LABORATORY STUDY ON PERMEABILITY OF LAYERED SOIL

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A Thesis report on

LABORATORY STUDY ON PERMEABILITY OF LAYERED SOIL

in partial fulfilment of the requirements of the degree in

Bachelor of Technology in "Civil Engineering" & Master of Technology in

"Geotechnical Engineering"

By

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ODISHA, INDIA -769008

CERTIFICATE

This is to certify that the thesis entitled **“Laboratory study on permeability of layered soil”**, submitted by **Ajit Dange (Roll No. 710CE1134)** in partial fulfilment of the requirements for the award of **Bachelor of Technology** in **Civil Engineering** &**Master of Technology** in **Geotechnical Engineering (Integrated Dual Degree)** during session 2014-2015 at National Institute of Technology, Rourkela.

The candidate has fulfilled all the prescribed requirements.

The Thesis is an authentic work, based on candidates’ own work,.

To my knowledge, the thesis is up to the standard required for the award of a Bachelor of Technology in Civil Engineering & Master of Technology in Geotechnical (Integrated Dual Degree) degree.

Prof. C. R. Patra

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Ajit Dange

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ABSTRACT

The coefficient of permeability of stratified soil deposits, when the flow is normal to the orientation of the bedding planes, has been observed to deviate from the value calculated theoretically. The coefficient of permeability is calculated by Darcy's law. The present technical study deals with the results from the study of permeability behaviour of two layer soil system and three-layer soil system. For two layer soil system the coefficient of permeability of exit layer is considering as controlling factor for three layer soil system the coefficient of permeability depends upon the relative positioning of soil. This study reinforces the point that the coefficient of permeability of a layered soil system, when the flow is normal to the orientation of the bedding planes, depends upon the relative positioning of the layers with different values of coefficient of permeability in the system.

CHAPTER 1

INTRODUCTION

1. INTRODUCTION

1.1 MOTIVATION

The capacity of a soil to permit the passage of fluids through its interconnecting voids, is one of the most important soil engineering properties. The study of the permeability of soils is important in soil mechanics. It is essential for calculating the quantity of underground seepage under various hydraulic conditions, In common practice, the permeability coefficient is usually obtained by constant head permeability test, and is utilized in filtration-drainage, settlement, and stability calculations. These problems are extremely important for environmental aspects such as waste water management, slope stability control, erosion, and structural failure related with the ground settlement issues. The drainage and water movement in fine-grained soils are of primary importance to geotechnical engineering, soil science, and hydrology. In the field of geotechnical engineering, permeability has a significant influence on the consolidation characteristics of soil and as a consequence of drainage, on the mobilization of shear strength of soils. In addition, the study of the seepage through the body of earth dams, slope stability problems, ground water flow, and many related topics requires reliable information on permeability characteristics of fine-grained soils.

For layered soil system the bedding planes of the layers may be horizontal or vertical or inclined. Each layer will have its own value of coefficient of permeability, k. The average or equivalent coefficient of permeability of the stratified deposit, k_{eq}, depends upon the direction of flow in relation to the orientation of the bedding planes.

Two simple cases are as follows:

1. Flow is normal to the soil layer.

2. Flow is parallel to the soil layer.

The equivalent coefficient of permeability in both the cases is calculated assuming the Darcy's law to be valid. If L_1, L_2, ..., L_n represent the thicknesses of individual layers and k_1, k_2, ..., k_n are the corresponding coefficients of permeability, then the equivalent coefficients of permeability normal to the bedding plane, $(k_{eq})_n$ and parallel to the bedding plane, $(k_{eq})_p$ are obtained by$(K_{eq})_n$

$$(K_{eq})_n = \frac{\sum_{i=1}^{n} L_i}{\sum_{i=1}^{n} (L_i / K_i)} \quad (1)$$

$$(K_{eq})_p = \frac{\sum_{i=1}^{n} L_i K_i}{\sum_{i=1}^{n} L_i} \quad (2)$$

The permeability characteristics of homogeneous soil deposits are known to be functions of void ratio and the soil type. The permeability characteristics of stratified deposits (i.e., layered systems), predominantly when the flow is normal to the bedding plane, can further be complicated by the possible mutual interaction among the soils of different layers and their

relative position in the deposit. Hence, in the present experimental investigation, it is proposed to study the permeability characteristics of stratified deposits when the flow is normal to the bedding planes, the factors affecting them, and the possible mechanisms controlling such flows. For the sake of simplicity, the simple cases of a two layer system and three layer system are considered.

Proceeding this in aspect, the important objectives of the present study are:

- To determine equivalent coefficient of permeability of two layer soil system
- To determine equivalent coefficient of permeability of three layer soil system
- Comparison of experimental values of permeability to theoretical values of permeability calculated from Darcy's law.

1.2 ORGANISATION OF THESIS

- **Chapter 1** focuses the introduction of the work related to permeability of layered soil.

The importance of the present work and objectives have been explained

Chapter 2 includes the knowledge, theoretical and methodological contributions to permeability of layered soils.

Chapter 3.focuses on the types of soil which are used and methods used in experimental work covers the experiments to determine the coefficient of permeability

.**Chapter 4** incorporates the results and discussion on the present study, graphs for comparison of experimental values,

.**Chapter 5** provides the summary, important conclusions and specific contribution made in the present work

Chapter 6 provides the references used in this project

CHAPTER 2

LITERATURE REVIEW

2. LITERATURE REVIEW

2.1 INTRODUCTION

.The subject of flow of water through porous soil media is important in soil mechanics,

1. Involving the amount of water flows through soil (i.e. determination of leakage through an earth dam)
2. Involving rate of settlement of a foundation
3. Involving strength (i.e. the evaluation of factor of safety of an embankment)

The water does not flow from one point to another point in a straight line at constant velocity but rather in a winding path from pore to pore

As per Bernoulli's equation the total head at a point in water under motion can be given by the sum of pressure head, velocity head, and elevation head

$$H = \frac{P_w}{\gamma} + \frac{v^2}{2g} + Z \qquad (3)$$

P_w/γ represents the pressure head of the fluid and has unit of length, $v^2/2g$ represents the kinetic or velocity head of fluid and also have unit of length since water is flowing in typically has very small velocities the kinetic head or velocity head is typically negligible compared to that of the pressure and elevation heads for this reason the velocity head is neglected in soil mechanics. Z represents the elevation head with respect to an arbitrary datum the value is the distance of the point at which head is being measured above the datum this can be either positive if the point is above the datum or negative if the point is below the datum therefore

$$H = \frac{P}{\gamma w} + Z$$

$$i = (h_1 - h_2) / L \qquad (4)$$

Where i is hydraulic gradient, L is length of flow beyond which the loss of head take place.

