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Modified Design of Experimental Setup and Measurement of Permeability of the Sand by Using Darcy's Law

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Abstract- This paper deals with the action of amendment in Darcy's apparatus by suitable changes. During fabrication there is a use of different materials which are assembled to make the experimental setup to measure the permeability of sand (except coarse grained soils) by falling head method at different length of samples used. Graphs and Experimental analysis shows that compactness of the sand verses moisture content first increases at certain higher value than decreases a moisture content increase. Results obtained are almost accurate within typical permeability range which is used in petroleum geology, casting industries for making mould etc. This setup is too simple to operate with low skilled workers.

Index Terms- Darcy's law, Hydraulic conductivity or Permeability, Porosity.

I. Introduction

IN 1855, Henry Darcy supervised a succession of experiments with the objective to determine the relation between the volumetric flow of water through sand beds and the hydraulic head loss [1]. Darcy used, long column permeameter were the filling of sand and sand removal was difficult task, liquid having Reynolds number less than unity, filter changing was difficult, used constant head method where it was difficult to always maintain constant pressure head. This setup is used to calculate the permeability by falling head method.

Permeability: The passage of gaseous materials, water and steam vapour through the sand is related to permeability. It is the property of the sand. It is define as the ability of transmit water [2].

Fig.1 Ability to transmit water

Porosity: It is defined as the ability to hold water [2].

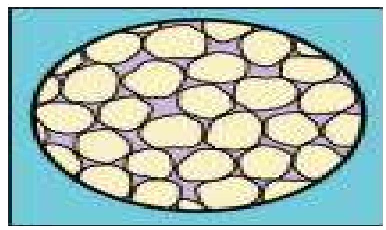

Fig.2 Ability to hold water

Darcy's Law: In fluid dynamics, Darcy's law is a phenomologically derived constitutive equation that describes the flow of a fluid through a porous medium. The law was formulated by Henry Darcy based on the result of experiments [3] on the flow of water through beds of sand [4]. Darcy's law is a simple proportional relationship between the instantaneous discharge rates through a porous medium. The viscosity of a fluid and the pressure drop over a given distance. The total discharge, Q (units of volume per time) is equal to the product of the permeability (k units of area) of the medium , the cross-sectional area(A) to flow , and the pressure drop (Pb-Pa) , all divided by the dynamic viscosity μ(in SI units) , and the length L the pressure drop is taking place over. The negative sign is needed because fluid flows from high pressure to low pressure. So if the change in pressure is negative (in the x- direction) then the flow will be positive (in x-direction) [5].

Where q is the flux (discharge per unit area, with the units of length per time, m/s) and is the pressure gradient factor. Thos value of flux, often referred to as the Darcy flux, is not the velocity which the water travelling through the pores is experiencing [5].

$$q = -k/\mu \, \Delta p$$

The pore velocity (V) is related to the Darcy's flux (q) by the porosity (Φ). The flux is divided by porosity to account for the fact that only a fraction of the total formation volume is available for flow. The pore velocity would be the velocity a conservative tracer would experience if carried by the fluid through the formation [5].

$$V=q/\Phi$$

Assumptions

Darcy law is a simple mathematical statement which neatly summarizes several familiar properties that groundwater flowing in aquifers exhibits, including.

- If there is no pressure gradient over a distance, no flow occurs (this is hydrostatic condition).
- If there is no gradient, flow will occur from high pressure towards low pressure (opposite the direction of increasing gradient – hence the negative sign in Darcy's law).
- The greater the pressure gradient (through the same formation material), the greater the discharge rate, and
- The discharge rate of fluid will often be different direction) – even if the same pressure gradient exists in both cases.

Hydraulic Conductivity: Hydraulic conductivity is a property of vascular plants, soil or rocks that describe the case with which water can move through pore spaces or fractures [6].Hydraulic conductivity is the proportionality constant in Darcy's law, which relates the amount of water which will flow through a unit cross-sectional area of aquifer under a unit gradient of hydraulic head [7]. It is analogous to the thermal conductivity of materials in heat conduction. The hydraulic conductivity (K) is specific to the flow of a certain fluid (typically water, sometimes air or oil); intrinsic permeability k is a parameter of a porous medium which is independent of fluid. Where

$$\mathbf{K=k\,\gamma/\,\mu}$$

K is the hydraulic conductivity [LT^{-1} or ms^{-1}];
k is the intrinsic permeability of the material [L^2 or m^2];
γ is the specific weight of water [$ML^{-2}T^{-2}$ or $N\,m^{-3}$], and;
μ is the dynamic viscosity of water [$ML^{-1}T^{-1}$ or $kg\,m^{-1}s^{-1}$].

II. OBJECTIVE

To modify a setup to calculate permeability of a medium by Darcy's law. Testing of samples and determine the relation between the flow rate, head difference, and length of flow path.

