is to insure the downward flow of movement of water and to insure proper measurement of infiltration rate of water. The experiment started by placed the outer ring with the cutting edge facing down on the ground. Then, the outer ring is hammered into the soil and the ring is covered by driving plate which is usually by using wood materials to absorb the impact of hammer as shown in Figure 3.12. The outer ring is insert into the soil for about 5 cm vertically. The soil cannot be disturbed too much because it will affect the infiltration rate.

After hammered the outer ring, the inner ring is inserted into the soil at the same level of the outer ring. Before hammered the inner ring, the driving plate also must cover the inner ring. Then, after outer ring and inner ring completely insert into the soil, the driving plate is remove and water is pour at the outer ring first to ensure water movement for inner ring is going lateral direction.

The outer ring is filled with the water approximately 15-30 cm. After that, the water is filled into the inner ring approximately 20-30 cm. For this study, the outer ring infiltration rate is ignored because the main measurement is at the inner ring and the main purpose of outer ring is to make sure the lateral movement of water for inner ring. Therefore, after filled the water for both rings, the experiment starts immediately. Thus, the time when the experiment begins is recorded and note the water level on depth gauge. The drop of the water level in the inner ring for a certain interval time is determined.

Thus the time and water level is noted for this experiment. For this study, the water level is measured for every 15-minute interval until the infiltration rate has reached a constant value. The infiltration rate is calculated from the data obtained by divided the changes of water level by time in term of hour.

After done the experiment, the both rings are removed by using the pull-out hooks. When rinse the rings, make sure no soil sticks and sets to the rings. The proper precaution will prevent unnecessary disturbance of the soil upon the installation.

Figure 3.12: Double Ring Infiltrometer

3.7.2 Direct Method

Using direct Method is the easiest way to determine the infiltration rate. Direct means the water is directly filled into the infiltration basin until certain depth without needed of any equipment and apparatus. It is important to make sure that there is no leakage of water flow out from the basin. If not the result obtained is not valid. The level of water filled is determined by using depth gauge and the reading is record.

The experiment starts immediately after filled the water into the basin. The time when the experiment begins is recorded and note the water level on the depth gauge. The water level is measured for every 15-minute interval until the infiltration rate has reached a constant value. The infiltration rate is calculated from the data obtained by divided the changes of water level by time in term of hour.

CHAPTER FOUR

RESULT AND DISCUSSION

4.1 Introduction

This chapter focuses in analysing the laboratory result such as sieve analysis test and infiltration rate by using double ring infiltrometer and by using direct infiltration method. There are three soil sample collected from the auger hole method and this sample are categorized by its depth of layer from the ground surface. The sample 1 is collected at the top soil layer while sample 2 is collected at the medium layer and sample 3 at the bottom layer and reach the ground water level. From the sieve analysis result, the graph of the particle size distribution curve is plotted which indicated the type of soil classification in terms of characteristic of the soil.

While, the results of infiltration rate by using double ring infiltrometer method and by using direct infiltration method under natural condition and under modified soil condition are obtained and compared. Under modified soil condition, the natural soil composition is removed and filled with three types of soil by the layer. For the great infiltration rate performance, the gravel and filler are filled at the bottom and middle layer. While for the top layer, the organic soil is filled because this organic soil type is very suitable for planting the grass. The infiltration rate under modified soil condition is tested with grass and without grass. The top layer is filled for about 15 cm depth, the middle layer is filled with the filler for about 20 cm depth and for the bottom layer is filled with the gravel for about 20 cm depth.

4.2 Determine Underlying Soil Composition

4.2.1 Sieve Analysis and Liquid Limit and Plastic Limit Test

Sieve analysis results are obtained by plotting the semi-log graph percentage passing versus particle size which can be referred in Appendix 1. The particle distribution curves are obtained from the three soil samples that obtained from the auger hole method for determine the groundwater level. The soil samples are categorized based on the depth of the layer from the ground surface. The uniformity coefficient (Cu) and coefficient of curvature (Cc) is calculated from the value of effective size (D_{10}), diameter corresponding to 60% finer (D_{60}) and diameter corresponding to 30% finer (D_{30}). The soil was classified according to Unified Soil Classification System (USCS) based on Cu and Cc parameter.

While for Liquid limit and Plastic limit is tested by using Casagrande's method. The soil sample from the soil that has been sieved through BS 425 ɥm sieve is use for these test. Liquid limit and Plastic limit test is being used to classified the fined grain soil for each sample. From the liquid limit test, the relationship between soil moisture content and number of blows is plotted on a semi-log graph. The value of moisture content that corresponds to 25 blows is taken as soil Liquid Limit(LL). While from the Plastic limit test, the average moisture content is considered as soil Plastic Limit(PL). The classification of fine-grained soils can be determining by using the Plasticity Chart.

4.2.1.1 Soil Sample 1

The result of the particle distribution test for the sample 1 is shown in Figure 4.1.

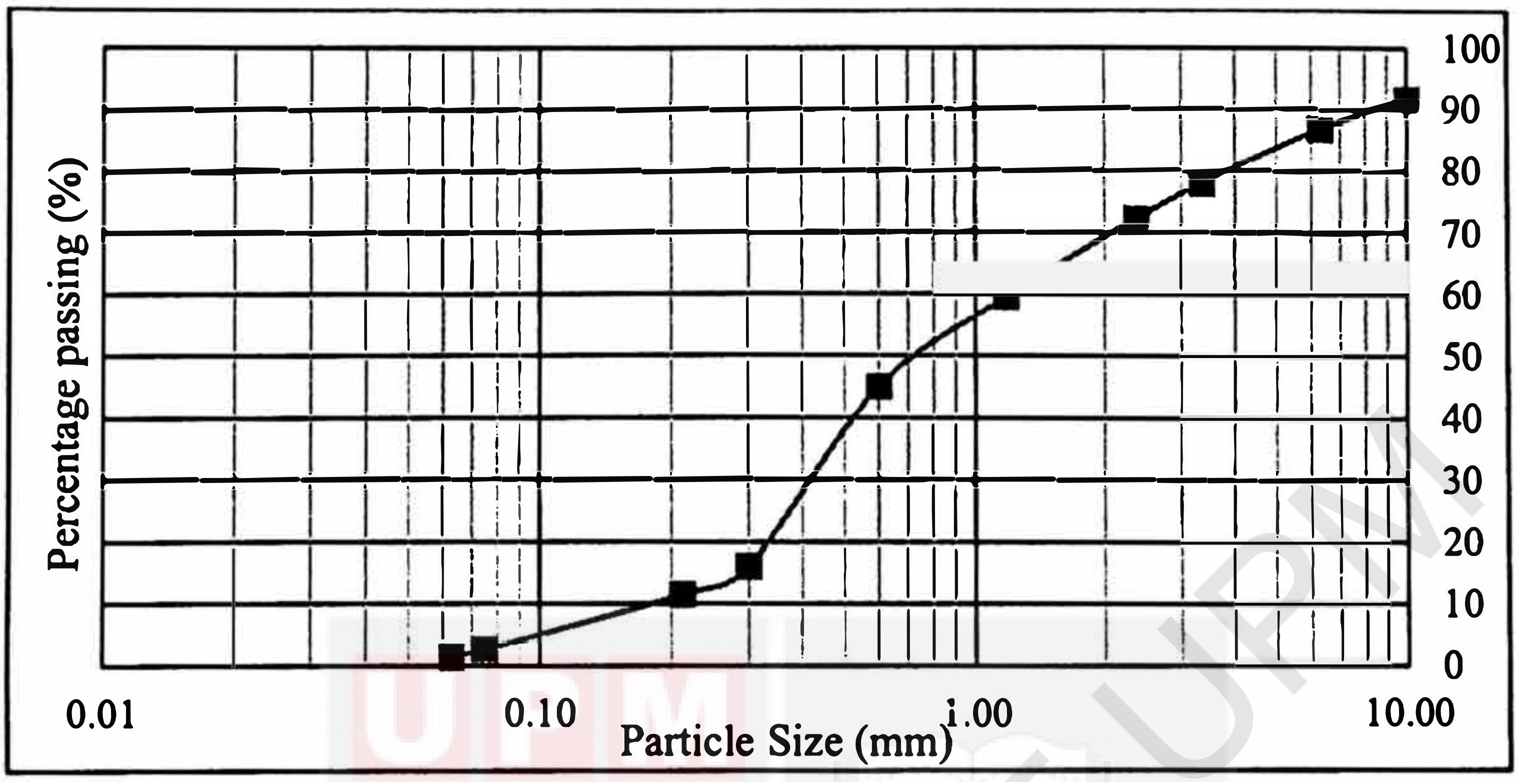

Figure 4.1: Particle size distribution of sample 1

From the Figure 4.1, D_{60}, D_{30} and D_{10} were obtained by plotting straight line towards the curve line from the y-axis of 10, 30 and 60 percentage passing. By using this set of the data, Cu and Cc are obtained by calculating using equation for Cu and Cc relatively as mention in previous chapter. From the calculation, value of Cu is equal to 6.89 and the value of Cc is equal to 0.675. The soil sample has more than 50% larger than BS 63 ųm size. Therefore, the soil is classified as coarse grained soils refer to Unified Soil Classification System. The soil is classified as Sand because the coarse fraction of the sand size is more than 50% fines fraction size is less than 5%. Since the Cu=6.89 ≥ 6 and the value of Cc is not meeting the soil sample is classified as SP: Sand – Gravelly sand with little fines.

From the Liquid Limit and Plasticity test, the value of liquid limit obtained is 30 and the value of plastic limit obtained is 27. By using plasticity chart and USCS table, the fine grained for the sample 1 is classified as ML: Sand-silty fine sand with little plasticity.

4.2.1.2 Soil Sample 2

The result of the particle distribution test for the sample 2 is shown in Figure 4.2.