Darcy's law:

Equation for the discharge velocity of flow through saturated soils which may be expressed as

$$V = Ki \tag{5}$$

Where,

K=coefficient of permeability (cm/s)

V=Discharge velocity or superficial velocity

Assumptions:

1. Soil is fully saturated.

2. Frictionless boundaries.

3. Flow in laminar (i.e. Reynolds number <1).

$$Re = \frac{\rho\ v\ D10}{\mu s} \tag{6}$$

v = discharge velocity

D_{10} = effective particle size

μ_s = dynamic velocity of water

When water flows through the soil media it exerts drag forces called seepage forces on individual grains of the soil the presence of seepage forces which causes changes in the direction of flow, will cause changes in the pore water pressure and effective stresses in the soil.

The value of coefficient of permeability K depends on:

1. Average size of pores and is related to the particle sizes and their packing
2. Particle shape

3. Soil structure

Factors affecting permeability:

Kozeny Carman equation:

$$v = \frac{1}{\mathrm{Cs}T^2}\left(\frac{\gamma w}{\mu}\right)\left(\frac{e^3}{1+e}\right)i \quad (7)$$

Equations reflecting the influence of permeant and the soil characteristics on k by Taylor (1948) using polssenlles law

$$v = c(de^2)\left(\frac{\gamma w}{\mu}\right)\left(\frac{e^2}{1+e}\right)t \quad (8)$$

Both the equations assume interconnected voids are visualized as a number of capillary tubes through which water can flow.

V= discharge velocity

C_s= shape factor for granular soils = 2.5

S_s = surface area

T = Tortuosity factor = 1.414 (for granular soil)

K = intrinsic permeability or absolute permeability

$$k = \frac{1}{\mathrm{CsSs}T^2}\left(\frac{e^3}{1+e}\right) \quad (9)$$

Units of k: Darcy's or cm^2

1 Darcy = 0.987×10^{-5} cm^2

List of factors affecting permeability:

- Void Ratio
- Degree of saturation
- Composition of soil particles
- Soil Structure

- Viscosity of the permeant
- Density and concentration of the permeant
- Shape and size of soil particles
- Effect of Grain size:

$$k = C(d_{10})^2 \tag{10}$$

C is a constant which includes effect of shape of the pore channels in direction of flow.

The permeability of granular soil depends mainly on the cross-sectional area of the pore channels, since the average diameter of the pores in a soil at a given porosity increases in proportion to the average grain size, the permeability of the granular soil might be expected to increase as the square of some characteristics grain size.

Effect of degree of saturation

$$k \propto S\gamma \tag{11}$$

At low saturation, there will be reduction in flow channels available for flow.

Effect of soil structure

The permeability of soil deposits is significantly affected by its place structure

A loose granular soil with flocculent structure will have higher permeability than soil with dispersed structure.

Even at similar void ratios a clay with an undisturbed flocculated structure will possess larger void openings than the same clay having a dispersed structure

Compactive effort: With increase in compactive effort permeability decreases

Effect of soil type

The volume of water that can flow through a soil mass is related more to the size of the void openings than to the number or total number of voids. Even though void ratios are frequently greater than for fine grained soil

For fine grained soils when void spaces are very small all lines of flow are physically

Close to the wall of conduit and therefore only low velocity flow occurs

In clays flow in already small channels is further hampered because some of water in the voids is held or adsorbed to the clay particles reducing the flow area and further restricting flow

Hence $K_{clay} <<< K_{sand}$

Effect of permeant

$$k \propto \frac{\gamma w}{\mu} \tag{12}$$

Variation of with temperature is negligible

Variation of μ with temperature is not negligible, higher the value of μ lower the permeability

Effect of specific surface area

$$K \propto \frac{1}{S} \tag{13}$$

Higher the value of specific surface area lower the permeability

Table 1: Classification of soils according to their coefficient of permeability

Degree of permeability	K (m/s)
High	$>10^{-3}$
Medium	10^{-3} to 10^{-5}
Low	10^{-5} to 10^{-7}
Very low	10^{-7} to 10^{-9}
Practically impervious	10^{-9}

Effective coefficient of permeability of layered soil

Flow in the horizontal direction (parallel to layers)

$$q = q_1 + q_2 + q_3 \ldots\ldots\ldots\ldots + q_n \tag{14}$$

For horizontal flow the head drop H_L over the same path length L will be the same for each layer,

So $i_1 = i_2 = i_3 = i_4 = i_n$ etc. the flow rate through a layered block of soil of breath B is therefore

$$K = K_1 L_1 B H_1 + K_2 L_2 B H_2 + K_2 L_2 B H_2 + \ldots$$

$$K_{eq} = \frac{K_1 H_1 + K_2 H_2 + \ldots + K_n H_n}{(H_1 + H_2 + \ldots + H_n)}$$

$$K_{eq} = \frac{\sum_{i=1}^{n} K_i H_i}{\sum_{i=1}^{n} H_i} \tag{15}$$

K_{eq} = equivalent coefficient of permeability

Flow in vertical direction (perpendicular to the layers)

For vertical flow, the flow rate 'q' through area 'A' of each layer is the same, hence the head drop across a series of layers is as follows:

$$iH = i_1 H_1 + i_2 H_2 + \ldots + i_n H_n$$

$$\frac{V}{K_v} H = \frac{V}{K_1} H_1 + \frac{V}{K_2} H_2 + \ldots + \frac{V}{K_n} H_n$$

$$K_{eq} = \frac{H_1 + H_2 \ldots + H_n}{\frac{H_1}{K_1} + \frac{H_2}{K_2} + \ldots + \frac{H_n}{K_n}}$$

$$K_{eq} = \frac{\sum_{i=1}^{n} H_i}{\sum_{i=1}^{n} \frac{H_i}{K\,i}} \tag{16}$$

Main points about stratified soil:

$$K_h \neq K_v$$

In cases where soil deposits permeability's are not the same in all direction we say that properties are anisotropic. If the properties are the same in all direction we say that properties are isotropic.

$K_h > K_v$

$\sigma_k < \sigma_v$

2.2 REVIEW OF LITERATURE:

In this section literature related to permeability and some of work done on permeability are discussed.

Uppot et al. (1989): Two clays are subjected to organic and inorganic permeants to study the changes in permeability caused by the reaction between clays and permeants.

Haug et al. (1990): The laboratory permeability tests were conducted on a prototype liner formed of Ottawa sand and sodium bentonite. This material was mixed, moisture-conditioned, and compacted into reinforced wooden frames. The in situ permeability test results were verified with low gradient, back-pressure saturated triaxial permeameter tests conducted on undisturbed cored and remolded samples

Sridharan and Prakash (2002): A detailed study of two-layer soil systems indicates that the mutual interaction among different layers of different soil types forming a stratified deposit affects the equivalent permeability of the stratified deposit, which cannot be simply calculated by the use of the equation for the equivalent coefficient of permeability of a stratified deposit when the flow is normal to the orientation of the bedding planes based on the Darcy's law. The permeability of the exit layer controls whether the measured permeability is greater or lesser than the theoretical values for a stratified deposit. The coefficient of permeability of a soil appears to be also a function of the interaction between the soil and the surrounding soil(s) with which it is in contact, in addition to the void ratio, thickness, and the soil type in the case of layered system. In this context, the coefficient of permeability of a soil in a layered system has to be considered as dependent upon how the layers of different *k* are relatively placed, their thicknesses, and the flow direction. While the present investigation is purely experimental, it opens up the scope for further work in that the validity of the results and proposed hypothesis have to be ascertained mathematically.