THEORY OF DARCY'S LAW

Derivation: A one- dimensional flow column is shown in figure:

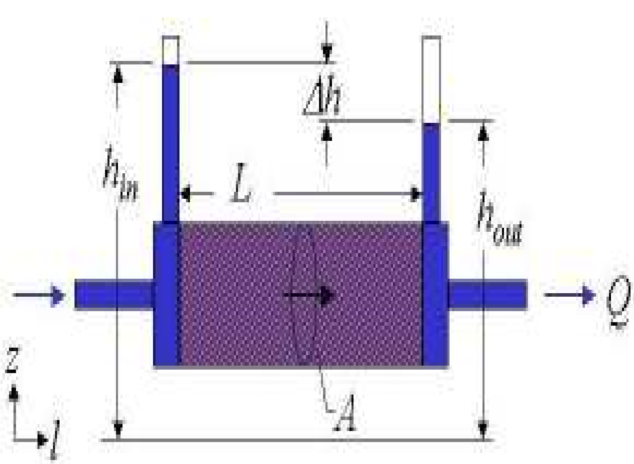

Fig.3: Simple column

$$\mathbf{Q = AK\,(\Delta h/L)\ldots\ldots\ldots\ldots\ (1)}$$

Q=volumetric flow rate (m^3/s),
A=flow area perpendicular to L (m^2)
K=hydraulic conductivity (m/s),
L=flow path length (m),
Δh =hydraulic head (m), and
Δ=denotes the change in h over the path L.

The hydraulic head at a specific point is the sum of pressure head and the elevation [8], or

$$\mathbf{h= (p/rg+z)\ldots\ldots\ldots\ldots\ (2a)}$$

$$\mathbf{h= (p/g+z)\ldots\ldots\ldots\ldots\ (2b)}$$

Where,
p=water pressure (N/m^2)
r=water density (kg/m^3)
ρ=water specific weight (N/m^3)
g=acceleration of gravity (m/s^2)
z=elevation (m)

The hydraulic head at a specific point. H is the sum of the pressure head and the elevation, or

$$\mathbf{h = (p/r\,g + z)\ldots\ldots\ldots\ldots\ (2)}$$

Where,
P = water pressure
r = water density
g = acceleration of gravity
z = elevation

Equation (2) is the normal SI form of the equation. The hydraulic head is the height that water would raise in a peizometer. Thus; Δh is simply the difference in height of water in peizometer placed at the inlet and the outlet.
Substituting (2(a)) into 1

$$\mathbf{q=-K\Delta\ [(p/\rho g) +z]/L\ldots\ldots\ldots\ldots\ (3)}$$

Equation (3) is approximately the form Darcy used to analyse his experimental data.
Note that the flow is not a function of the absolute pressure or the allegation. It is only a function of the change in hydraulic head.

Differential Form
A more general form of equation results when the limit of Dh with respect to the flow direction L, as the flow path L goes to zero.
Applying that step to equations (1) and (3) yields,

$$\mathbf{Q=-AK\ dh/dl= -AKd\{(p/\rho g) +z\}/dl\ldots\ldots\ldots\ldots\ (4)}$$

The minus sign on the right hand terms reflects that the hydraulic head always decreases in the direction of flow.

Flow Variables
(i) Darcy Flux
The Darcy's flux is defined as,

$$\mathbf{q= Q/A\ldots\ldots\ldots\ldots\ (5)}$$

Where q =Darcy flux (m/s)

The Darcy's flux is the volumetric flow per unit area. Substitution of equation (5) into (4) yields,

$$q= -K\, dh/dl= -Kd\,\{(p/\rho g) +z\}/dl \quad\ldots\ldots\ldots\ldots (6)$$

(ii) Seepage Velocity
While the Darcy's flux has the unit of velocity, it is not the velocity of the water in the pores. The solid matrix takes up some of the flow area. The average pore water velocity is termed as the seepage velocity, and is given by

$$v =Q/Af = q/f \quad\ldots\ldots\ldots\ldots (7)$$

Where f is the porosity of the porous media. The maximum pore velocity is the function of the pore geometry and cannot be easily predicted except of simple shaped. In circular tubes the maximum velocity is twice of seepage velocity (v) [9].

Application and Scope
Subsurface Pavement Drainage System Installation
Excessive and uncontrolled subsurface water has been responsible for large numbers of pavement failures, slope failures, and unsatisfactory projects. Groundwater can have a considerable impact on the success of a highway construction project. If groundwater and seepage are not identified and adequately addressed it can significantly impair the following:

- Constructability;
- Pavement performance; and
- Slope stability.

Surface water infiltrating through porous or cracked pavements and unsealed joints, capillary water rising from the underlying water table, accumulated water vapour from temperature fluctuations and other atmospheric conditions and high groundwater table[10].

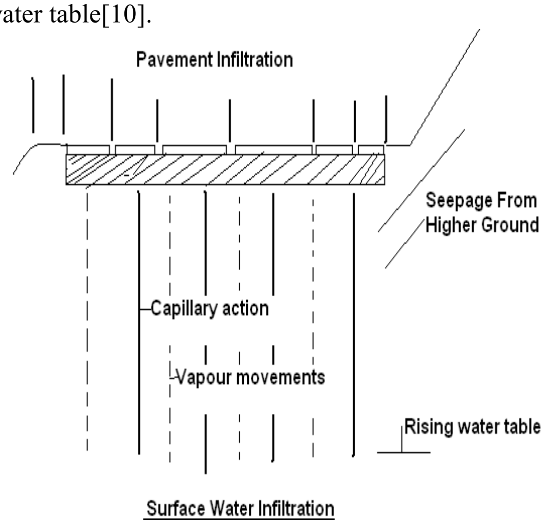

Fig.5

Pavement Subsurface Drainage System Installation

A drainable pavement contains the following integral components: the asphalt or concrete surface pavement, a permeable base, a separator/filter layer, the sub grade, and edge drains. To construct a subsurface pavement drainage system we need to determine permeability of a soil and its properties such as seepage velocity and flow rate by using Darcy's setup [11].

