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**CE 363 / 364 – SOIL MECHANICS**

***Laboratory Session 7 –– Constant Head Permeability Test***

# Purpose of the test

The main purpose of the constant head permeability test is to investigate the hydraulic conductivity of a coarse grained soil sample. Furthermore, boiling which is also named quick condition is observed in this laboratory session; even though, it is not a part of the standard test.

# Equipment

* A rubber ring – sealed cylinder of soil with inlets/outlets at the top, bottom, and optionally two more at different levels along the length. (using a modified 4” Proctor mold is a common practice)
* porous stones and filter papers of the same diameter.
* constant head reservoir
* 2 piezometer tubes with a height scale.
* flexible tubing, valves, etc.
* beakers (a graduated cylinder also helps)
* chronometer
* thermometer
* a large water container or sink (so that the lab floor doesn’t get too wet)

# General Rules

* This test has rubber ring seals. The solid surfaces contacting rubber ring seals must be clean, flat; free of particles, hair, dents, scratches. The rubber rings must be flexible and without cracks. Rings must be greased before placement.
* Taking the volume measurements by weighing water is a more precise measurement than reading the marks of a graduated cylinder, but the graduated cylinder is ok for this session.
* This test assumes steady-state. Flow measurements taken after steady-state is reached are the only values that can be used in the calculations correctly. Steady-state is verified by successive flow volume measurements for equal time increments – two, preferably three of them should be equal at steady state. For finer soils, reaching the steady state takes longer.
* When you assemble the setup, it is better to do it such that flow is upwards inside the mold. Therefore, “inlet” is through the lower plate, “outlet” is through the upper plate.

# Calibration

-The dimensions of the mold are measured and the temperature of water is measured.

-If the setup did not have any side outlets for piezometers, additional calibration steps would have been made. Because our setup has piezometric tubes in this lab, calibration is not needed at this time.

# Specimen Preparation

Because of the time limitations, the following processes copied from the word document of the experiment are done by assistant before the laboratory session.

* Place the soil homogeneously into the mold, at the desired density or void ratio.
* Remove excess soil with a straight-edge. Always cut outwards.
* Weigh the entire test container (mold + lower plate) with the specimen. Obtain the weight of the specimen by subtracting weight of the equipment.
* If the material is moist, determine its water content (use the excess soil).
* Place a filter paper, then upper porous stone on the soil.
* Clean the top of the rim of the mold and place a greased rubber ring seal on it.
* Put the upper plate on top, and tighten the nuts and bolts.

In addition to the above points, the connection of the reservoir to the bottom plate with a closed valve is done before the experiment. Moreover, the side outlets to the piezometer tubes are connected, and the top outlet to a pipe that ends in a large container is connected.

* That is, the setup is completed before the laboratory session. It is not seen how to set up because of the time constraints, however, the assistant informs the student in detail about the formation of the set up.

The valve should open, and allow the water to flow for a while. At this point, the total flowing volume of the water should be equal to the volume of the specimen.

# Procedure

* Adjust the head difference by setting the valve from the reservoir. If this cannot be done via a valve, change the elevation of either the setup or the reservoir by carrying them.
* At this step, to make easy process there should be two people. One person record time while the other person can gather the flowing water.
* At a random time or when the flowing water, stop gathering the water for measuring and note this time and the volume of water to the data sheet.
* Wait for a while depends on the permeability of the specimen and after that repeat the third step for two more times to get two more recordings.
* Stop the water flow and disconnect the pipes from the mold.
* Measure the height of the piston rod from the upper plate of the cylinder.

# Boiling demonstration

After finish the test, we have second setup to observe this phenomenon.

- Give the water flow in, fill the all pores, and spill out from the top.

- Situate a metal object tied to a rope on the soil surface.

- Stepwise increase the upwards hydraulic gradient until quick condition/boiling is reached.

- In this condition, the soil expands in volume, and loses all strength (because of that the metal object sinks into the soil)

- Measure the minimum head difference that causes quick condition.

- Calculate the critical hydraulic gradient, icr.

1. **Calculations**

Height of Piston Rod= 8.1 cm

Height of Piston Rod (after valve is closed)= 7.5 cm

Dry mass of sand, volume of the solid particles, and the area of the sample are calculated and written in dark, in the Table-1.

Dry Mass of Sand, MD=M/(1+w) →1250/(1+0.06)= 1179.245 g

Volume of Solid Particles, Vs=MD/Gs →1179.245/2.65= 444.998 ml

Area of Sample, A=π\*D²/4 → π\*7.4²/4= 43.008 cm²

|  |  |
| --- | --- |
| *Mass of Sand, M* | 1250 g |
| *Initial Water Content, w* | 6 % |
| *Dry Mass of Sand MD=M/(1+w)* | **1179.245 g** |
| *Specific Gravity of Sand, Gs* | 2.65 |
| *Volume of Solid Particles Vs=MD/GS* | **444.998 ml** |
| *Internal Diameter of Permeameter* | 7.4 cm |
| *Area of Sample, A* | **43.008 cm2** |
| *Temperature of Water* | 25 °C |
| *Length of Permeameter, L* | 19 cm |
| *Difference Between Two Piezometers, y* | 7 cm |

Table.1- Dark writings are calculated, the others are the data taken in the laboratory session.