Galvaeo et al. (2004): coefficient of permeability of saprolitic soil increased about five times when two percent lime was added and then decreased on further addition of lime. This is assign to the creation of chemical bonds and aggregation. As for lateritic soil, the coefficient of permeability decreased as lime was added. This is also assign to the same mechanism except that the bonds are weaker than those developed in Soil.

Nikraz et al. (2011): A series of laboratory permeability tests carried out to evaluate fiber effect on hydraulic conductivity behavior of composite sand. Clayey sand was selected as soil part of the composite and natural fiber was used as reinforcement.

Sridharan and Prakash (2013): A comparative study of the measured equivalent coefficient of permeability of three-layer soil sediments with the theoretically calculated values has been made. The results demonstrate that, by and large, the coefficient of permeability of the bottom layer controls whether the measured value of equivalent coefficient of permeability is greater or lesser than the theoretically calculated value. The consequence of this observation is the realization that the equivalent coefficient of permeability of any layered soil deposit is not just dependent upon the values of k of the individual layers constituting the deposit, and that it also depends upon the relative positioning of the layers in the system

.

CHAPTER 3

MATERIALS AND METHODOLOGY

3.1 INTRODUCTION:

Clay**:** Clay used in this project is collected from sector 5 Rourkela. Clays are plastic in nature because of their water content and become hard, brittle. Clay minerals commonly form over large periods of time from the continuous chemical weathering of rocks. The geotechnical properties of clay is as follows:

Table 2: The geotechnical properties of clay.

Liquid limit	35 %
Optimum moisture content	18 %
Specific gravity	2.46
Maximum dry density	1.79 gm/cc

Black soil:

In India black soil is mainly utilized as agriculture purpose however for civil engineering these soils are giving risky problem to engineers. In this project black soil is collected from 'VNIT Nagpur' and it is used to analyze permeability of layered soil. The geotechnical properties of black soil are as follows:

Table 3: The geotechnical properties of black soil

Liquid limit	57 %
Optimum moisture content	23 %
Specific gravity	2.29
Maximum dry density	1.67 gm/cc

Sand: The sand used in the laboratory study was collected from the river bed of Koel River. It is made free from roots, organic element etc. by sanitation. The above sample was then oven dried and perfectly sieved by passing through 710 micron and retained at 300 micron IS sieve to get the required grading.

Table 4: The geotechnical properties of sand.

Liquid limit	Non plastic
Optimum moisture content	17 %
Specific gravity	2.65
Maximum dry density	1.638 gm/cc

3.2 METHODOLOGY

1. Liquid limit test
2. Grain size distribution analysis
3. Sieve analysis
4. Standard proctor test
5. Specific gravity test
6. Constant head permeability test
7. Variable head permeability test

3.2.1 Liquid limit test:

About 200 grams of air dried soil passing through 425 micron I. S. sieve weighted. Than soil is taken in a porcelain basin and water is added till it becomes paste the fall of the liquid limit device cup was checked and adjusted exactly 1 cm, using the gauge on the handle of the grooving device. Soil paste is placed in the cup of liquid limit device and level it horizontal with the lowest edge of cup, with spatula so that the maximum depth of soil in the cup is 1 cm.

a groove is made in the middle of the soil along the diameter, and hence dividing the soil into two parts .turn the handle of the liquid limit device at the rate of two revolutions per second, till the two parts of the soil in the cup join together i.e. the groove closes by 12 mm length ensure that the grooving closes by flow and not by slipping of soil on the surface of the cup the number of blows were noted. About 10 grams of soil moist from the centre of the groove in a moisture tin was taken and its moisture content is determined. By altering the water content of the soil and the above operation is repeated five to six times, for blows in the range of 15 to 35 .the test is performed to proceed from drier to welter condition of soil.

3.2.2 Grain size distribution analysis:

Hydrometer analysis

This process defines the quantitative determination of the distribution of particle sizes in soils. The distribution of particle sizes larger than 75 mm is determined by a sedimentation process, by means of a hydrometer to secure the essential data. Dispersing agent – Sodium metaphosphate solution is prepared in distilled or demineralized water. 2 gm. of sodium hexametaphosphate/litre is used in the solution. About 50gm of soil is taken and added with water and sodium hexametaphosphate and put into the mechanical stirring cup. Stirring process occurs for a period of 15 minutes. After that it is poured into the hydrometer flask. After 20 seconds the Hydrometer is inserted gently to a depth slightly below its floating position. Hydrometer readings are taken in the interval of ½, 1, 2,4,8,15,30 minutes, 1, 2, 4,8,16 and 24 hours. After that it was taken out and rinse with distilled water. The hydrometer was re-inserted in the suspension and readings were taken over periods of 8, 15, and 30 minutes; 1, 2, 4, 8, 16 and 24 hours after shaking. The hydrometer is removed and rinsed with water after each reading.

3.2.3 SIEVE ANALYSIS

Sieving is conducted by arranging the various sieves over one another in order of their mesh openings biggest aperture at the top and smallest at the bottom. A holder is kept at the bottom and a cover is put at the top of the whole setup. The soil is put through the top sieve and adequate amount of shaking is done to let the soil particles pass through the various sieves. 4.25mm, 2mm, 1mm, 425 micron, 150 micron and 75 micron IS sieves were used to perform the sieving. The results of sieve analysis are plotted on a graph of percentage passing versus the sieve size. On the graph the sieve size scale is logarithmic. To find the percentage of cumulative passing through each sieve, the percentage retained on each sieve is found.

After this the cumulative percentage of aggregate retained in a sieve is found. To do so, the total amount of aggregate that is retained on each sieve and the amount in the previous sieve are added up. The cumulative percentage passing of the aggregate is found by subtracting the percentage retained from 100%.The values are then plotted on a graph with cumulative percentage passing on the y axis and logarithmic sieve size on the x axis.

3.3.4 STANDARD PROCTOR TEST

The empty mould was weighted the mould was fixed to the base plate at attach collar to the mould a thin layer of grease applied to the inside surface of mould and collar around 2.4 kg soil passing through 4.75mm size sieve was taken and water added to bring its moisture content about 14% in case of clayey soil for uniformity this quantity of water is sprinkled on the soil and the soil is mixed thoroughly. The weight of soil divided into three equal parts one part of mould was filled with soil and compacted to 25 evenly distributed blows with the standard rammer this process was repeated for second and third part of soil taking precaution to scratch the top of the previously compacted layer with a spatula in order to avoid stratification the collar was removed by rotating it and trim the top of the soil to flash with the top of the mould

.detach the mould from the base plate the weight of compacted soil taken with the mould extract the soil from the mould and take some wet soil from the core of tempacted soil and determine the moisture content .This procedure is repeated by taking fresh soil sample and adding water to make the water content 2 to 4 % more than the previous water content**.**

3.3.5 SPECIFIC GRAVITY TEST:

Specific gravity is defined as the ratio of the weight in air of a given volume of the material at a specified temperature to the weight in air of an equal volume of distilled water at a specified temperature. The purpose of the test is to define the specific gravity of soil passing the 4.75 mm sieve by density bottle method. 50g of sample of soil is taken in each 3 bottles and added to distilled water; the weight of the water + bottle is taken. Then all the 3 bottle are subjected to sand bath, heating is done up to air bubbles are seen in the bottle. This is done to remove the entrapped air in the mixture; the bottle is kept for around 1 hour so that the temperature comes to 27oC.