- Petroleum geology: In extraction and filtration of crude oil by passing the oil through the layers with different permeability.
- Wastage dumping: To prevent soil pollution release from the wastage.
- Water harvesting: To prevent loss of water a comparatively less permeable base layer is used.

Terminology
Hydraulic Conductivity: Hydraulic Conductivity is a property of vascular plants, soil or rock that describes the ease with which water can move through a pore spaces or features. It is the proportionality constant in Darcy's Law, which relates the amount of water which will flow through a unit cross-section area of aquifer under a unit gradient of hydraulic head.

Permeability: Permeability is a measure of the ability of material (typically, a rock or unconsolidated material) to transmit fluids.

Porosity: Porosity is a measure of the void spaces in a material, and is measured as a fraction, between 0-1, and percentage between 0-100 percent.
Seepage velocity: While the Darcy flux has the unit of velocity, it is not the velocity of water in the pores. The solid matrix takes up some of the flow area. The average pore water velocity is termed as the seepage velocity, and is given by

$$v =Q/Af = q/f$$

Where f is the porosity of the porous media. The maximum pore velocity is the function of the pore geometry and cannot be easily predicted except of simple shaped. In circular tubes the maximum velocity is twice of seepage velocity.
Darcy flux: The Darcy flux is the volumetric flow per unit area. The Darcy flux is defined as

$$q=Q/A$$

Where,
q=Darcy flux (m/s or ft/s)
Q=volumetric flow rate (m^3/s or ft^3/s),
A=Flow area perpendicular to L.

III. MODIFICATION IN DESIGN OF APPARATUS

Material Required

- Circular cross-section tube of plastic
- Sand filter
- Metal box with one open face
- Clamp
- Gate valve, T-joint
- Stop watch
- Hollow iron rod

- Flexible pipe
- Hard adhesive
- Measuring Flask
- Rolling wheel

Description of parts

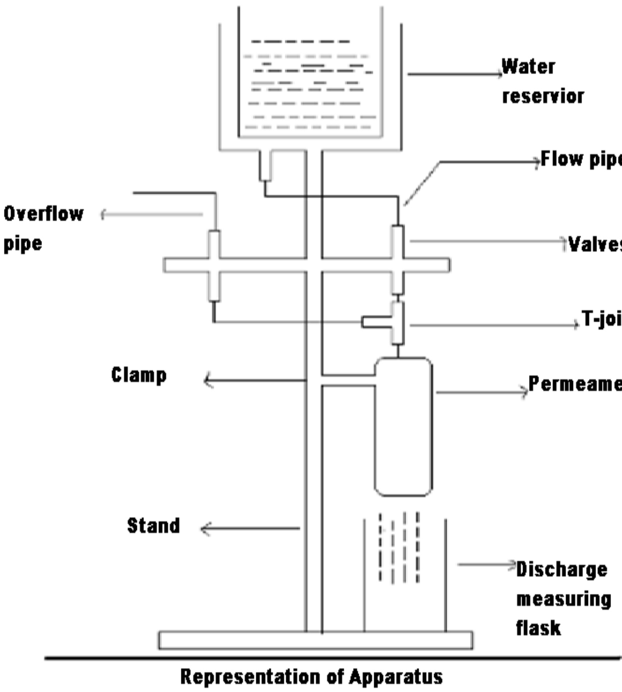

Fig.6

Permeameter: Circular cross-section tube of plastic of 10.2 cm diameter and 1-2 mm thickness to hold sand sample. Plastic material is selected to prevent rusting and corrosion.

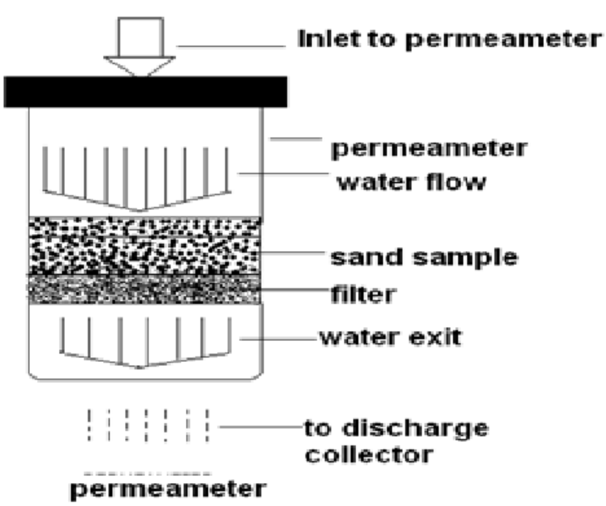

Fig.7

Sand filter: It consists of two layers of thin plastic strainers or cloth strainer sandwiched between perforated metal plates. This is one of major parts of apparatus and should be able to prevent the flow out of sand particle in sample with proper passage of water. Its mesh size is 60µm.