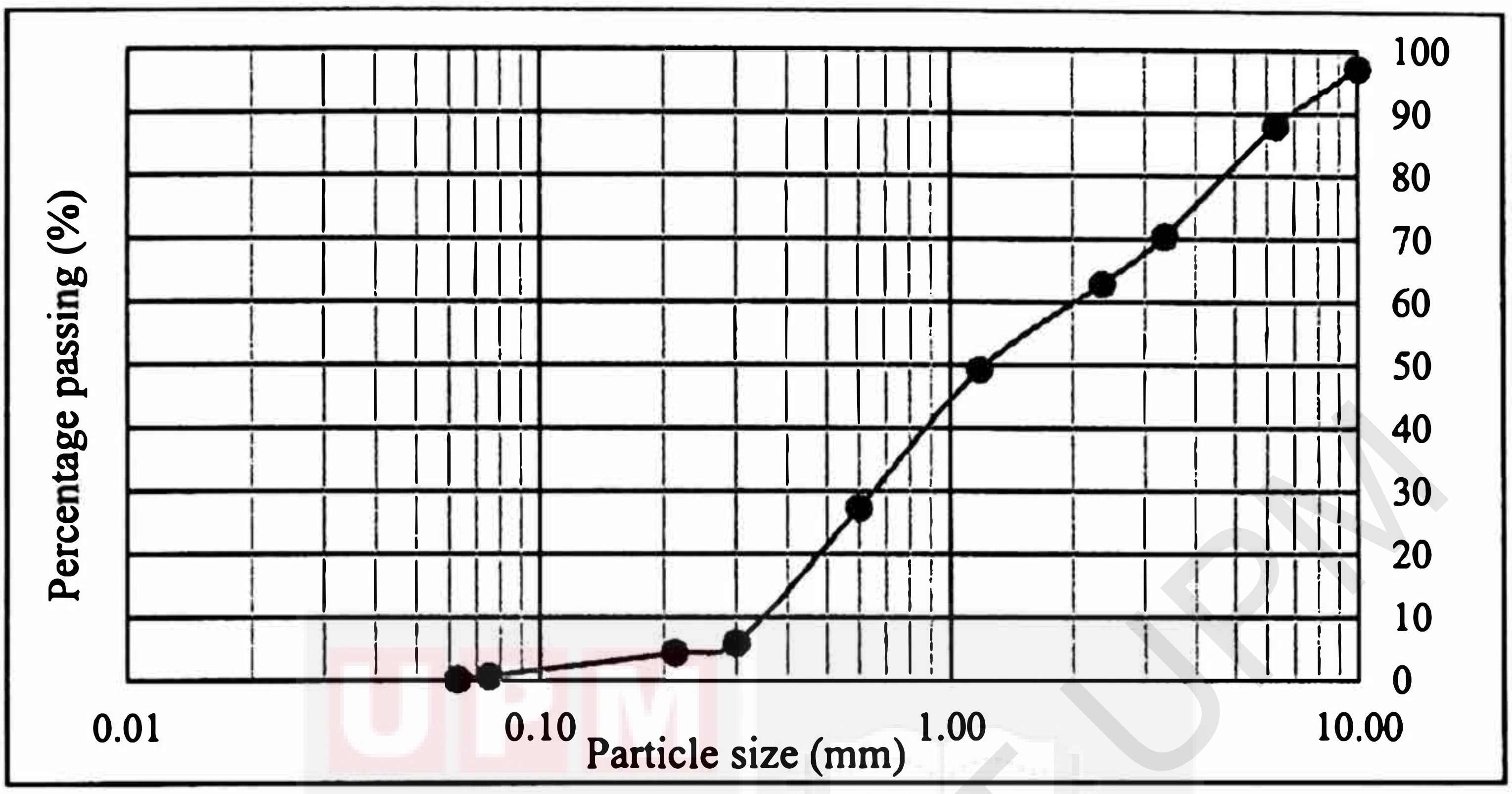

Figure 4.2: Particle size distribution of sample 2

From the Figure 4.2, D_{60}, D_{30} and D_{10} were obtained by plotting straight line towards the curve line from the y-axis of 10, 30 and 60 percentage passing. By using this set of the data, Cu and Cc are obtained by calculating using equation for Cu and Cc relatively as mention in previous chapter. From the calculation, value of Cu is equal to 5.71 and the value of Cc is equal to 0.60. The soil sample has more than 50% larger than BS 63 ɥm size. Therefore, the soil is classified as coarse grained soils refer to Unified Soil Classification System. The soil is classified as Sand because the coarse fraction of the sand size is more than 50% fines fraction size is less than 5%. Since the value of $Cu=5.4 \leq 6$ and the value of Cc is not meeting the soil sample 2 is classified as SP: Sand – Gravelly sand with little fines.

From the Liquid Limit and Plasticity test, the value of liquid limit obtained is 29 and the value of plastic limit obtained is 28. By using plasticity chart and USCS table, the fine grained for the sample 2 is classified as ML: Sand-silty fine sand with little plasticity.

4.2.1.3 Soil Sample 3

The result of the particle distribution test for the sample 3 is shown in Figure 4.3.

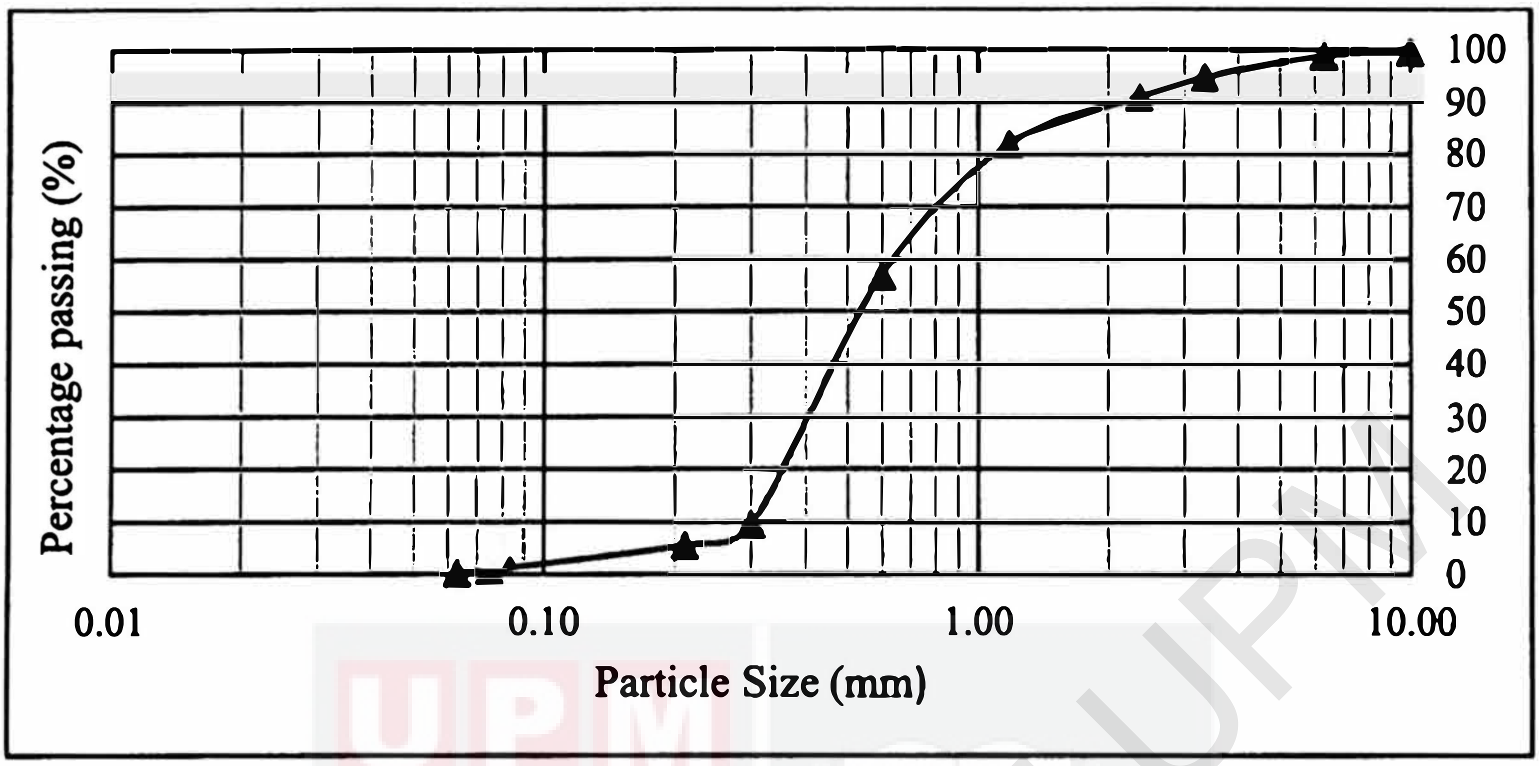

Figure 4.3: Particle size distribution of sample 3

From the Figure 4.3, D_{60}, D_{30} and D_{10} were obtained by plotting straight line towards the curve line from the y-axis of 10, 30 and 60 percentage passing. By using this set of the data, Cu and Cc are obtained by calculating using equation for Cu and Cc relatively as mention in previous chapter. From the calculation, value of Cu is equal to 2.17 and the value of Cc is equal to 0.82. The soil sample has more than 50% larger than BS 63 ɥm size. Therefore, the soil is classified as coarse grained soils refer to Unified Soil Classification System. The soil is classified as Sand because the coarse fraction of the sand size is more than 50% and the fines fraction size is less than 5%. Since the value of Cu=2.17 ≤ 6 and the value of Cc is not meeting the soil sample 2 is clarified as SP: Sand – Gravelly sand with little fines.

From the Liquid Limit and Plasticity test, the value of liquid limit obtained is 24 and the value of plastic limit obtained is 23. By using plasticity chart and USCS table, the fine grained for the sample 1 is classified as ML: Sand-silty fine sand with little plasticity.

The comparison of particle distribution test for the three sample collected is shown in Figure 4.4.