The measured flow rates for each head difference are calculated and tabulated in Table-2.Furthermore, the conversion of the flow rates into flux and head difference values to gradients are also tabulated in Table-2.

Volume of sand placed in permeameter,V=L\*A =19\*43.008 = 817.152 cm3

Bulk density ρ=M/V = 1250/817.152 =1.5297 cm3

Dry density ρd = ρ/(1+w) = 1.5297 /(1+0.06) =1.4431 g/cm3

Initial porosity ni= (V-Vs)/V = (817.152 -444.998)/ 817.152 =0.4554

Change in soil level, s= 0.6

Final volume Vf= (L-s)\*A = (19-0.6)\*43.008 =791.3472 cm3

Final porosity nf=(Vf-Vs)/Vf = (791.3472 -444.998)/ 791.3472 = 0.43767

***For t=28.5 sec.:***

At 25° C μ=0.895 (mPa.s) , At 20° C μ20= 1.009 (mPa.s)

Discharge, Q=Vb/t → 66/28.5= 2.315789 ml/t

Flux, q=Q/A → 2.315789/43.008= 0.053846 cm/s

Hydraulic Gradient, i=Δh/(y) → 7.5/7= 1.071429

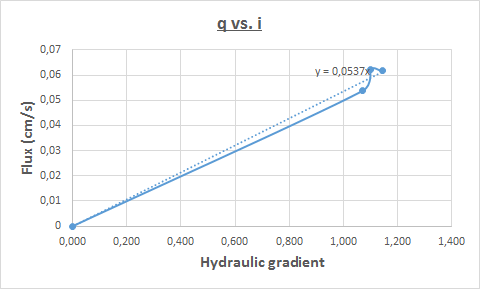
Hydraulic Conductivity, k=q/i → 0.053846/1.071429= 0.050256 cm/s

k20=k\*μ/μ20 → 0.050256\*0.895/1.009= 0.044578 cm/s

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| *Time t (sec)* | *V in Graduated Bowl (Vb) (cm3)* | *Discharge Q=Vb/t (ml/t)* | *Flux q=Q/A (cm/s)* | *Head Difference Δh (cm)* | *Hydraulic Gradient i=Δh/(y)* | *Hydraulic Conductivity k=q/i (cm/s)* | *k20=k\*μ/μ20 (cm/s)* |
|
|
|
| 28.5 | 66 | **2.315789** | **0.053846** | 7.5 | **1.071429** | **0.050256** | **0.044578** |
| 23.1 | 62 | **2.683983** | **0.0624** | 7.7 | **1.1** | **0.056727** | **0.050318** |
| 34.7 | 92 | **2.651296** | **0.061647** | 8.0 | **1.142857** | **0.053941** | **0.047847** |

Table.2- Dark writings are calculated, the others are the data taken in the laboratory session.

q vs i. graph is plotted (see Figure-1) and a best line fixed at the origin (q=ki) which has a slope of k.



**Figure.1-** q vs i. Graph & the best line fixed at the origin (q=ki)

Hydraulic conductivity, k:0.0537 cm/s (From the q vs. i graph)

Hydraulic conductivity at 20 °C, k20=k\*μ/μ20 → k20 :0.0537\*0.895/1.009=0.0476 cm/s Critical hydraulic gradient: 1.0 (in order not to boil)

When FSboiling=icr/i >1, it is safe.

FSboiling >1, it will not be boiling/quick condition.

The corrected value of the hydraulic conductivity (k) is shown in Table-2**.** Viscosity of the water at 20 °C and 25 °C are given in Table-3.

|  |  |  |
| --- | --- | --- |
| **Viscosity (mPa.s)** | | |
| μ | 0.0537 | @ 25 °C |
| μ20 | 0.04763 | @ 20 °C |

Table.3-Viscosity of the water at different temperatures

1. **Discussion of Results**

Our theoretical icr and experimental i cr are different from each other. That can be happened because our experimental values can be wrong. For example; we could not read exact height of soil in permeameter..

We assume the temperature is 20 0 C but it could be different. In addition of that; aim of the experiment is to determine k from A\*k\*I and observe the ‘boiling’. When there are differences between bottom of soil and top of soil, there will be seepage. Water slip among soil particles and because of friction of these particles it could not slip well. When this friction is zero, boiling is occurred. This experiment enable us to determine permeability of soil. However; we should do this experiment very carefully. The values are so significantly so we read properties truly such as height, time.