Water Reservoir: Metal box of width 47.5 cm, length 47.5 cm and height 17 cm. It has one open face to fill water into it.

Clamp: Welded with stand to hold permeameter in vertical position.

Gate Valve: To regulate water flow through pipes.

Stop Watch: To record time for discharge.

Hollow Iron Rod: To make stand to hold above mentioned parts.

Flexible Pipe: To make connections.

Hard Adhesive: To stop leakage at pipe joints.

T joint: To connect air flow pipe and water flow pipes.

Measuring flask: To collect the definite discharge through permeameter.

Difficulties Faced While Fabrication of Apparatus

Difficulty 1: Leakage of pipe joints at reservoir, gate valve, T-joint.
Remedy: Putting hard adhesive at pipe joints.

Difficulty 2: Flow out of fine sand particles through filter.
Remedy: Make filter multilayered and use filter materials with very fine pores.

LIMITATIONS

Medium in Darcy's tube should not solidify as it can result in blockage of flow path.

Medium should not chemically react with water.

No bubble formation in Darcy's tube and flow pipe.

Properly compress the medium to avoid loose packing of medium particles and reduce the inter particle space.

Water flow through the medium should be laminar.

Water should flow through whole cross-section of medium.

Apparatus can be used only for one dimensional vertical flow.

IV. WORK DONE

Experiments

By using Darcy's Law we are going to perform experiments on samples of different permeability by using either the constant head method or falling head method depending on the type of sample being tested.

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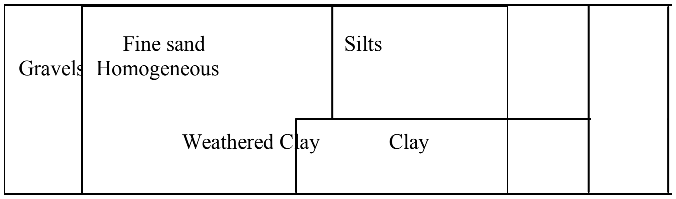


Typical permeability ranges [13]

Soils exhibit a very wide range of permeability and while particle size may vary by about 3-4 orders of magnitude, permeability may vary by about 10 orders of magnitude.

10^{-1} 10^{-2} 10^{-3} 10^{-4} 10^{-5} 10^{-6} 10^{-7} 10^{-8} 10^{-9} 10^{-10} 10^{-11}

Falling Head Test

The falling head test is different in that it does not fix the total head difference across the specimen. Instead, a stand pipe is connected to the inflow, and the water is then allowed to flow through the soil without maintaining a constant pressure head [12]. This will also well for coarse-grained soils, because they are so permeable that the head drops too rapidly to be accurately measured.

Samples

We will test two samples of varying permeability. The samples are:

SAMPLE 1: Sandy Gravel (From River Betwa, Hamirpur (U.P)

Permeability range of sample: 10^{-1}-10^{-3}

Porosity range: 23% to 35%

SAMPLE 2: Fine Sand (From River Yamuna, Agra)

Permeability range of sample: 10^{-3}-10^{-5}

Porosity range: 44% to 50%

Experiment Number 1

Objective: To test following sample to determine hydraulic conductivity, Darcy's velocity and seepage velocity by falling head test.

Sample 1: Sandy Gravel

Apparatus: Darcy's setup, sand sample, timer clock

Theory

Darcy's Law: Darcy's Law is a generalized relationship for flow of porous media. It shows that the volumetric flow rate is a function of a flow area, elevation, fluid pressure and proportionality constant.

K = (Q/t) (L/Ah)

K = hydraulic conductivity or coefficient of permeability (cm/sec)

Q = volume (ml) of water flowing through the sand in time t

t = time period (sec) for the volume Q to flow

h = change of head in water surfaces (cm)

A = horizontal cross-section area (cm^2) of sand sample

L = length (cm) of a sand sample

Darcy's Flux: The Darcy's flux is the volumetric flow per unit area

$$q = Q/A$$

Where q = Darcy's flux

Seepage velocity: While the Darcy flux has the unit of velocity, it is not the velocity of the water in the pores. The solid matrix takes up the some of the flow area. The average pore water velocity is termed the seepage velocity, v, and is given by

$$V = Q/A\ f = q/f$$

Where f is the porosity of the pores media. The maximum pore velocity is a function of the pore geometry and cannot be easily predicted except for simple shaped.

PROCEDURE [14]

- Close all gate valves and fill the water in reservoir.
- Insert filter in permeameter.
- Fill permeameter with 6 cm height of sample.
- Close permeameter opening and connect inlet pipe to permeameter.
- Place discharge collecting plastic containers below permeameter.
- Open permeameter inlet gate valve and allow water to flow and collect in the discharge tube.
- Allow water to flow for sometime so that sand adjust in the permeameter and steady state condition is obtained.
- Start timer and measure the time taken for 100 ml and 200 ml discharge of water.
- Repeat above step for two more readings (for same volume of discharge) and take average of three values as final time for calculations.
- Repeat above steps for sample length of 8 cm height of sand sample.
- Record results in observation table.