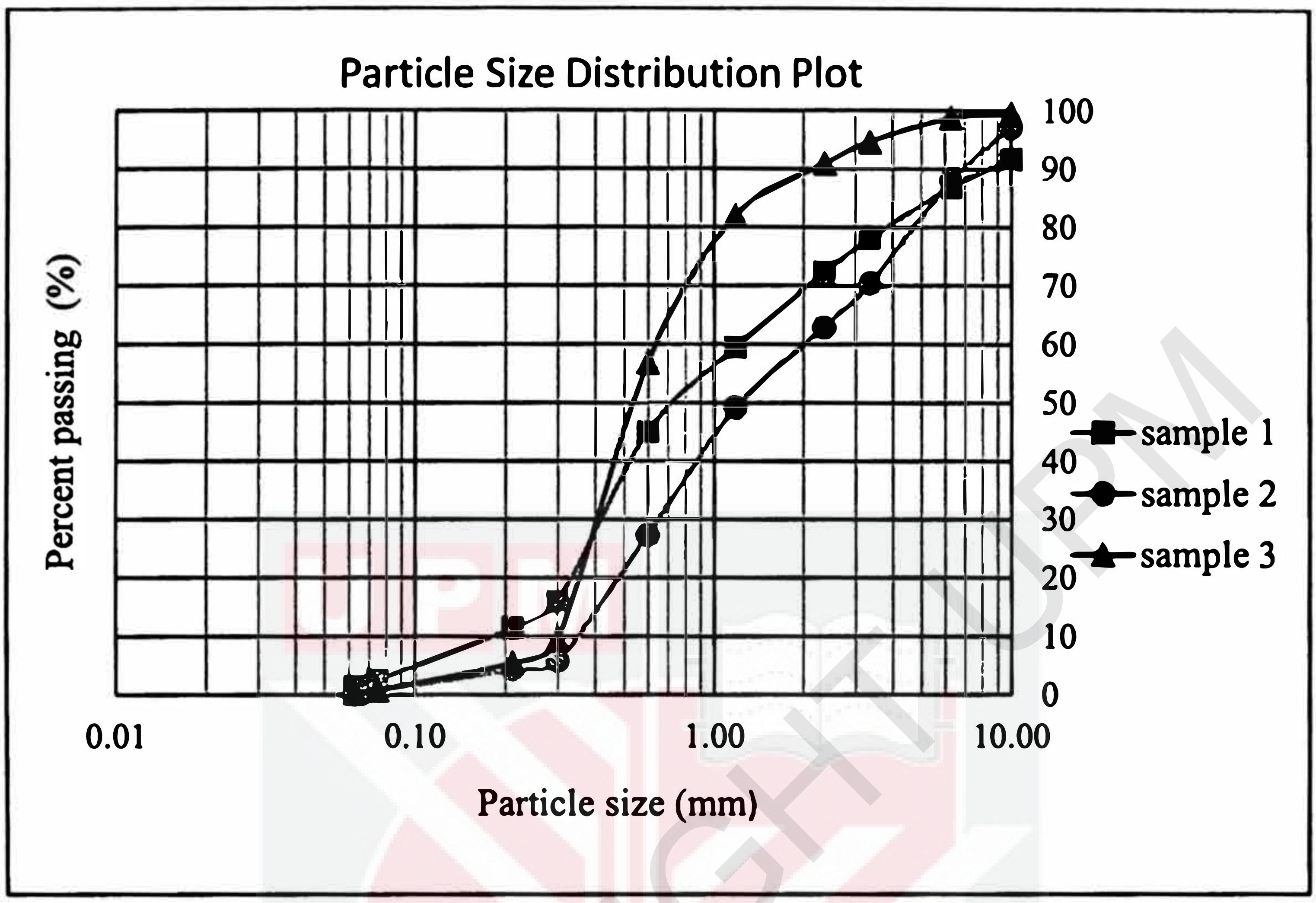

Figure 4.4: Comparison of particle size distribution test for three sample

From Figure 4.4, at 10 mm particle size the sample 3 is 100% passing. That means, the particle size of sample 3 is smaller than 10mm. while, sample 1 and 2 are not 100% passing. That means the particle size of sample 1 and 2 were bigger than 10mm. The particle size of sample 1 is the biggest than sample 2 and sample 3. From above figure, the particle size distribution of sample 3 is smallest compare to sample 1 and 2. While the particle size distribution of sample 2 is bigger than sample 1.

From the result of sieve analysis, the type of soil composition of sample 1,2 and 3 is classified as SP: Sand – Gravelly sand with little fines. The fines are tested using Plastic and Liquid Limit Test. From this test, the fines are classified as ML: Sand-silty fine sand with little plasticity.

4.3 Infiltration Rate Test

Infiltration rate are obtained by using two methods which is by using double ring infiltrometer and by using direct method. The infiltration rate is determined under natural soil composition with and without grass and under modified underlying soil composition with and without grass. The performance of the infiltration rate under this condition is observed and determined. The infiltration rate results are calculating by divided decreasing water depth in interval (cm) over time in hours. The graph of infiltration rate versus time were plotted to determine the trend of this infiltration rate. Before started the testing, the ground water level was determined.

4.3.1 Under natural soil composition with grass

The result of infiltration rate under natural soil composition with grass by using double ring infiltrometer as shown in Figure 4.5.

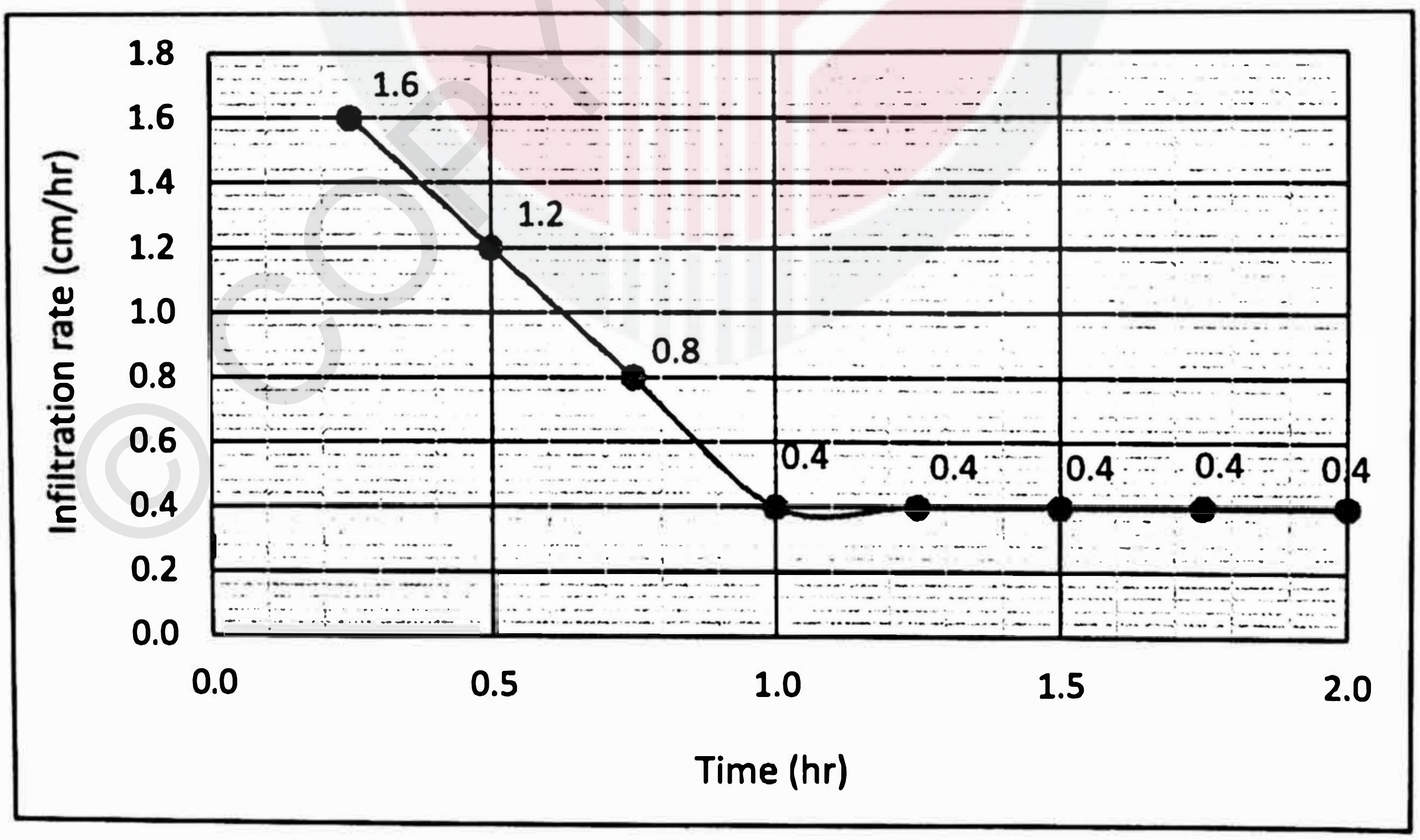

Figure 4.5: Infiltration rate under natural soil composition with grass using double ring infiltrometer

4.3.2 Under natural soil composition without grass

The result of infiltration rate under natural soil composition with grass by using double ring infiltrometer as shown in Figure 4.6 and by using direct method as shown in Figure 4.7.

4.3.2.1 Using double ring infiltrometer

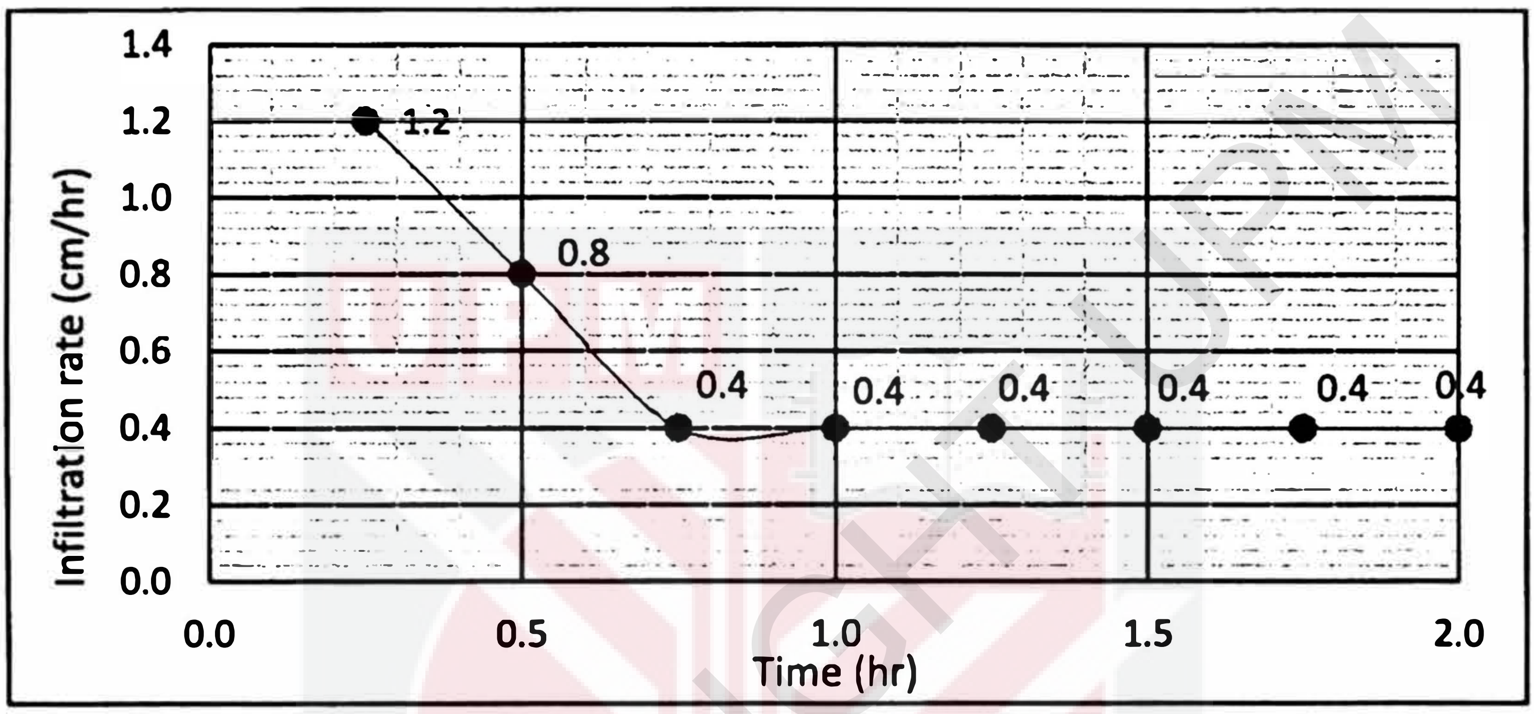

Figure 4.6: Infiltration rate under natural soil composition without grass by using double ring infiltrometer