Calculation:

Specific Gravity,

$$G = \frac{W2-W1}{(W2-W1)-(W3-W1)} \qquad (15)$$

Where

W_1= Wt. of density bottle in gm.

W_2=Wt. of bottle with dry soil in gm.

W_3=Wt. of bottle with soil and water in gm.

W_4=Wt. of bottle full of water in gm.

3.2.6 CONSTANT HEAD PERMEABILITY TEST:

The oversize particles were removed by sieving the soil specimen and the dimensions of the permeameter was noted and its volume is calculated. The amount of water and dry soil was calculated to achieve a particular density and moisture content the height of mould marked in three equal parts. And the soil was compacted into the mould in three layers after fixing the mould to its base plate containing porous stone and placing the collar on the top. Put the porous stone on the top of the soil and fix the top plate which is provided with an inlet valve and air cock. Filter paper was added on the top and bottom of the soil. Secure both the base plate and top plate to mould with suitable clamps and rubber gasket to make the entire assembly water tight. Attach the constant head water tank with the sliding bracket to a vertical stand. This tank has three openings one of them connected to water supply source, the second to overflow tube and the third to inlet valve provided on the cap of the permeameter. Allow the soil sample to saturate. When the steady state flow is attained, the sufficient quantity of water (about 250 cc) and time interval is noted .and the procedure is repeat three to four times.

CALUCLATIONS:

$$K = \frac{Q}{A\,i\,t} \qquad (16)$$

Where

K= coefficient of permeability

Q = total discharge

A= cross section area of specimen in cm^2

i= hydraulic gradient

t = time in seconds

3.2.7 VARIABLE HEAD PERMEABILITY TEST

The oversize particles were removed by sieving the soil specimen and the dimensions of the permeameter was noted and its volume is calculated. The amount of water and dry soil was calculated to achieve a particular density and moisture content the height of mould marked in three equal parts. And the soil was compacted into the mould in three layers after fixing the mould to its base plate containing porous stone and placing the collar on the top. Put the porous stone on the top of the soil and fix the top plate which is provided with an inlet valve and air cock. Filter paper was added on the top and bottom of the soil. Secure both the base plate and top plate to mould with suitable clamps and rubber gasket to make the entire assembly water tight. The top cap attached with the stand pipe and scale to the mould. The assembly was placed in a shallow metal tray with an outlet .the tray is filled with water to submerge the base plate completely. Water was poured into the stand pipe and allowed to run through the sample. The cross sectional area of stand pipe was determined. Inlet valve was opened and water was allowed flow through the soil sample. Initial height of the water level in the stand pipe was noted and at the same time stop watch had started. Time is taken such that water level falls by 30 to 50 cm. in the stand pipe. Height of the water level and time was noted. The procedure was repeated and calculations were done as follows,

Calculations:

$$K = 2.303 \, \frac{a\,L}{A(Tf - Ti)} \times \log \frac{H1}{H2} \tag{17}$$

Where

K = coefficient of permeability

A= cross section area of specimen

a = cross section area of stand pipe

L= length of specimen

T_f = final time

T_i= initial time

H_1 = initial height

H_2 = final height

CHAPTER 4

RESULT AND DISCUSSION

4. RESULT AND DISCUSSION

4.1 INTRODUCTION

Different types of permeability test were conducted in laboratory by using clay , sand and black soil and the equivalent coefficient of permeability was determined for three types of layered soil .the analysis of results is discussed in following paragraph.

Table 5: specific gravity of soils

Clay	2.46
Black soil	2.29
Sand`	2.65

Particle size distribution:

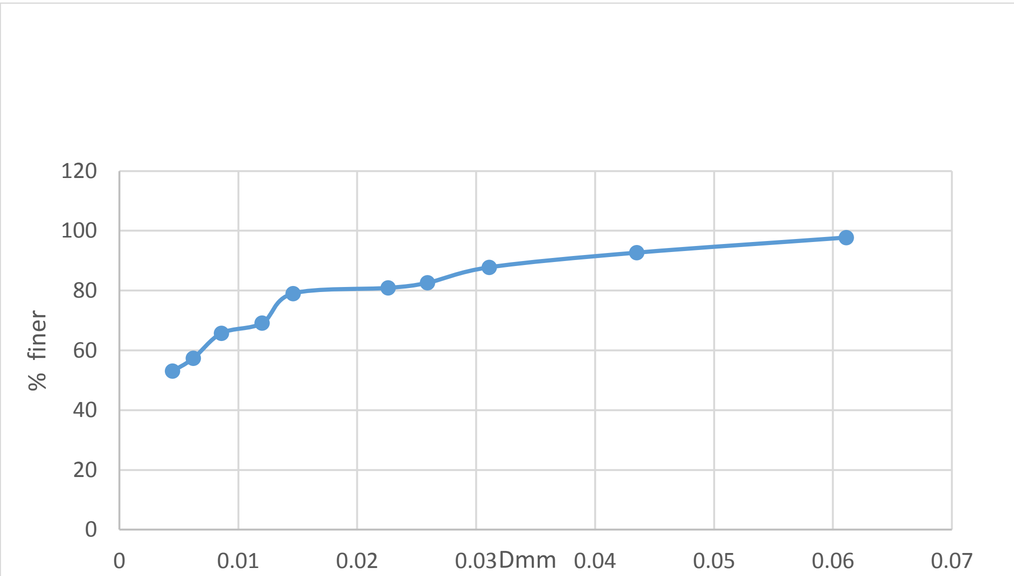

Figure 1: Particle size distribution of clay.