Discharge (Q) cc	Pressure Head (H) cm	Time Taken for Discharge Q (t_1) sec	Time Taken for Discharge Q (t_2) sec	Time Taken for Discharge Q (t_3) sec	Average Time Taken for Discharge Q (t_{avg}) sec
100	101.5	26	28	33	29
200	101.5	41	47	49	45.67

OBSERVATION TABLES:

Sample: sandy Gravel

Length of sample (L) =6 cm

Diameter (D) =10.2 cm

Area of cross-section (A) =81.713 cm^2

Porosity for sample (f) =35%

Table1: observations for sandy gravel (L=6 cm)

Calculations

For discharge (Q) =100 ml

Coefficient of permeability $K_1 = (Q\times L)/(A\times H\times t_{avg})$

$K_1 = (100\times6)/(81.713\times101.5\times29)$

$K_1 = 0.249\text{x}10^{-2}$ cm/sec, i.e.

$K_1 = 0.00249$ cm/sec

Darcy velocity, V_1=Q/ (A× t_{avg})
V_1 = 100/ (81.713×29)
V_1 = 0.0421 cm/s

Seepage velocity, Vs_1 = Q/ (A×f× t_{avg})
Vs_1 = 100/ (81.713×0.35×29)
Vs_1 = 0.120 cm/s

Discharge (Q) cc	Pressure Head (H) cm	Time Taken for Discharge Q (t_1) sec	Time Taken for Discharge Q (t_2) sec	Time Taken for Discharge Q (t_3) sec	Average Time Taken for Discharge Q (t_{avg}) sec
100	101.5	26	29	30	28.33
200	101.5	41	44	46	43.67

For discharge (Q) =200 ml

Coefficient of permeability K_2 = (Q×L)/ (A×H× t_{avg})

Sample: sandy Gravel

Length of sample (L) =8 cm
Diameter (D) =10.2 cm
Area of cross-section (A) =81.713 cm²
Porosity for sample (f) =35%

Table 2: observations for sandy gravel (L=8 cm)

K_2 = (200×6)/ (81.713×101.5×45.67)
K_2 = 0.316×10^{-2} cm/s
K_2 = 0.00316 cm/s

Darcy velocity V_2 = Q/ (A× t_{avg})
V_2 = 200/ (81.713×45.67)
V_2 = 0.053 cm/s

Seepage velocity, Vs_2= Q/ (A×f× t_{avg})
Vs_2= 200/ (81.713×0.35×45.67)
Vs_2 = 0.153 cm/s

Calculations

For discharge (Q) =100 ml

Coefficient of permeability K_1 = (Q×L)/ (A×H×t_{avg})

K_1 = (100×8)/ (81.713×101.5×28.33)

K_1= 0.340×10^{-2} cm/sec, i.e.
K_1= 0.00340 cm/sec

Darcy velocity, V_1=Q/ (A× t_{avg})
V_1 = 100/ (81.713×28.33)
V_1 = 0.0432 cm/s

Seepage velocity, Vs_1 = Q/ (A×f× t_{avg})
Vs_1 = 100/ (81.713×0.35×28.33)
Vs_1 = 0.123 cm/s

For discharge (Q) =200 ml

Coefficient of permeability K_2 = (Q×L)/ (A×H× t_{avg})

K_2 = (200×8)/ (81.713×101.5×43.67)
K_2 = 0.442×10^{-2} cm/s
K_2 = 0.00442 cm/s

Darcy velocity, V_2 = Q/ (A× t_{avg})
V_2 = 200/ (81.713×43.67)
V_2 = 0.0562 cm/s

Seepage velocity, Vs_2 = Q/ (A×f× t_{avg})
Vs_2= 200/ (81.713×0.35×43.67)
Vs_2 = 0.160 cm/s

Precautions

Precaution to be considered before and while conducting of experiment is:

- Reservoir should have sufficient water.
- Steady state should be obtained before taking readings.
- Ensure removal of air bubbles from the flow pipe.
- Flow amount should be properly measured and the time taken accurately noted.
- Excess water should not fill up in the permeameter.
- Type of sample should be considered to determine type of test to be conducted.
- Before starting to take the reading, it should be insured that the soil sample and the filter are properly filled.
- Flow of water through sample should be made as laminar as possible.
- The sand should be filled freely in the permeameter without pressing.

Experiment Number 2

Objective: To test following sample to determine hydraulic conductivity, Darcy's velocity and seepage velocity falling head test.

Sample 1: fine sand

Apparatus: Darcy's setup, sand sample, timer clock
Theory

Darcy's Law: Darcy's Law is a generalized relationship for flow of porous media. It shows that the volumetric flow rate is a function of a flow area, elevation, fluid pressure and proportionality constant.

$$K = (Q/t)\ (L/Ah)$$

K = hydraulic conductivity or coefficient of permeability (cm/sec)
Q = volume (ml) of water flowing through a sand in time t
t = time period (sec) for the volume Q to flow
h = change of head in water surfaces (cm)
A = horizontal cross-section area (cm^2) of sand sample
L = length (cm) of a sand sample
Darcy's Flux: The Darcy's flux is the volumetric flow per unit area

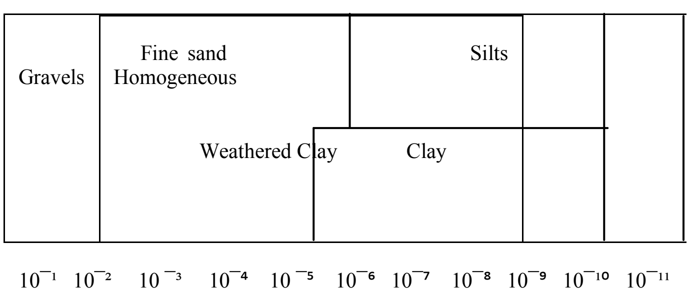
$$q = Q/A$$

Where q = Darcy's flux
Seepage Velocity: While the Darcy flux has the unit of velocity, it is not the velocity of the water in the pores. The solid matrix takes up the some of the flow area. The average pore water velocity is termed the seepage velocity, v, and is given by

$$V = Q/A\ f = q/f$$

Where f is the porosity of the pores media. The maximum pore velocity is a function of the pore geometry and cannot be easily predicted except for simple shaped.