4.3.2.2 Using direct method

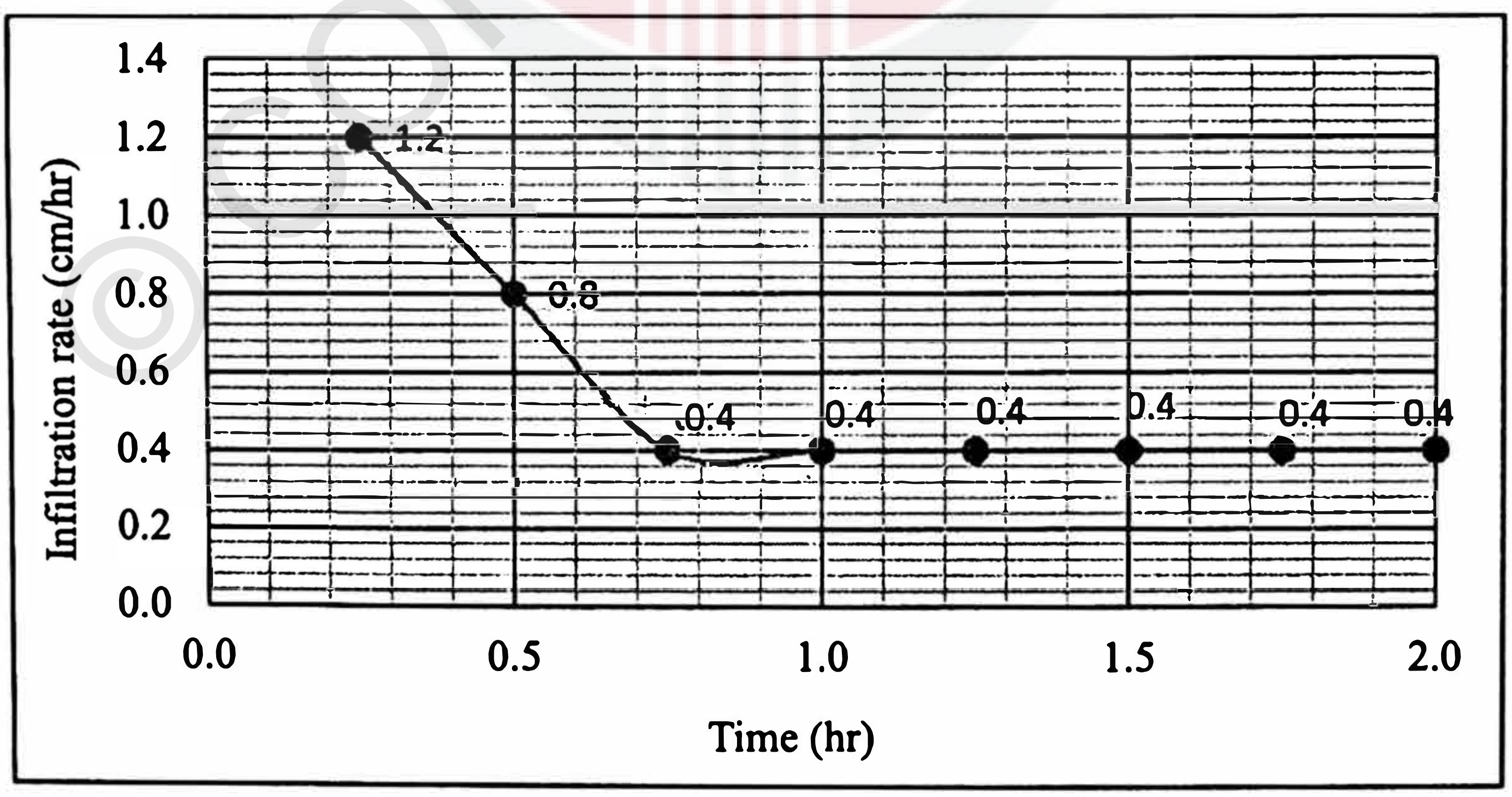

Figure 4.7: Infiltration rate under natural soil composition without grass by direct method

4.3.3 Under modified soil composition without grass

The result of infiltration rate under modified soil composition without grass by using direct method with organic soil at the top layer of basin as shown in Figure 4.8.

4.3.3.1 Using direct method- organic soil at the top layer

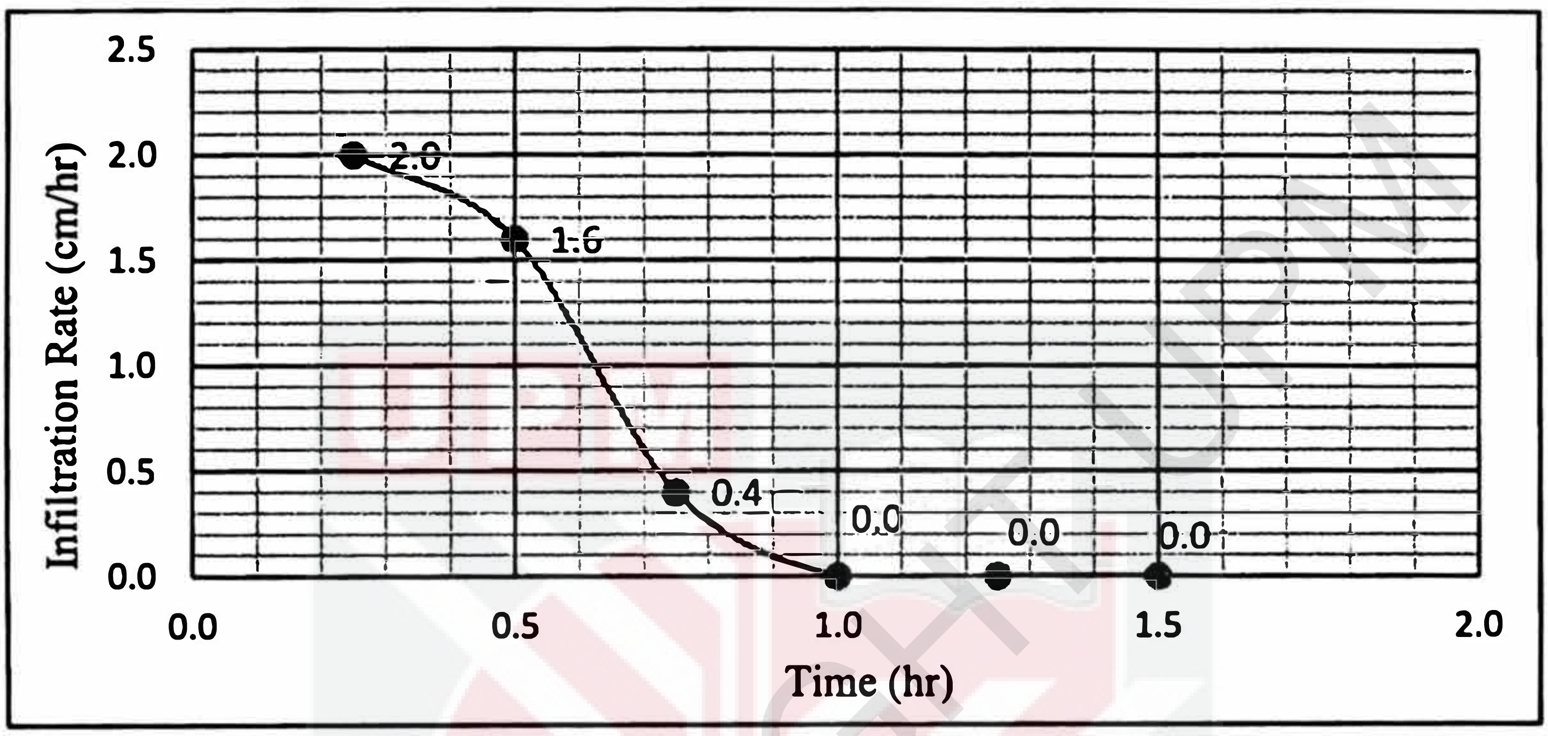

Figure 4.8: Infiltration rate under modified soil composition without grass by direct method-organic soil at top layer

From the Figure 4.8, as the organic soil filled at the top layer, it does not show any infiltration rate after one-hour testing. Therefore, the organic soil is not suitable to choose as modified soil composition to increase the infiltration rate. Thus, the organic soil is replaced with the natural soil at this site to fill at the top layer for about 15 cm depth. The natural soil is choosing because to decrease the costing to construct this infiltration basin as we know gravel and is expensive. Therefore, we cannot increase the depth layer of the gravel although the permeability of the gravel is high because of large pore space. The natural soil is choosing because to observe its performance under modified soil composition compare its performance under natural soil composition. For the next experiment under modified soil composition, the natural soil at the top layer, filler at the middle layer and gravel at the bottom layer.

The result of infiltration rate under modified soil composition without grass by using direct method with natural soil at the top layer of basin as shown in Figure 4.9 and by using double ring infiltrometer as shown in Figure 4.10.