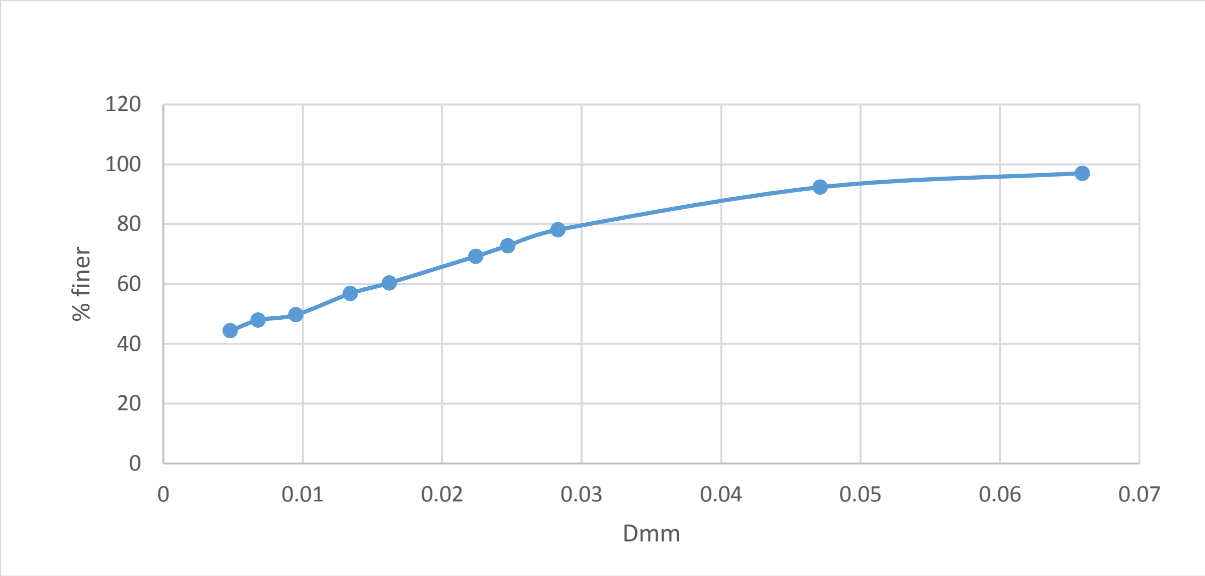

Figure 2: Particle size distribution of black soil

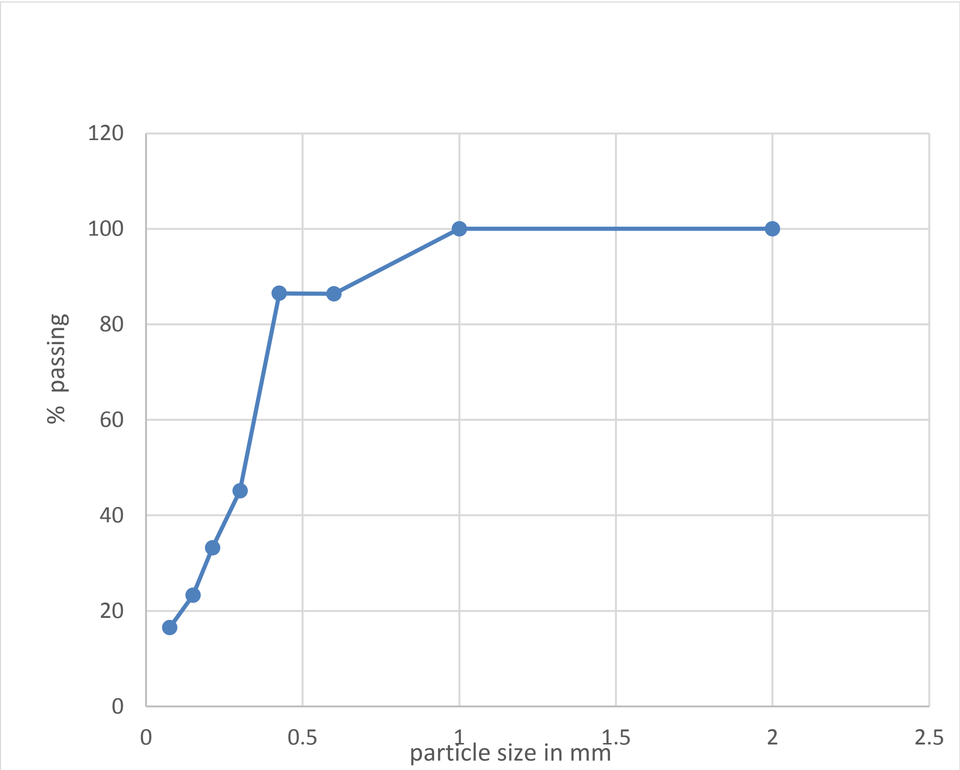

Figure 3: Sieve analysis for sand

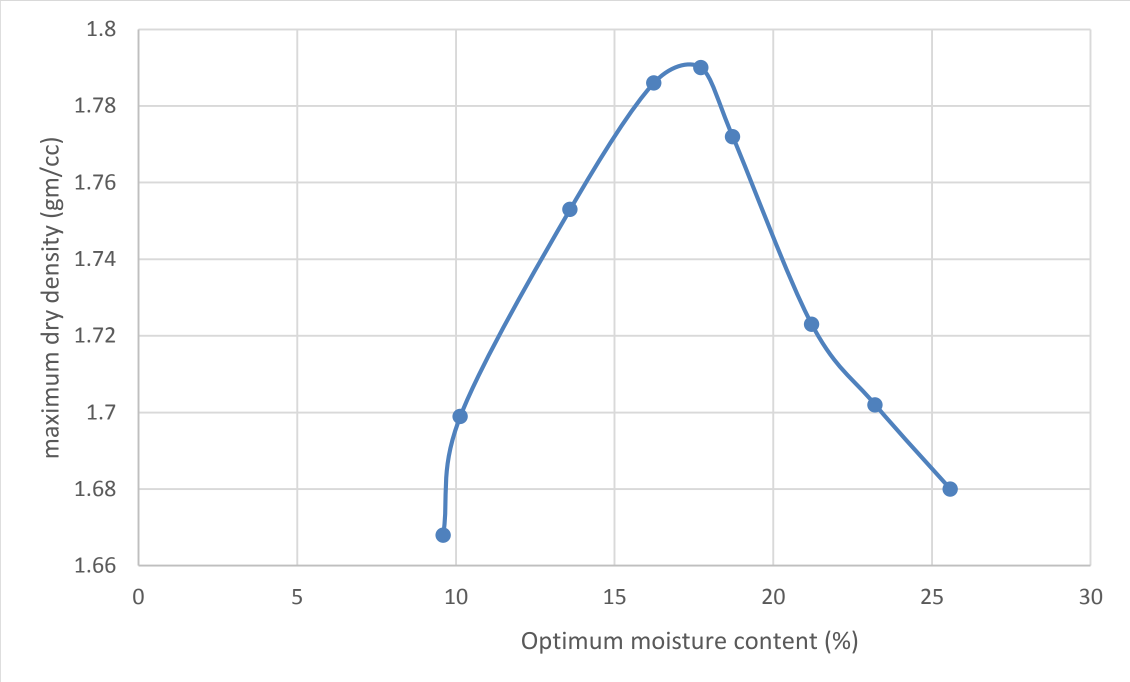

Figure 4: Relationship between maximum dry density and optimum moisture content for clay