Typical permeability ranges
Soils exhibit a very wide range of permeability and while particle size may vary by about 3-4 orders of magnitude, permeability may vary by about 10 orders of magnitude.



PROCEDURE

- Close all gate valves and fill the water in reservoir.
- Insert filter in permeameter.
- Fill permeameter with 6 cm height of sample.
- Close permeameter opening and connect inlet pipe to permeameter.
- Place discharge collecting plastic containers below permeameter.
- Open permeameter inlet gate valve and allow water to flow and collect in the discharge tube.
- Allow water to flow for sometime so that sand adjusts in the permeameter and steady state condition is obtained.
- Start timer and measure the time taken for 100 ml and 200 ml discharge of water.
- Repeat above step for two more readings (for same volume of discharge) and take average of three values as final time for calculations.
- Repeat above steps for sample length of 8 cm height of sand sample.
- Record results in observation table.

OBSERVATION TABLES:
Sample: fine sand
Length of sample (L) =6 cm
Diameter (D) =10.2 cm
Area of cross-section (A) =81.713 cm^2
Porosity for sample (f) =44%

Discharge (Q) cc	Pressure Head (H) cm	Time Taken for Discharge Q (t_1) sec	Time Taken for Discharge Q (t_2) sec	Time Taken for Discharge Q (t_3) sec	Average Time Taken for Discharge Q (t_{avg}) sec
100	101.5	108	113	115	112
200	101.5	170	192	208	190

Table3: observations for fine sand (L=6 cm)

CALCULATIONS:

For discharge (Q) =100 ml

Coefficient of permeability $K_1 = (Q\times L)/\ (A\times H\times t_{avg})$

$K_1 = (100\times 6)/\ (81.713\times 101.5\times 112)$
$K_1 = 0.646\times 10^{-3}$ cm/sec, i.e.
$K_1 = 0.000646$ cm/sec

Darcy velocity, $V_1 = Q/\ (A\times t_{avg})$
$V_1 = 100/\ (81.713\times 112)$
$V_1 = 0.011$ cm/s

Seepage velocity, $Vs_1 = Q/\ (A\times f\times t_{avg})$
$Vs_1 = 100/\ (81.713\times 0.44\times 112)$
$Vs_1 = 0.0248$ cm/s

For discharge (Q) =200 ml

Coefficient of permeability, $K_2 = (Q\times L)/\ (A\times H\times t_{avg})$
$K_2 = (200\times 6)/\ (81.713\times 101.5\times 190)$
$K_2 = 0.761\times 10^{-3}$ cm/s
$K_2 = 0.000761$ cm/s

Darcy velocity, $V_2 = Q/\ (A\times t_{avg})$
$V_2 = 200/\ (81.713\times 190)$
$V_2 = 0.0128$ cm/s

Seepage velocity, $Vs_2 = Q/\ (A\times f\times t_{avg})$
$Vs_2 = 200/\ (81.713\times 0.44\times 190)$

Vs_2 = 0.029 cm/s

Sample: fine sand
Length of sample (L) =8 cm
Diameter (D) =10.2 cm
Area of cross-section (A) =81.713 cm^2
Porosity for sample (f) =44%

Discharge (Q) cc	Pressure Head (H) cm	Time Taken for Discharge Q (t_1) sec	Time Taken for Discharge Q (t_2) sec	Time Taken for Discharge Q (t_3) sec	Average Time Taken for Discharge Q (t_{avg}) sec
100	101.5	156	160	163	159.67
200	101.5	253	280	302	278.33

Table 4: observations for fine sand (L=8 cm)

CALCULATIONS:

For discharge (Q) =100 ml

Coefficient of permeability, $K_1 = (Q\times L)/ (A\times H\times t_{avg})$
$K_1 = (100\times 8)/ (81.713\times 101.5\times 159.67)$
$K_1 = 0.604\times 10^{-3}$ cm/sec, i.e.
K_1= 0.000604 cm/sec

Darcy velocity, $V_1=Q/ (A\times t_{avg})$
$V_1 = 100/ (81.713\times 159.67)$
V_1 = 0.0076 cm/s

Seepage velocity, $Vs_1 = Q/ (A\times f\times t_{avg})$
$Vs_1 = 100/ (81.713\times 0.44\times 159.67)$
Vs_1 = 0.0174 cm/s

For discharge (Q) =200 ml

Coefficient of permeability, $K_2 = (Q\times L)/ (A\times H\times t_{avg})$
$K_2 = (200\times 8)/ (81.713\times 101.5\times 278.33)$
$K_2 = 0.693\times 10^{-3}$ cm/s
K_2 = 0.000693 cm/s