4.3.3.2 Using direct method - natural soil at the top layer

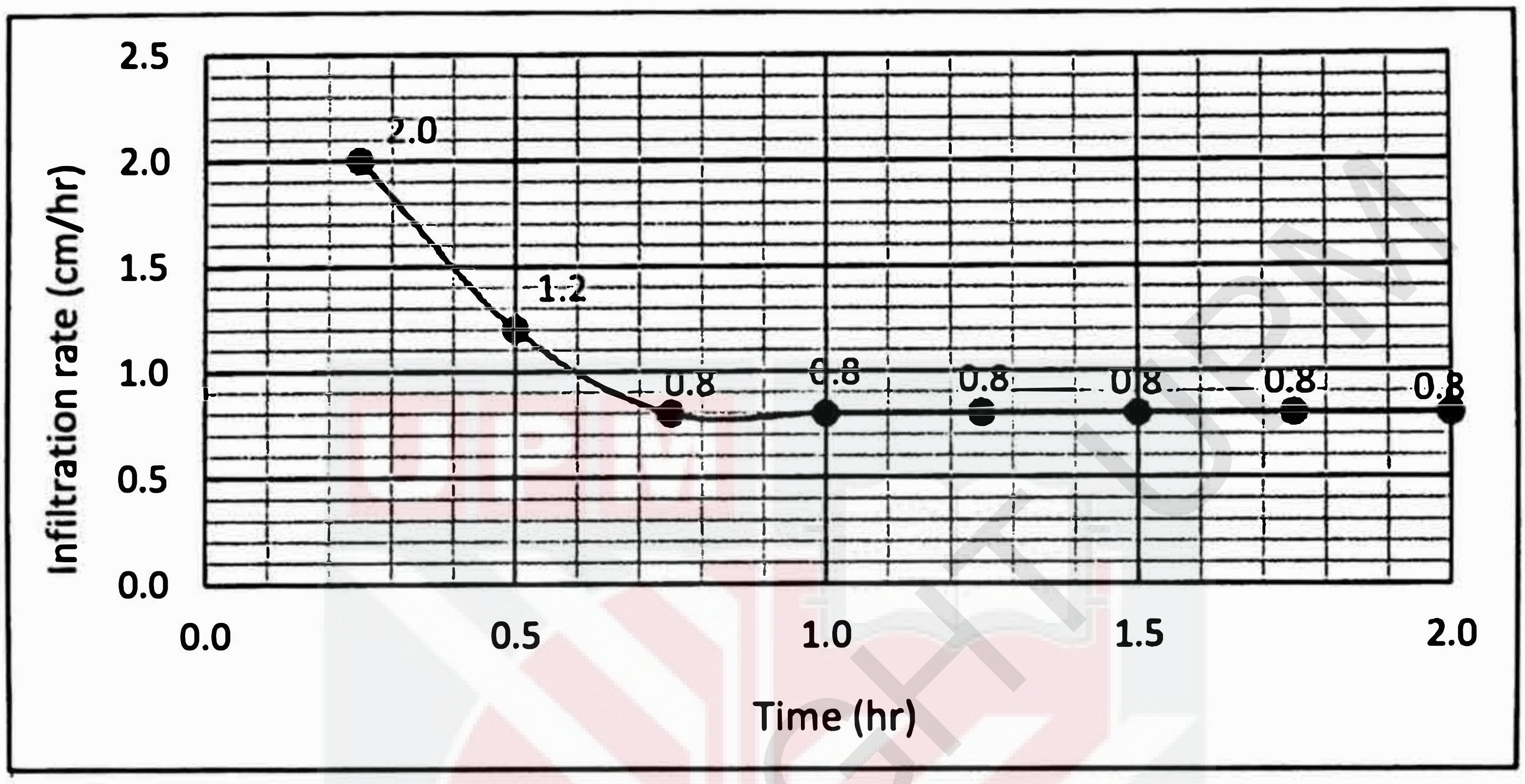

Figure 4.9: Infiltration rate under modified soil composition without grass by direct method-natural soil at top layer

4.3.3.3 Using double ring infiltrometer

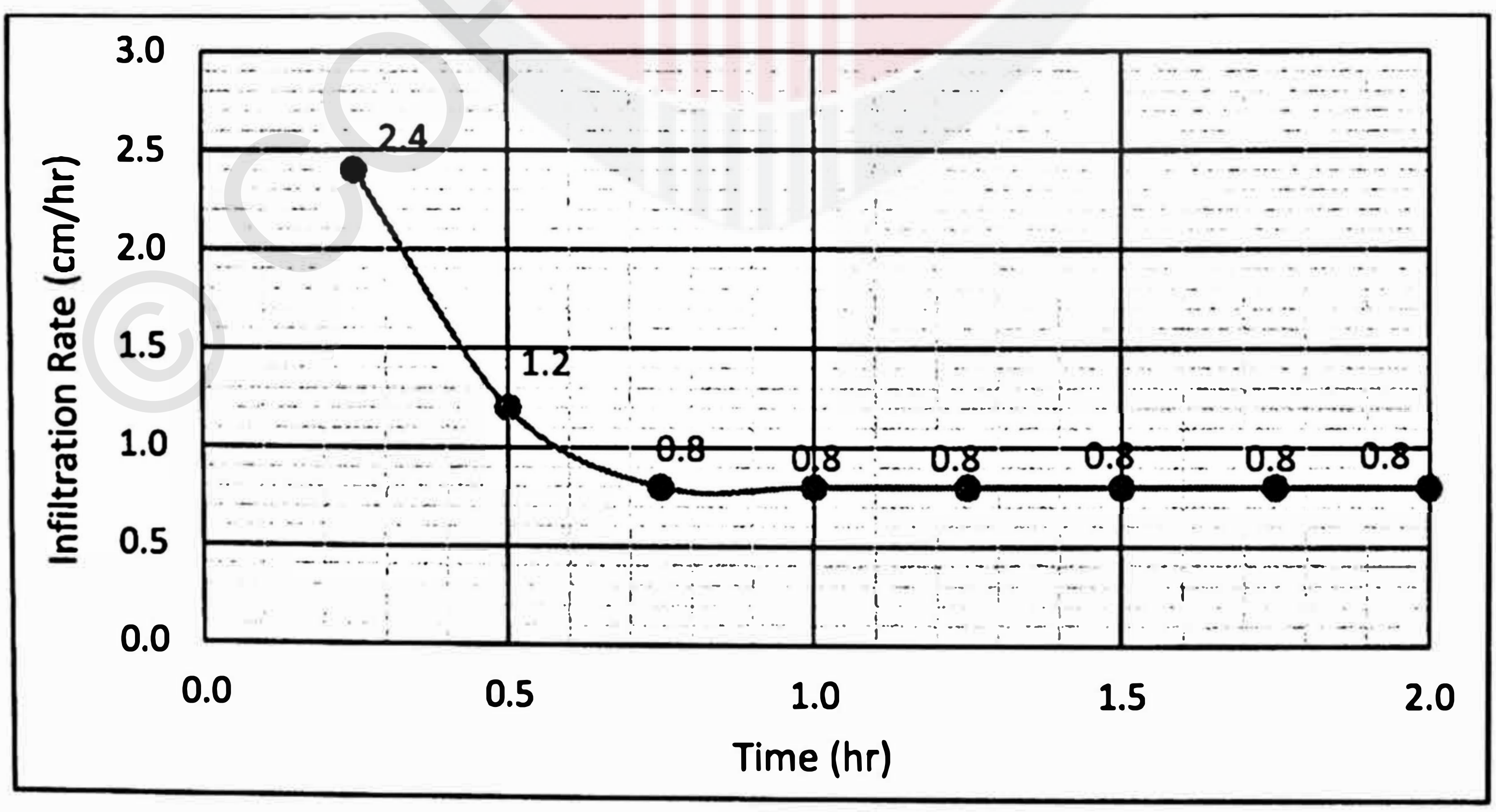

Figure 4.10: Infiltration rate under modified soil composition without grass by double ring infiltrometer

4.3.4 Under modified soil composition with grass

The result of infiltration rate under modified soil composition with grass by using direct as shown in Figure 4.11 and by using double ring infiltrometer as shown in Figure 4.12.

4.3.4.1 Using direct method

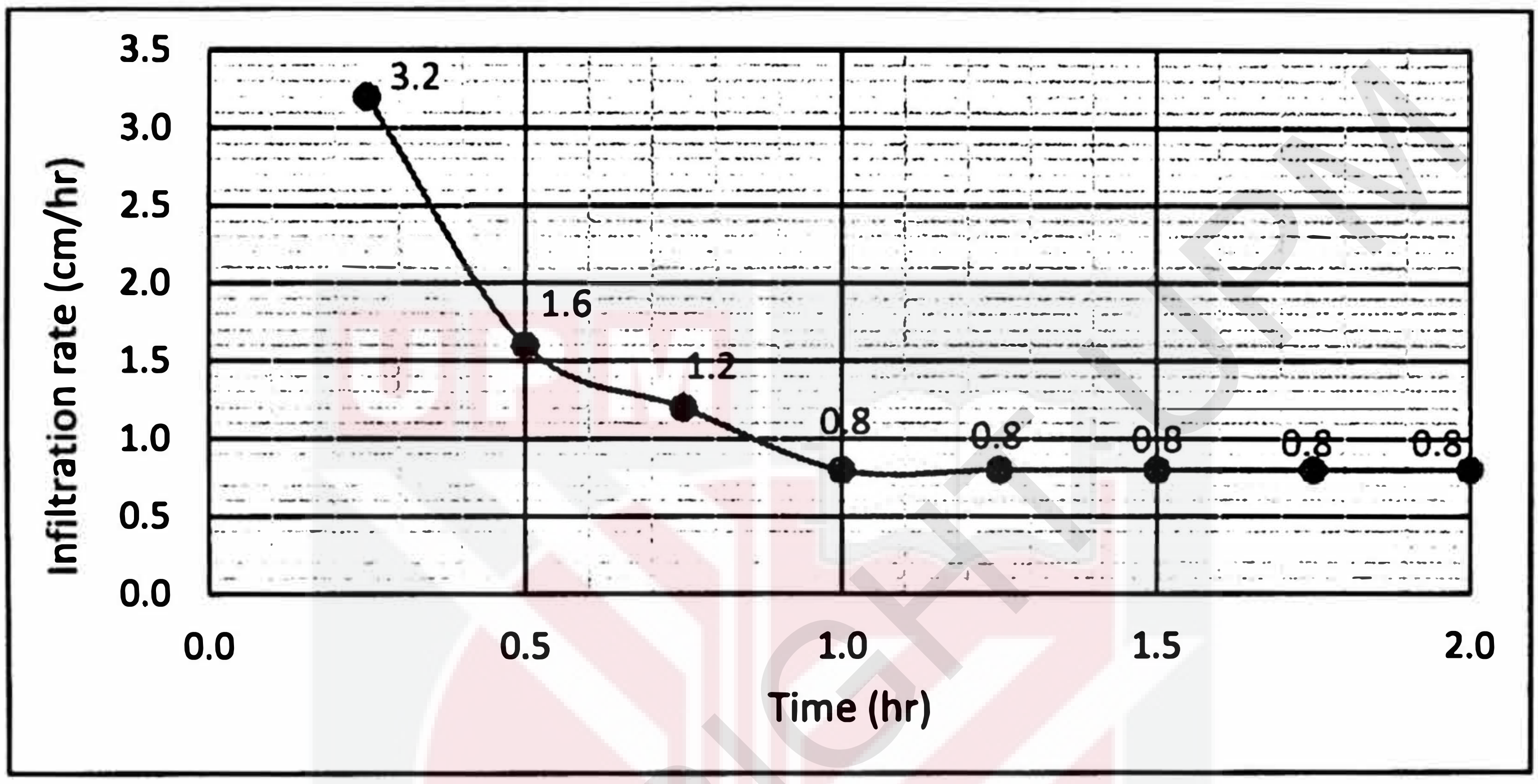

Figure 4.11: Infiltration rate under modified soil composition with grass by direct method