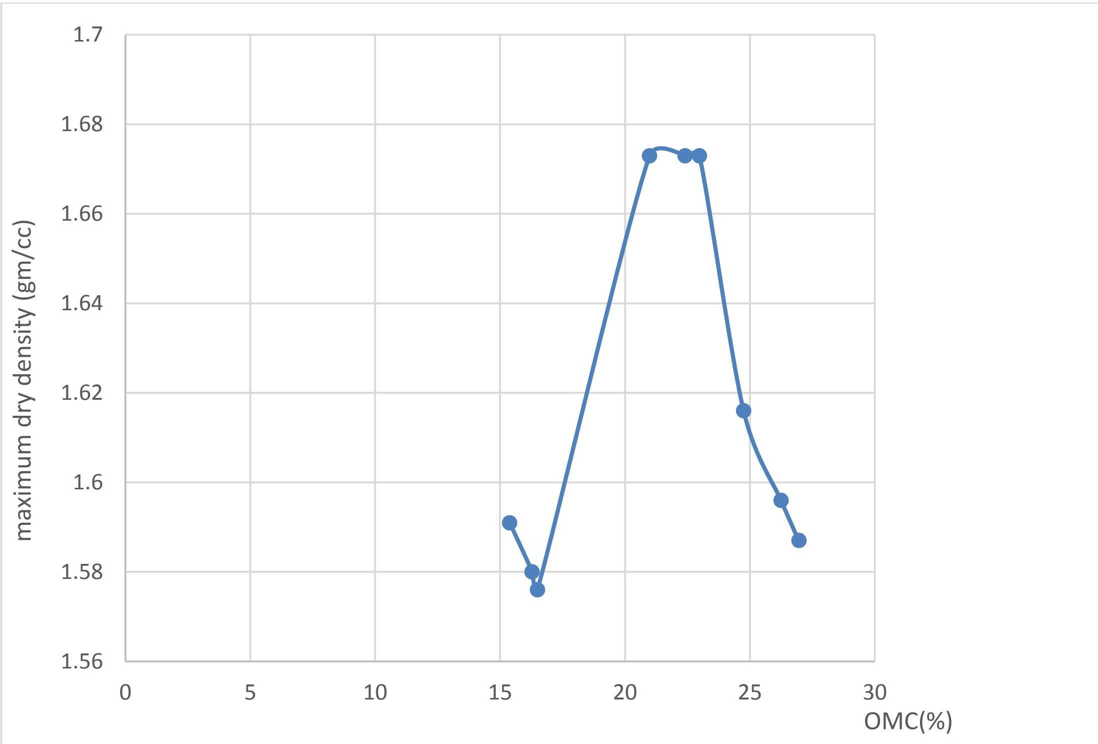

Figure 5: Relationship between maximum dry density and optimum moisture content for black soil

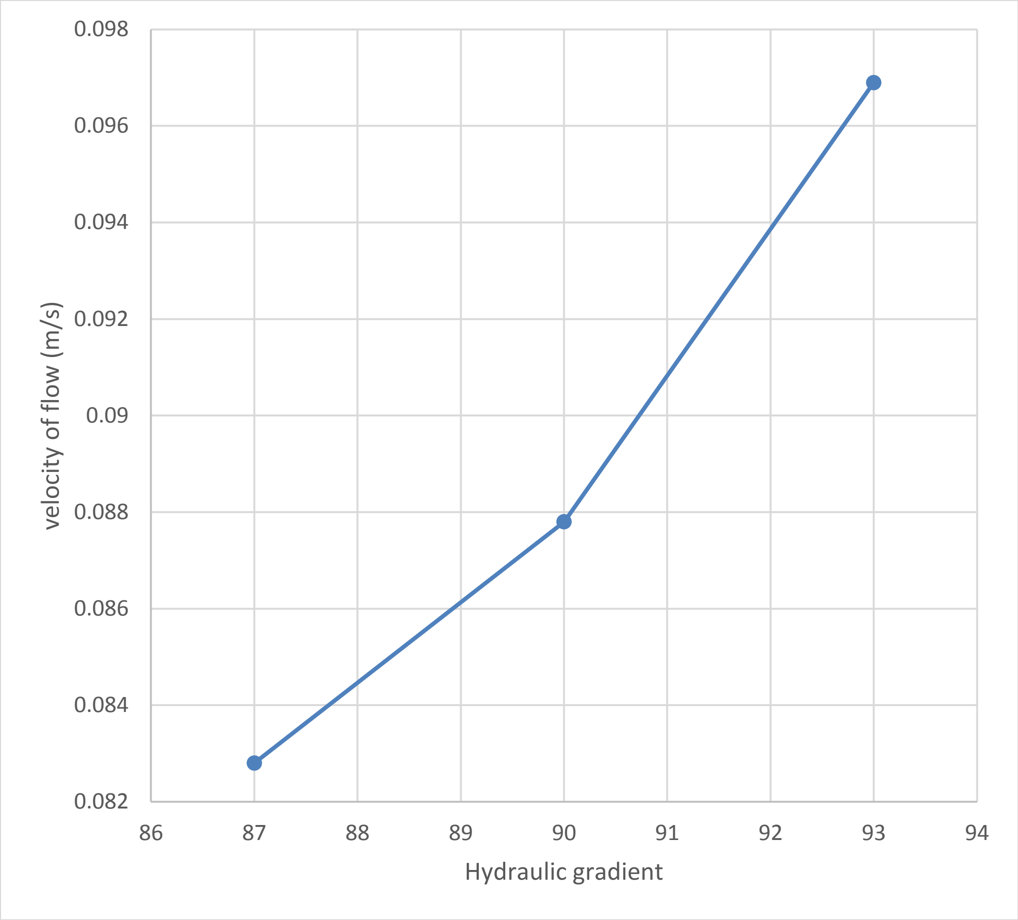

Figure 6: relationship between hydraulic gradient and velocity of flow for sand**.**