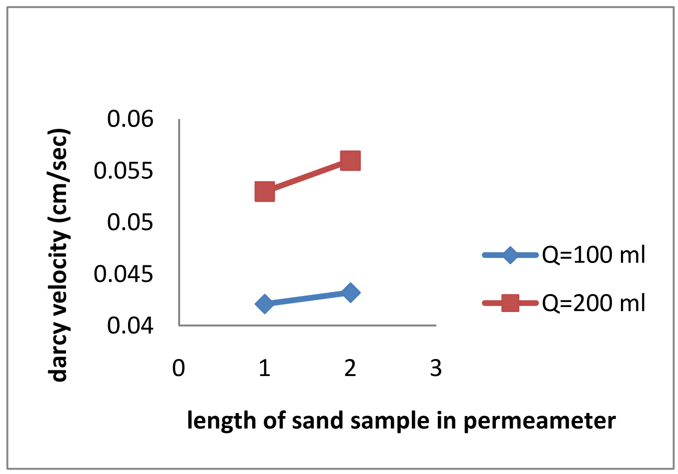
Darcy velocity, $V_2 = Q/ (A\times t_{avg})$
$V_2 = 200/ (81.713\times 278.33)$
V_2 = 0.00879 cm/s

Seepage velocity, $Vs_2 = Q/ (A\times f\times t_{avg})$
$Vs_2= 200/ (81.713\times 0.44\times 278.33)$
Vs_2 = 0.0199 cm/s

PRECAUTIONS

Precaution to be considered before and while conducting of experiment is:

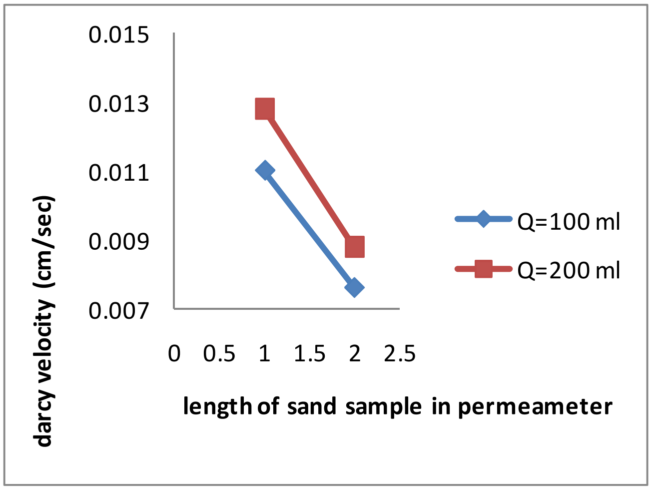
- Reservoir should have sufficient water.
- Steady state should be obtained before taking readings.
- Ensure removal of air bubbles from the flow pipe.
- Flow amount should be properly measured and the time taken accurately noted.
- Excess water should not fill up in the permeameter.
- Type of sample should be considered to determine type of test to be conducted.
- Before starting to take the reading, it should be insured that the soil sample and the filter are properly filled.
- Flow of water through sample should be made as laminar as possible.
- The sand should be filled freely in the permeameter without pressing.



Scale on x axis, point 1=6 cm & point 2=8cm

Graph 1: length of sand sample of sandy gravel in permeameter versus Darcy velocity

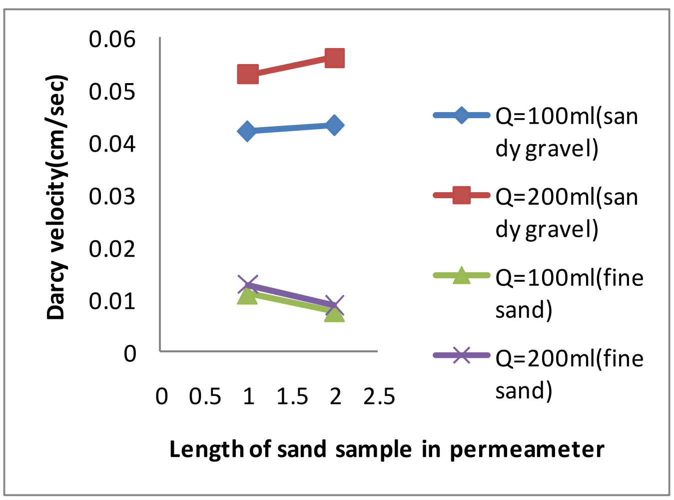
Sample: sandy gravel
Series 1= discharge is 100ml
Series 2= discharge is 200 ml



Scale on x axis, point 1= 6 cm & point 2= 8 cm

Graph 2: length of sand sample of fine sand in permeameter versus Darcy velocity

Sample: fine sand
Series 1= discharge is 100ml
Series 2= discharge is 200 ml



Scale on x axis, point 1 = 6 cm & point 2 = 8 cm

Graph 3: length of sand sample of fine sand and sandy gravel in permeameter versus Darcy velocity

Where,
Series 1= discharge is 100ml (sandy gravel)
Series 2= discharge is 200ml (sandy gravel)
Series 3= discharge is 100ml (fine sand)
Series 4= discharge is 200ml (fine sand)