4.3.4.2 Using double ring infiltrometer

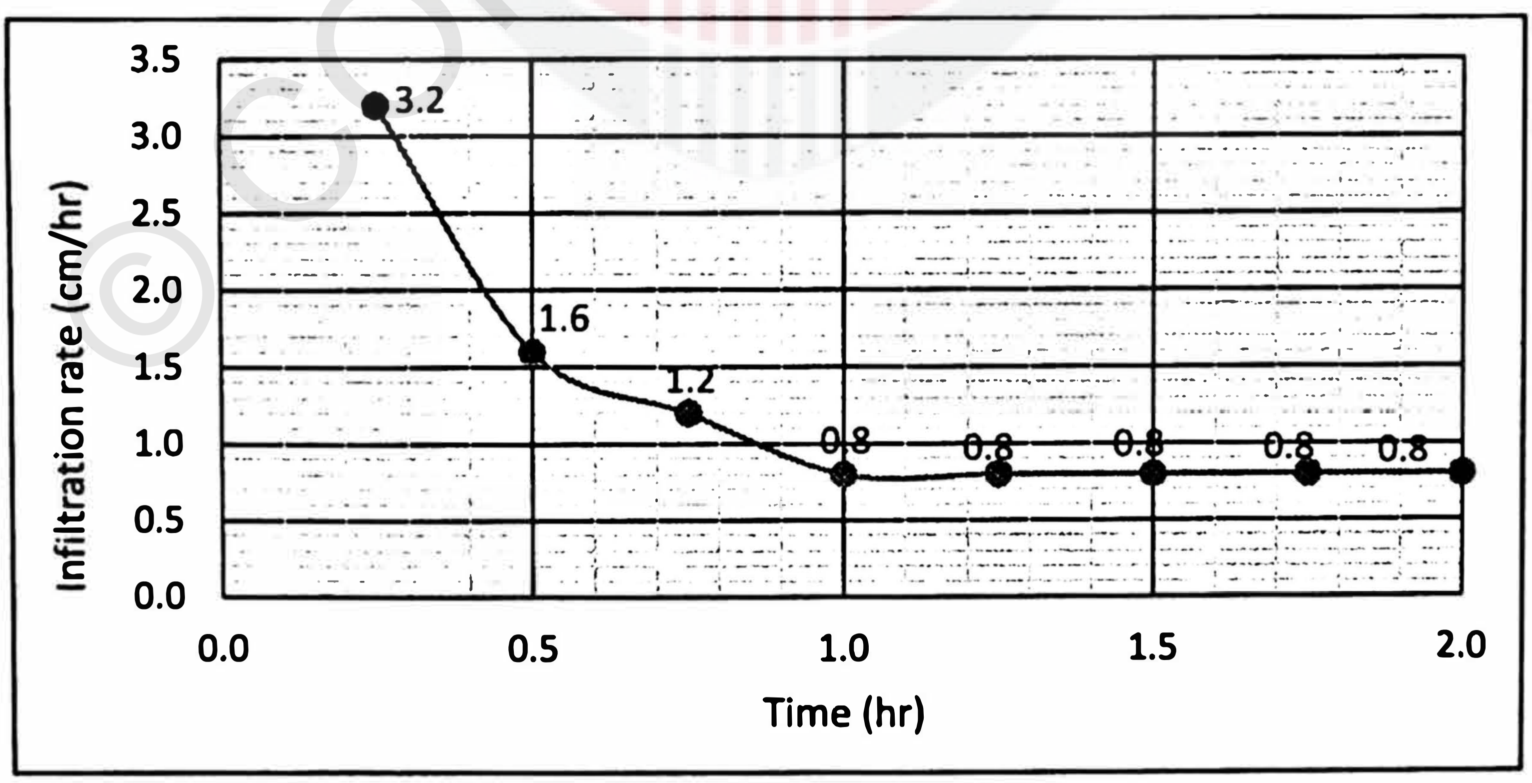

Figure 4.12: Infiltration rate under modified soil composition with grass by double ring infiltrometer

4.3.5 Comparison of infiltration rate value of different basin configurations

The comparison of infiltration rate value of different configurations by using direct method as shown in Figure 4.13 and by using double ring infiltrometer as shown in Figure 4.14.

4.3.5.1 Direct method

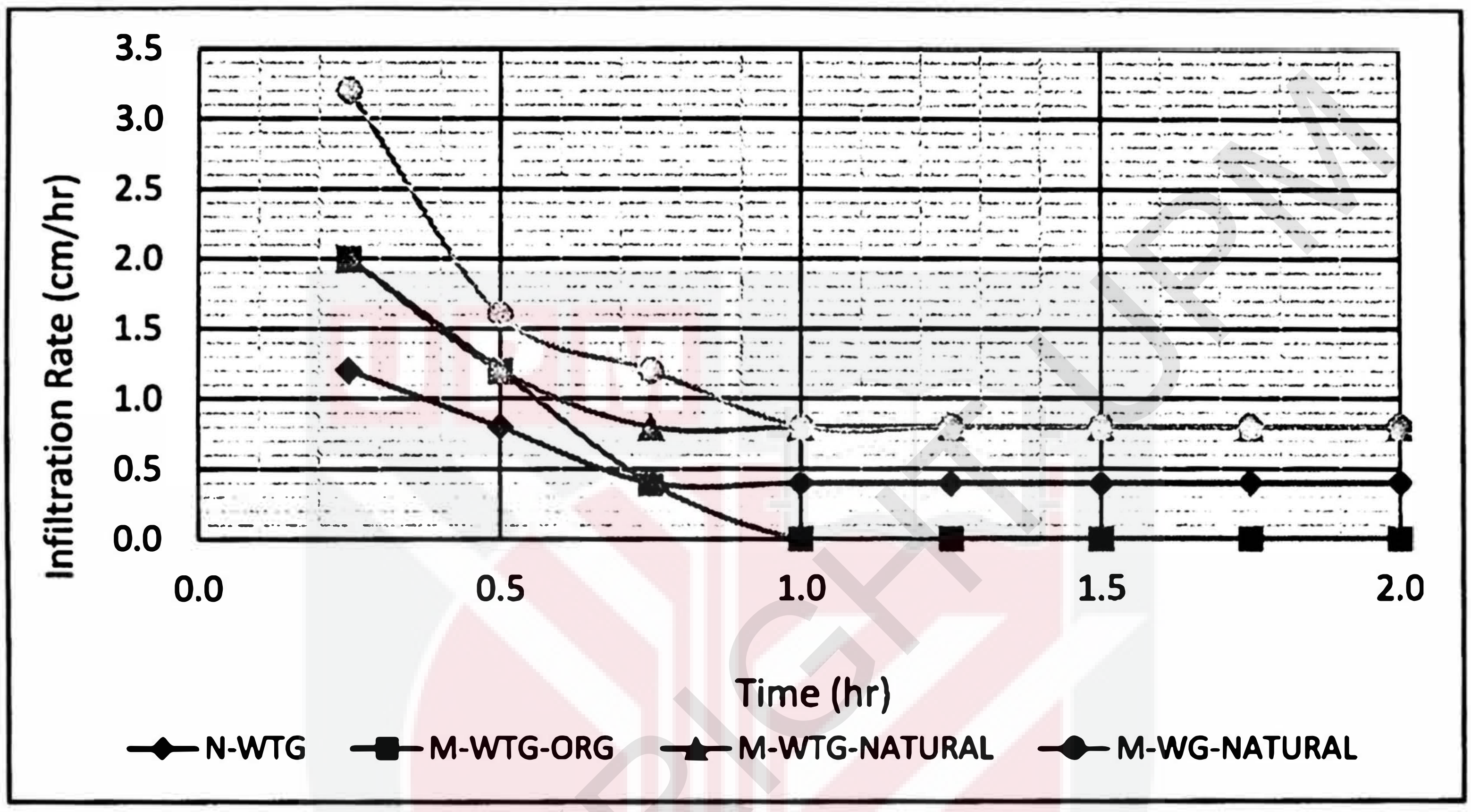

Figure 4.13: Comparison of infiltration rate value of different basin configurations by using direct method

From the Figure 4.13, the infiltration rate under modified soil composition with grass of natural soil at top layer (M-WG-NATURAL) show the highest performance of infiltration rate at the beginning compare to the others. Under modified soil composition, the performance of infiltration rate with grass is higher compare the performance of infiltration rate without the grass(M-WTG-NATURAL) during the beginning of the test. Meanwhile, after one hour, the infiltration rate under modified soil composition is same for with grass and without the grass. while compare under modified soil composition and under natural soil composition without grass (N-WTG), the performance of infiltration under modified soil composition with natural soil at the top layer show the higher performance.