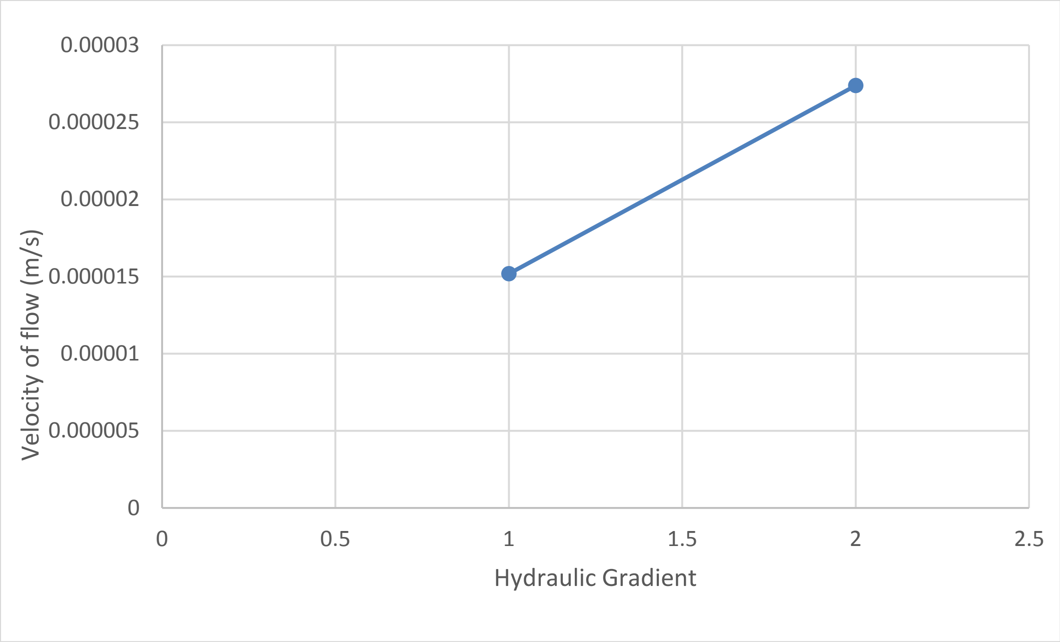

Figure 7: relationship between hydraulic gradient and velocity of flow for clay

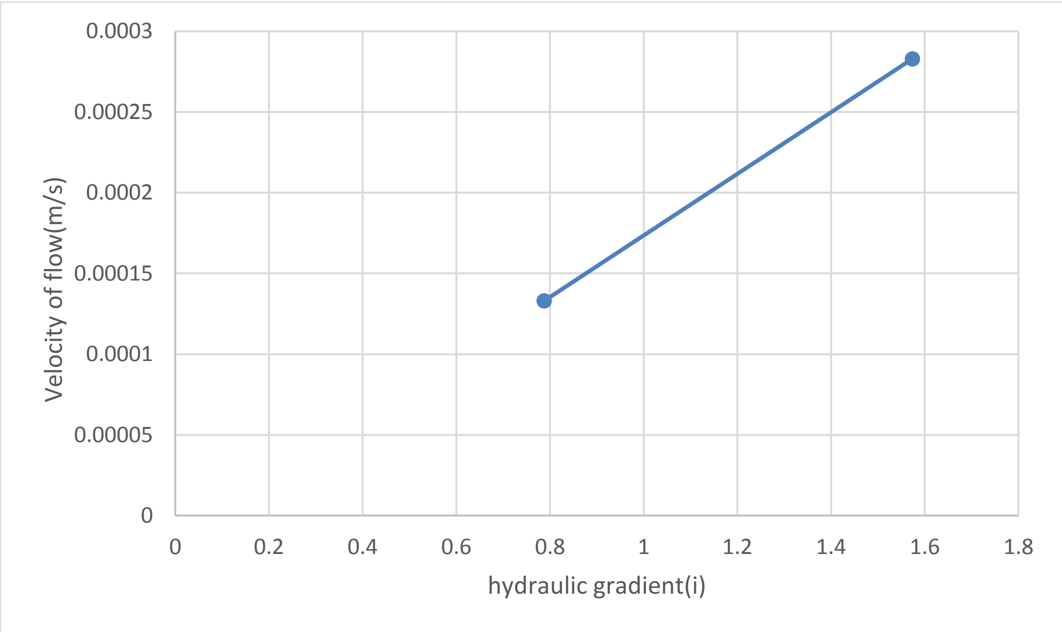

Figure 8: relationship between hydraulic gradient and velocity of flow for black soil

4.2 PERMEABILITY OF TWO LAYER SOIL SYSTEM WITH COMBINATION OF CLAY AND SAND

SN	TYPE OF LAYER	TYPE OF SOIL	PROPORTION	K (actual) (Cm/sec)	K_{eq} (calculated) (Cm/sec)	K_{eq} (measured) (Cm/sec)	K_{eq} (measured) /K_{eq} (calculated) * 100
1	Inlet	Clay	50 %	2.098×10^{-4}	4.06×10^{-4}	7.15×10^{-5}	17.58
	Exit	Sand	50%	2.96×10^{-2}			
2	Inlet	Sand	50%	2.96×10^{-2}	4.06×10^{-4}	4.76×10^{-5}	11.67
	Exit	Clay	50%	2.098 x 10-4			
3	Inlet	Clay	33%	2.098×10^{-4}	6.06×10^{-4}	5.65×10^{-5}	9.32
	Exit	Sand	67%	2.96×10^{-2}			
4	Inlet	Sand	67%	2.96×10^{-2}	6.06×10^{-4}	2.97×10^{-5}	4.90
	Exit	Clay	33%	2.098×10^{-4}			
5	Inlet	Clay	67%	2.098×10^{-4}	3.05×10^{-4}	4.24×10^{-5}	13.90
	Exit	Sand	33%	2.96×10^{-2}			
6	Inlet	Sand	33%	2.96×10^{-2}	3.05×10^{-4}	2.40×10^{-5}	7.88
	Exit	Clay	67%	2.098×10^{-4}			

Table 6: permeability of two layer soil system with combination of clay and sand.

4.3 PERMEABILITY OF TWO LAYER SOIL SYSTEM WITH COMBINATION OF BLACK SOIL AND SAND

Table 7: permeability of two layer soil system with combination of black soil and sand.

SN	TYPE OF LAYER	TYPE OF SOIL	PROPORTION	K (actual) (Cm/sec)	K_{eq} (calculated) (Cm/sec)	K_{eq} (measured) (Cm/sec)	K_{eq} (measured) / K_{eq} (calculated) x 100
1	Inlet	Black soil	50 %	1.98×10^{-4}	3.94×10^{-4}	1.66×10^{-5}	4.21
	Exit	Sand	50%	2.96×10^{-2}			
2	Inlet	Sand	50%	2.96×10^{-2}	3.94×10^{-4}	4.048×10^{-5}	10.27
	Exit	Black soil	50%	1.98×10^{-4}			
3	Inlet	Black soil	33%	1.98×10^{-4}	5.88×10^{-4}	8.16×10^{-5}	13.87
	Exit	Sand	67%	2.96×10^{-2}			
4	Inlet	Sand	67%	2.96×10^{-2}	5.88×10^{-4}	2.46×10^{-5}	4.18
	Exit	Black soil	33%	1.98×10^{-4}			
5	Inlet	Black soil	67%	1.98×10^{-4}	2.972×10^{-4}	1.748×10^{-5}	6.00
	Exit	Sand	33%	2.96×10^{-2}			
6	Inlet	Sand	33%	2.96×10^{-2}	2.972×10^{-4}	6.23×10^{-5}	20.96
	Exit	Black soil	67%	1.98×10^{-4}			

The simplest two-layer systems were obtained by following the permeability method with sand, clay, and black soil as the materials of individual layers. With these three soils, six two-layer systems were obtained with different proportion of material table shows the comparison between the equivalent coefficients of permeability of the two-layer systems obtained from the direct measurement and from the use of Darcy's equation. The observed difference between the two quantities is of the order of about 20%. As the value of k_{eq} is in between K_{inlet} and K_{exit}, and as the continuity of flow over the entire thickness of the stratified deposit has to be ensured, it appears that the coefficients of permeability of both the layers forming the stratified deposit have to be different from their individual values when considered separately.