V. RESULTS AND DISCUSSION

Results Table

Sandy Gravel

L = 6 cm, D =10.2 cm, A=81.713 cm ², H =101.5 cm

Discharge (Q) cc	Average Time Taken for Discharge Q (t_{avg}) sec	Hydraulic Conductivity (K) cm/s	Darcy Velocity (V) cm/s	Seepage Velocity (Vs) cm/s	L/H
100	29	0.00249	0.0421	0.120	0.0591
200	45.67	0.00316	0.053	0.153	0.0591

Table 5: results for sandy gravel (L=6 cm)

Sandy Gravel
L =8 cm, D =10.2 cm, A=81.713 cm ², H =101.5 cm

Discharge (Q) cc	Average Time Taken for Discharge Q (t_{avg}) sec	Hydraulic Conductivity (K) cm/s	Darcy Velocity (V) cm/s	Seepage Velocity (Vs) cm/s	L/H
100	28.33	0.00340	0.0432	0.123	0.0788
200	43.67	0.00442	0.0562	0.160	0.0788

Table 6: results for sandy gravel (L=8 cm)

Fine Sand
L = 6 cm, D =10.2 cm, A=81.713 cm², H =101.5 cm

Discharge (Q) cc	Average Time Taken for Discharge Q (t_{avg}) sec	Hydraulic Conductivity (K) cm/s	Darcy Velocity (V) cm/s	Seepage Velocity (Vs) cm/s	L/H
100	112	0.000646	0.011	0.0248	0.0591
200	190	0.000661	0.0128	0.0290	0.0591

Table 7: results for fine sand (L=6 cm)

Fine sand
L = 8 cm, D =10.2 cm, A=81.713 cm ², H =101.5 cm

Discharge (Q) cc	Average Time Taken for Discharge Q (t_{avg}) sec	Hydraulic Conductivity (K) cm/s	Darcy Velocity (V) cm/s	Seepage Velocity (Vs) cm/s	L/H
100	159.67	0.000604	0.0076	0.0174	0.0788
200	278.33	0.000693	0.00879	0.0199	0.0788

Table 8: results for fine sand (L=8 cm)

Discussion of Graph

From graph between length of sand sample of sandy gravel in permeameter and Darcy velocity it is shown that:
With increases in the sample length (L), the value of Darcy velocity increases because as the length of sample increases, the average time decreases, and according to formula {V=Q/ (A× t_{avg})} Darcy velocity is inversely proportional to t_{avg}..
For sandy gravels (same length), on increasing discharge collected, the value of Darcy velocity increases because Darcy velocity V is directly proportional to discharge Q.
Slight variation in the value of hydraulic conductivity or coefficient of permeability is seen due to exit of water, air bubbles in flow pipe, improper packing etc.

From graph between length of sand sample of fine sand in permeameter and Darcy velocity it is shown that:
With increases the sample length (L), the value of Darcy velocity decreases because as the length of sample increases, the average time increases and according to formula {V=Q/ (A× t_{avg})} Darcy velocity is inversely proportional to t_{avg}.
For fine sand (same length), on increasing discharge collected, the value of Darcy velocity increases because Darcy velocity V is directly proportional to discharge Q.
Slight variation in the value of hydraulic conductivity or coefficient of permeability is seen due to exit of water, air bubbles in flow pipe, improper packing etc.

When we combine both graph (graph between length of sand sample of sandy gravel in permeameter and Darcy velocity & graph between length of sand sample of fine sand in permeameter and Darcy) it is shown that Darcy velocity of fine sand is less then sandy gravel sample because according to formula (V=Q/ (A× t_{avg})) . We calculate that the average time in case of fine sand is more than the average time in case of sandy gravel for a same discharge due to grain size of fine sand is greater than the grain size of sandy gravel [15].

V. CONCLUSION

There are so many permeability testers to measure the permeability now a day but this apparatus is simplification of Darcy's apparatus and is too simple to operate. By this apparatus it is easy to check the permeability of porous medium with good accuracy. This method also uses to calculate the Darcy velocity and seepage velocity.

This apparatus not only uses to calculate the permeability of sand but also uses to calculate the permeability of soil (except coarse grained soils) and clays. In casting industries there is a need of value of permeability of sand which is used in making mould sand for moulding purpose and permeability of sand is also needed in petroleum geology, wastage dumping, water harvesting for different working.
In our project we have measure the permeability of fine sand and sandy gravels by using falling head method at different length and different discharge. We calculate the

- Hydraulic conductivity or coefficient of permeability.
- Darcy velocity
- Seepage velocity or actual pore velocity
- L/H ratio which is constant for fine sand and sandy gravel

We also conclude that at different length of the sample in permeameter there is variation in Darcy velocity. By varying the length of sample (fine sand), Darcy velocity decreases while varying the length of sample (sandy gravel), Darcy velocity increases (shown in result and discussion). Slight variation in the value of hydraulic conductivity or coefficient of permeability is seen due to exit of water, air bubbles in flow pipe, improper packing etc. Darcy velocity of fine sand is less then sandy gravel sample (shown in result and discussion).Our results also evaluated with in a typical range of permeability (shown in experiments) so, this apparatus gives satisfactory results at different length of sample used and different discharge for sandy gravel and fine sand respectively.

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