4.3.5.2 Using double ring infiltrometer

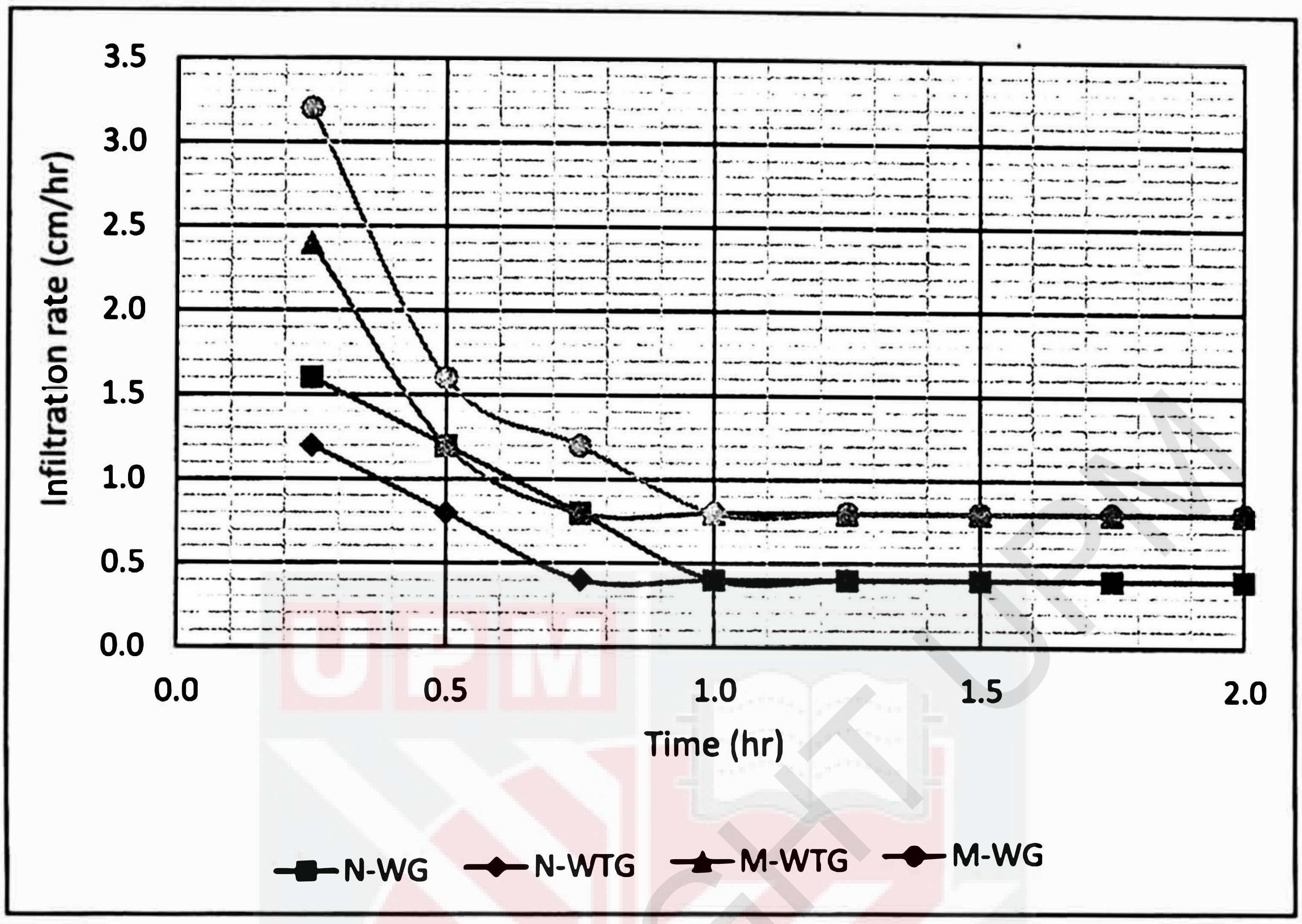

Figure 4.14: Comparison of infiltration rate value of different basin configurations by using double ring method

From the Figure 4.14, the infiltration rate under modified soil composition with grass (M-WG) show the highest performance of infiltration rate at the beginning compare to the others. Under modified soil composition, the performance of infiltration rate with grass is higher compare the performance of infiltration rate without the grass(M-WTG) during the beginning of the test. Meanwhile, after one hour, the infiltration rate under modified soil composition is same for with grass and without the grass. while compare under modified soil composition and under natural soil composition, the performance of infiltration under modified soil composition with grass and without grass show the higher performance.

4.3.6 Comparison of infiltration rate value between using direct method and using double ring infiltrometer

When compare the infiltration rate value between using direct method and using double ring infiltrometer under natural soil composition without grass, the initial value of infiltration rate by using both method is same which is 1.2 cm/hr. After two hours, the value of infiltration rate by using both method is still same which is 0.4 cm/hr and this value is constant for next time.

When compare the infiltration rate value between using direct method and using double ring infiltrometer under modified soil composition without grass, the initial value of infiltration rate by using direct method is 2 cm/hr. While, by using double ring infiltrometer, the infiltration rate is slightly higher which is 2.4 cm/hr. But after two hours, the value of infiltration rate by both method is same which is 0.8 cm/hr.

As we compare the infiltration rate by using both method is almost the same under natural soil composition without grass and under modified soil composition without the grass. By using direct method, the result is more accurate because the water infiltrate under actual application of water infiltration in infiltration basin.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Introduction

This chapter summarize all the finding based on the objectives of this research study to construct and determine the performance of an infiltration basin with regard to its ability to allow the infiltration process. The infiltration basin of 1m^2 area is constructed near the Hydraulic Laboratory in Faculty Engineering of UPM. The soil properties studied are tested through a sieve analysis test to carry out the particle size distribution curve which indicated the type of underlying soil composition at this area. The rate of infiltration is determined by using double ring infiltrometer method and direct method. The infiltration rate is calculated based on the difference of runoff depth every 15 minutes.

5.2 Conclusion

Underlying soil composition at this area is classified as SP: Sand – Gravelly sand with little fines and the fines is classified as ML: Sand-silty fine sand with little plasticity according to Unified Soil Classification System (USCS). The soil categorizes as large particle and expected to reduce the surface runoff at high volume. But based on the result obtain under natural soil condition, the infiltration rate is low. This because the natural soil already compacted and the soil is not the original soil from that place, it actually the soil from the other place. The gravelly sand of this natural soil actually from the cement mixture. Due to the tight packing and cementing particles, it seals off the pores from one another. Thus water cannot flow freely.

Based on the result obtained, infiltration rate under modified soil composition is slightly higher than infiltration rate under natural soil composition. Natural soil composition is removed then filled with three types of soil which is gravel at the bottom layer, filler at middle layer and natural soil at top layer. Under modified soil condition, high infiltration rate is expected to obtain. Although based on result obtain, the infiltration rate under modified soil condition is higher than under natural soil condition but the value of infiltration rate obtained is not satisfied enough because only a slightly difference. The environmental weather condition has slightly effected this testing.

During the period of this test is carried out, the infiltration basin surface experiences overly wet period. Almost every day there are heavily raining at evening until the night. The water from the rainfall is infiltrated and store at the underlying soil. Therefore, during every testing of infiltration is carried out, the soil is in moist condition. Therefore, the infiltration rate is slow because the pores spaces almost fill with the water. Before every testing is carried out, the ground water level is measured first.

Besides that, based on the result obtain, the infiltration rate with surface cover is higher compare to the infiltration rate without surface cover. Surface cover allows greater infiltration because of the roots in the plants absorbing all of the excessive water. As the roots absorb the excessive water, the overflow is decreased.

In conclusion, infiltration basin has been construct and it performance with regard to its ability to allow the infiltration process have been tested. The rate of infiltration with different surface cover and with different underlying soil layers of this infiltration basin have been determined.

5.3 Recommendation

Recommendation and precaution for sieve analysis result to make sure the results accurate. There are a few precautions and recommendations to take note when carry out the experiment. The time for shaking the mechanical shaker should not exceed 15 minutes as finer particles could easily loss. The sieve should dry and clean properly to ensure that the sieve is clear from any particles before the test starts. If not, it might affect the result obtain. The size arrangement of the stack of the sieve also need to concern to make sure the arrangement is follow the standards before the test is begin. During carried out the test, wind blow or fan should be avoiding since it might reduce the mass of the soil. Before start the Plastic Limit and Liquid Limit test, make sure to understands and follow the procedure correctly to avoid any incorrect result obtain.

Conducted the double ring infiltrometer test is not so easy. It is quite tough and challenging because a lot of energy is necessary to handle the ring especially when hammering the ring into the soil. It should be handle more than one person because it is quite difficult to handle alone. During hammering the ring make sure cover the ring with driving plate. The water is pour at the outer ring first to ensure water movement in inner ring is going lateral direction. Before start the experiment make sure there are no any water out from the double ring and no water leakage from infiltration basin because the result obtained will invalid.

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APPENDIX

Appendix 1: Result of Particle Distribution Analysis for Three Sample

Appendix 1a: Result of Particle Distribution Analysis of Sample 1

BS Sieve (mm)	Weight of Sieve (g)	Weight of sieve + Soil (g)	Weight Retained (g)	Percentage Weight Retained (%)	% Cumulative Weight Retained	% Passing
10.000	415.50	783.23	367.73	8.2	8.2	91.8
6.300	514.58	732.11	217.53	4.9	13.1	86.9
3.350	439.84	832.50	392.66	8.8	21.9	78.1
2.360	511.79	771.48	259.69	5.8	27.7	72.3
1.180	482.77	1054.08	571.31	12.8	40.5	59.5
0.600	440.60	1086.60	646.00	14.5	55.0	45.0
0.300	404.06	1698.05	1293.99	29.0	84.0	16.0
0.212	378.51	583.20	204.69	4.6	88.6	11.4
0.075	365.22	760.46	395.24	8.9	97.4	2.6
0.063	286.20	336.12	49.92	1.1	98.5	1.5
Pan	364.98	430.85	65.87	1.5	100.0	0.0
		9068.68	4464.63	100.00		

Appendix 2b: Result of Particle Distribution Analysis of Sample 2

BS Sieve (mm)	Weight of Sieve (g)	Weight of sieve + Soil (g)	Weight Retained (g)	Percentage Weight Retained (%)	% Cumulative Weight Retained	% Passing
10.000	415.50	532.82	117.32	2.9	2.9	97.1
6.300	514.58	887.46	372.88	9.2	12.1	87.9
3.350	439.84	1149.64	709.80	17.5	29.6	70.4
2.360	511.79	819.21	307.42	7.6	37.1	62.9
1.180	482.77	1038.22	555.45	13.7	50.8	49.2
0.600	440.60	1326.67	886.07	21.8	72.6	27.4
0.300	404.06	1276.33	872.27	21.5	94.1	5.9
0.212	378.51	440.88	62.37	1.5	95.7	4.3
0.075	365.22	513.90	148.68	3.7	99.3	0.7
0.063	286.20	305.36	19.16	0.5	99.8	0.2
Pan	364.98	373.56	8.58	0.2	100.0	0.0
		8664.05	4060.00	100.00		

Appendix 3c: Result of Particle Distribution Analysis of Sample 3

BS Sieve (mm)	Weight of Sieve (g)	Weight of sieve + Soil (g)	Weight Retained (g)	Percentage Weight Retained (%)	% Cumulative Weight Retained	% Passing
10.000	415.50	423.28	7.78	0.5	0.5	99.5
6.300	514.58	526.86	12.28	0.8	1.2	98.8
3.350	439.84	507.87	68.03	4.2	5.4	94.6
2.360	511.79	572.83	61.04	3.7	9.1	90.9
1.180	482.77	628.68	145.91	8.9	18.0	82.0
0.600	440.60	850.01	409.41	25.0	43.1	56.9
0.300	404.06	1179.30	775.24	47.4	90.4	9.6
0.212	378.51	444.59	66.08	4.0	94.5	5.5
0.075	365.22	442.53	77.31	4.7	99.2	0.8
0.063	286.20	293.73	7.53	0.5	99.7	0.3
Pan	364.98	370.70	5.72	0.3	100.0	0.0
		6240.38	1636.33	100.00		

Appendix 2: Data form for the Liquid Limit and Plastic Limit Test

Appendix 2a: Result of Liquid Limit and Plastic Limit Test of Sample 1

i) Liquid Limit

Test No	1	2	3	4
Number of blows	28	15	16	11
Weight of moist soil and container (g)	25.44	23.51	25.66	21.02
Weight of dry soil and container (g)	22.71	21.30	23.19	19.23
Weight of container (g)	13.53	13.92	15.06	13.48
Weight of water (g)	2.73	2.21	2.47	1.79
Weight of dry soil (g)	9.18	7.38	8.13	5.75
Moisture Content (%)	29.74	29.95	30.38	31.13

ii) Plastic Limit

Container No	1	2	3	4
Weight of moist soil and container (g)	16.35	16.66	16.31	16.66
Weight of dry soil and container (g)	15.90	16.25	15.88	16.34
Weight of container (g)	14.38	14.63	14.02	15.21
Weight of water (g)	0.45	0.41	0.43	0.32
Weight of dry soil (g)	1.52	1.62	1.86	1.13
Moisture Content (g)	29.61	25.31	23.12	28.32