4.4 PERMEABILITY OF THREE LAYER SOIL SYSTEM HAVING COMBINATION OF CLAY, SAND AND BLACK SOIL

Table 8: Permeability of three layer soil system with combination of clay, black soil and sand

SN	SEQUENCE OF LAYERING		K_{actual} (Cm/sec)	K_{eq} (calculated) (Cm/sec)	K_{eq} (measured) (Cm/sec)	K_{eq} (measured) / K_{eq} (calculated) * 100
1	Flow	Sand(inlet)	2.96×10^{-2}	3.0529×10^{-4}	8.148×10^{-6}	2.666
		Clay	2.098×10^{-4}			
		Black soil(exit)	1.98 x 10-4			
2	Flow	Clay (inlet)	2.098×10^{-4}	3.0529×10^{-4}	4.0075×10^{-5}	13.12
		Sand	2.96×10^{-2}			
		Black soil(exit)	1.98×10^{-4}			
3	Flow	Sand(inlet)	2.96×10^{-2}	3.0529×10^{-4}	7.314×10^{-5}	20.94
		Black soil	1.98×10^{-4}			
		Clay (exit)	2.098×10^{-4}			
4	Flow	Black soil (inlet)	1.98×10^{-4}	3.0529×10^{-4}	2.513×10^{-5}	8.22
		Sand	2.96×10^{-2}			
		Clay (exit)	2.098×10^{-4}			
5	Flow	Black soil (inlet)	1.98×10^{-4}	3.0529×10^{-4}	5.02×10^{-5}	1.64
		Clay	2.098×10^{-4}			
		Sand (exit)	2.96 x 10-2			
6	Flow	Clay (inlet)	2.098×10^{-4}	3.0529×10^{-4}	5.92×10^{-5}	19.39
		Black soil	1.98×10^{-4}			
		Sand (exit)	2.96×10^{-2}			

4.4 DISCUSSION

Case (1): In this case the exit layer is black soil, middle layer is clay and the top most layer is sand; black soil losses the permeability of clay and clay losses the permeability of sand so, the measured k_{eq} has occurred less than calculated.

Case (2): In this case top most layer is clay followed by sand and black soil. The black soil decreases the permeability of sand and permeability of clay depends upon the decrease in k of sand. Hence, in this case, the measured value of k_{eq} is found less than that of calculated.

Case (3): In this case, the bottom most layer is clay with black soil and sand as the middle and top layers respectively. The permeability of clay losses the permeability of black soil and the black soil losses the permeability of sand. Thus, the measured k_{eq} is less than calculated.

Case (4): In this case clay layer is at bottom, sand and black soil form the middle and top most layers respectively. The permeability of bottom layer (clay) is less than that of middle layer (sand) so it decreases the permeability of sand and the influence of sand layer on the black soil depends upon the decrease in value of permeability of sand and hence the k_{eq} measured is less than that of calculated.

Case (5): In this case, top layer is black soil followed by clay and sand layer. The exit layer is expected to increase the value of k of clay lying immediately above it. The examination of the individual values of k of clay and black soil layers indicates that the observed value is less than the calculated value.

. Case (6): The three layers arranged in such a way that permeability values are in the increasing order of magnitude in the direction of flow (i. e. clay layer at the top followed by the black soil layer in the middle and sand layer at the bottom). The bottom most exit layer has the maximum value of k. Hence, this is a clear case where the measured value of k_{eq} is greater than the above case.

CHAPTER 5

CONCLUSION

5.1 CONCLUSION

A laboratory study was done for two layer and three layer soil system having different types of soil, type of layer, varying proportion and position for clay, sand and black soil .and it is found that equivalent coefficient of permeability differs from the value calculated from Darcy's law. The permeability of the exit layer controls whether the measured permeability is greater or lesser than the theoretical values for a stratified deposit. The coefficient of permeability of a soil appears to be also a function of the interaction between the soil and the surrounding soil(s) with which it is in contact, in addition to the void ratio, thickness, and the soil type in the case of layered system. And hence the coefficient of permeability of a soil in a layered system has to be considered as dependent upon flow direction , relative position and thickness of layer also this study is purely experimental and it opens up the scope for further work and hence to obtain a mathematical equation for layered soils.

CHAPTER 6

REFERENCES

6.1 REFERENCES

[1] Boroumand, A., & Baziar, M. H. (2005). Determination of compacted clay permeability by artificial neural networks. In *Ninth International Water Technology Conference, IWTC9, Sharm El-Sheikh, Egypt*.[2] Chegenizadeh, A., &Nikraz, H. (2011). Permeability test on reinforced clayey sand. World Academy of Science, Engineering and Technology, 2011, 130-133.

[3] Fernando, J. (2008, October). Determination of coefficient of permeability from soil percolation test. In Proceedings of the 12th lnternational Conference of lAClVlACr (pp. 1824-1881).

[4] Fernuik, N., &Haug, M. (1990). Evaluation of in situ permeability testing methods. Journal of geotechnical engineering, 116(2), 297-311.

[5] Li, X., Li, J. H., & Zhang, L. M. (2014). Predicting bimodal soil–water characteristic curves and permeability functions using physically based parameters. Computers and Geotechnics, 57, 85-96.

[6] Lafhaj, Z., &Shahrour, I. (2002). Influence of the presence of partially saturated layer on the interpretation of field water tests. In Unsaturated Soils: Proceedings of the Third International Conference on Unsaturated Soils, UNSAT 2002, 10-13 March 2002, Recife, Brazil (Vol. 1, p. 33). Taylor & Francis US

[7] Osinubi, K. J. (1998). Permeability of lime-treated lateritic soil. Journal of Transportation Engineering, 124(5), 465-469.

[8] Raisinghani, D. V., &Viswanadham, B. V. S. (2010). Evaluation of permeability characteristics of a geosynthetic-reinforced soil through laboratory tests. Geotextiles and Geomembranes, 28(6), 579-588.

[9] Rajapakse A. (1993), SHORT-TERM AND LONG-TERM PERMEABILITIES OF CONTAMINATED CLAYS,ASCE, ISSN, 1993.119:725-743.

[10] Sathananthan, I., &Indraratna, B. (2006). Laboratory evaluation of smear zone and correlation between permeability and moisture content. Journal of Geotechnical and Geoenvironmental Engineering, 132(7), 942-945.

[11] Sezer, A., Göktepe, A. B., &Altun, S. (2009). Estimation of the Permeability of Granular Soils Using Neuro-fuzzy System. In AIAI Workshops (pp. 333-342).

[12] Sridharan, A., & Prakash, K. (2002). Permeability of two-layer soils. Geotechnical Testing Journal, 25(4), 443-448.

[13] Swartzendruber, D. (1962). MODIFICATION OF DARCY'S LAW FOR THE FLOW OF WATER IN SOILS. Soil Science, 93(1), 22-29.

[14] Uppot, J. O., & Stephenson, R. W. (1989). Permeability of clays under organic permeants. Journal of Geotechnical Engineering, 115(1), 115-131.

[15] de Brito Galvão, T. C., Elsharief, A., &Simões, G. F. (2004). Effects of lime on permeability and compressibility of two tropical residual soils. Journal of environmental engineering, 130(8), 881-885.

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