Appendix 2b: Result of Liquid Limit and Plastic Limit Test of Sample 2

i) Liquid Limit

Test No	3	2	1	4
Number of blows	44	40	29	25
Weight of moist soil and container (g)	27.88	27.91	23.77	26.67
Weight of dry soil and container (g)	24.90	25.12	21.55	23.70
Weight of container (g)	14.00	15.01	13.65	13.58
Weight of water (g)	2.98	2.79	2.22	2.97
Weight of dry soil (g)	10.90	10.11	7.90	10.12
Moisture Content (%)	27.34	27.60	28.10	29.35

ii) Plastic Limit

Container No	1	2	3	4
Weight of moist soil and container (g)	17.00	17.05	16.10	17.40
Weight of dry soil and container (g)	16.48	16.58	15.67	16.88
Weight of container (g)	14.46	14.67	14.15	15.30
Weight of water (g)	0.52	0.47	0.43	0.52
Weight of dry soil (g)	2.02	1.91	1.52	1.58
Moisture Content (g)	25.74	24.61	28.29	32.91

Appendix 2c: Result of Liquid Limit and Plastic Limit Test of Sample 3

i) Liquid Limit

Test No	1	2	3	4
Number of blows	50	30	26	22
Weight of moist soil and container (g)	25.77	28.4	30.47	32.04
Weight of dry soil and container (g)	23.69	25.63	27.44	28.63
Weight of container (g)	14.38	13.94	14.87	14.6
Weight of water (g)	2.08	2.77	3.03	3.41
Weight of dry soil (g)	9.31	11.69	12.57	14.03
Moisture Content (%)	22.34	23.70	24.11	24.31

ii) Plastic Limit

Container No	1	2	3	4
Weight of moist soil and container (g)	16.78	17.37	17.79	17.47
Weight of dry soil and container (g)	16.4	16.64	17.24	16.93
Weight of container (g)	14.34	13.91	14.51	14.94
Weight of water (g)	0.38	0.73	0.55	0.54
Weight of dry soil (g)	2.06	2.73	2.73	1.99
Moisture Content (g)	18.45	26.74	20.15	27.14

Appendix 3: Data form for the Infiltration rate

Appendix 3a: Result of infiltration rate test under natural soil composition with grass by using double ring infiltrometer

Time	Time (hr)	Time Interval (hr)	Elevation (cm)	Difference of Elevation (cm)	Infiltration rate (cm/hr)
0:00:00	0	0	16.7	0.0	0.0
0:15:00	0.25	0.25	16.3	0.4	1.6
0:30:00	0.50	0.25	16.0	0.3	1.2
0:45:00	0.75	0.25	15.8	0.2	0.8
1:00:00	1.00	0.25	15.7	0.1	0.4
1:15:00	1.25	0.25	15.6	0.1	0.4
1:30:00	1.50	0.25	15.5	0.1	0.4
1:45:00	1.75	0.25	15.4	0.1	0.4
2:00:00	2.00	0.25	15.3	0.1	0.4

Sunday 5 March 2017

Ground water level = 1.06 m

Dimension of infiltration basin = 1.8 m × 1.8 m × 0.5 m

Area of Infiltration basin = 3.24 m^2

Appendix 3b: Result of infiltration rate test under natural soil composition without grass by using double ring infiltrometer

Time	Time (hr)	Time Interval (hr)	Elevation (cm)	Difference of Elevation (cm)	Infiltration (cm/hr)
0:00:00	0	0	16.6	0.0	0.0
0:15:00	0.25	0.25	16.3	0.3	1.2
0:30:00	0.50	0.25	16.1	0.2	0.8
0:45:00	0.75	0.25	16.0	0.1	0.4
1:00:00	1.00	0.25	15.9	0.1	0.4
1:15:00	1.25	0.25	15.8	0.1	0.4
1:30:00	1.50	0.25	15.7	0.1	0.4
1:45:00	1.75	0.25	15.6	0.1	0.4
2:00:00	2.00	0.25	15.5	0.1	0.4

Saturday 11 March 2017

Ground water level = 1.0 m

Dimension of infiltration basin = 1.0 m × 1.0 m × 0.5 m

Area of Infiltration basin = 1.0 m^2

Appendix 3c: Result of infiltration rate test under natural soil composition without grass by using direct method

Time	Time (hr)	Time Interval (hr)	Elevation (cm)	Difference of Elevation (cm)	Infiltration rate (cm/hr)
0:00:00	0	0	7.8	0.0	0.0
0:15:00	0.25	0.25	7.5	0.3	1.2
0:30:00	0.50	0.25	7.3	0.2	0.8
0:45:00	0.75	0.25	7.2	0.1	0.4
1:00:00	1.00	0.25	7.1	0.1	0.4
1:15:00	1.25	0.25	7	0.1	0.4
1:30:00	1.50	0.25	6.9	0.1	0.4
1:45:00	1.75	0.25	6.8	0.1	0.4
2:00:00	2.00	0.25	6.7	0.1	0.4

Monday 13 March 2017

Ground water level = 0.93 m

Dimension of infiltration basin = 1.0 m × 1.0 m × 0.5 m

Area of Infiltration basin = 1.0 m^2

Appendix 3d: Result of infiltration rate test under modified soil composition without grass by using direct method- organic soil at the top layer

Time	Time (hr)	Time Interval (hr)	Elevation (cm)	Difference of Elevation (cm)	Infiltration (cm/hr)
0:00:00	0	0	16	0.0	0.0
0:15:00	0.25	0.25	15.5	0.5	2.0
0:30:00	0.50	0.25	15.1	0.4	1.6
0:45:00	0.75	0.25	15	0.1	0.4
1:00:00	1.00	0.25	15	0.0	0.0
1:15:00	1.25	0.25	15	0.0	0.0
1:30:00	1.50	0.25	15	0.0	0.0

Wednesday 12 April 2017

Ground water level = 0.74 m

Dimension of infiltration basin = 1.0 m × 1.0 m × 0.5 m

Area of Infiltration basin = 1.0 m^2

Top layer- organic soil

Middle layer- filler

Bottom layer- gravel

Appendix 3e: Result of infiltration rate test under modified soil composition without grass by using direct method- natural soil at the top layer

Time	Time (hr)	Time Interval (hr)	Elevation (cm)	Difference of Elevation (cm)	Infiltration (cm/hr)
0:00:00	0	0	8	0.0	0.0
0:15:00	0.25	0.25	7.5	0.5	2.0
0:30:00	0.50	0.25	7.2	0.3	1.2
0:45:00	0.75	0.25	7	0.2	0.8
1:00:00	1.00	0.25	6.8	0.2	0.8
1:15:00	1.25	0.25	6.6	0.2	0.8
1:30:00	1.50	0.25	6.4	0.2	0.8
1:45:00	1.75	0.25	6.2	0.2	0.8
2:00:00	2.00	0.25	6	0.2	0.8

Saturday 15 April 2017

Ground water level = 0.745 m

Dimension of infiltration basin = 1.0 m × 1.0 m × 0.5 m

Area of Infiltration basin = 1.0 m^2

Top layer- natural soil

Middle layer- filler

Bottom layer- gravel

Appendix 3f: Result of infiltration rate test under modified soil composition without grass by using double ring infiltrometer- natural soil at the top layer

Time	Time (hr)	Time Interval (hr)	Elevation (cm)	Difference of Elevation (cm)	Infiltration (cm/hr)
0:00:00	0	0	19.3	0.0	0.0
0:15:00	0.25	0.25	18.7	0.6	2.4
0:30:00	0.50	0.25	18.4	0.3	1.2
0:45:00	0.75	0.25	18.2	0.2	0.8
1:00:00	1.00	0.25	18	0.2	0.8
1:15:00	1.25	0.25	17.8	0.2	0.8
1:30:00	1.50	0.25	17.6	0.2	0.8
1:45:00	1.75	0.25	17.4	0.2	0.8
2:00:00	2.00	0.25	17.2	0.2	0.8

Wednesday 19 April 2017

Ground water level = 0.9 m

Dimension of infiltration basin = 1.0 m × 1.0 m × 0.5 m

Area of Infiltration basin = 1.0 m2

Top layer- natural soil

Middle layer- filler

Bottom layer- gravel

Appendix 3g: Result of infiltration rate test under modified soil composition with grass by using direct method

Time	Time (hr)	Time Interval (hr)	Elevation (cm)	Difference of Elevation (cm)	Infiltration (cm/hr)
0:00:00	0	0	6.7	0.0	0.0
0:15:00	0.25	0.25	5.9	0.8	3.2
0:30:00	0.50	0.25	5.5	0.4	1.6
0:45:00	0.75	0.25	5.2	0.3	1.2
1:00:00	1.00	0.25	5	0.2	0.8
1:15:00	1.25	0.25	4.8	0.2	0.8
1:30:00	1.50	0.25	4.6	0.2	0.8
1:45:00	1.75	0.25	4.4	0.2	0.8
2:00:00	2.00	0.25	4.2	0.2	0.8

Wednesday 3 May 2017

Ground water level = 0.8 m

Dimension of infiltration basin = 1.0 m × 1.0 m × 0.5 m

Area of Infiltration basin = 1.0 m2

Top layer- natural soil

Middle layer- filler

Bottom layer- gravel

Appendix 3h: Result of infiltration rate test under modified soil composition with grass by using double ring infiltrometer method

Time	Time (hr)	Time Interval (hr)	Elevation (cm)	Difference of Elevation (cm)	Infiltration (cm/hr)
0:00:00	0	0	21.4	0.0	0.0
0:15:00	0.25	0.25	20.6	0.8	3.2
0:30:00	0.50	0.25	20.2	0.4	1.6
0:45:00	0.75	0.25	19.9	0.3	1.2
1:00:00	1.00	0.25	19.7	0.2	0.8
1:15:00	1.25	0.25	19.5	0.2	0.8
1:30:00	1.50	0.25	19.3	0.2	0.8
1:45:00	1.75	0.25	19.1	0.2	0.8
2:00:00	2.00	0.25	18.9	0.2	0.8

Friday 5 May 2017

Ground water level = 0.84 m

Dimension of infiltration basin = 1.0 m × 1.0 m × 0.5 m

Area of Infiltration basin = 1.0 m2

Top layer- natural soil

Middle layer- filler

Bottom layer- gravel