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ABSTRACT

This SOIL MECHANIC report gives details about soil permeability and capillarity.

1.0 SOIL PERMEABILITY

Soil Permeability
Soil Permeability can be defined as the property of the soil which enables the flow of water through it. There are voids in the soil, which if are interconnected to each other, provides the path for the flow of water through it. It is very important to study the permeability of soil here are a few reasons why.

1.1 IMPORTANCE OF SOIL PERMEABILITY

(1) Almost all civil engineering structures are constructed on soil and if the soil below them is pervious, this may result in the percolation of the water, and may also result in piping action, which will reduce the strength of the soil to handle structural weight.

(2) Soil embankments are likely to fail if the soil used to construct them is of high permeability, because it will reduce the soil shear strength. So it is important to study the permeability of the soil to be used for pavement construction.

(3) The canals are likely to fail if there is any leakage from the embankments, so it is important to study soil used to construct them.

(4) The earth dams use material which has zero permeability to store the water.

(5) The gravity dams fails if there is any piping action taking place through the soil used below.

1.2 FACTORS EFFECTING SOIL PERMEABIITY

Following are factors effecting permeability of soils.

1. Size of soil particle
2. Specific Surface Area of Soil Particle
3. Shape of soil particle
4. Void ratio
5. Soil structure
6. Degree of saturation
7. Water properties

8. Temperature

9. Adsorbed water

10. Organic Matter

1. Size of Soil Particle

Permeability varies according to size of soil particle. If the soil is coarse grained, permeability is more and if it is fine grained, permeability is low. The relation between coefficient of permeability (k) and particle size (D) can be shown from equation (1) as follows.

$$k \; \alpha \; D^2$$

2. Specific Surface Area of Particles

Specific surface area of soil particles also effects the permeability. Higher the specific surface area lower will be the permeability.

$$k \; \alpha \; \frac{1}{Specific\ Surface\ Area}$$

3. Shape of Soil Particle

Rounded Particles will have more permeability than angular shaped. It is due to specific surface area of angular particles is more compared to rounded particles.

4. Void Ratio

In general, Permeability increases with void ratio. But it is not applicable to all types of soils. For example, Clay has high void ratio than any other types of soil but permeability for clays is very low. This is due to, the flow path through voids in case of clays is extremely small such that water cannot permit through this path easily.

The relation between coefficient of permeability and void ratio can be expressed from equation (1) as

For Clay

$$k \propto \frac{C\, e^3}{1+e}$$

Where, C = Shape of the flow path,

e = Void ratio.

For coarse grained soil, "C" can be neglected. Hence

5. Degree of Saturation

Partially saturated soil contain air voids which are formed due to entrapped air or gas released from the percolating fluid or water. This air will block the flow path thereby reduces the permeability. Fully saturated soil is more permeable than partially saturated soil.

1.3 TEST FOR SOIL PERMEABILITY

Test Procedure:

(1) Measure the initial mass of the pan along with the dry soil (**M_1**).

(2) Remove the cap and upper chamber of the permeameter by unscrewing the knurled cap nuts and lifting them off the tie rods. Measure the inside diameter of upper and lower chambers. Calculate the average inside diameter of the permeameter (**D**).

(3) Place one porous stone on the inner support ring in the base of the chamber then place a filter paper on top of the porous stone

(4) Mix the soil with a sufficient quantity of distilled water to prevent the segregation of particle sizes during placement into the permeameter. Enough water should be added so that the mixture may flow freely.

(5) Using a scoop, pour the prepared soil into the lower chamber using a circular motion to fill it to a depth of 1.5 cm. A uniform layer should be formed.

(6) Use the tamping device to compact the layer of soil. Use approximately ten rams of the tamper per layer and provide uniform coverage of the soil surface. Repeat the compaction procedure until the soil is within 2 cm. of the top of the lower chamber section.

(7) Replace the upper chamber section, and don't forget the rubber gasket that goes between the chamber sections. Be careful not to disturb the soil that has already been compacted. Continue the placement operation until the level of the soil is about 2 cm below the rim of the upper chamber. Level the top surface of the soil and place a filter paper and then the upper porous stone on it.

(8) Place the compression spring on the porous stone and replace the chamber cap and its sealing gasket. Secure the cap firmly with the cap nuts.

(9) Measure the sample length at four locations around the circumference of the permeameter and compute the average length. Record it as the sample length.

(10) Keep the pan with remaining soil in the drying oven.

(11) Adjust the level of the funnel to allow the constant water level in it to remain a few inches above the top of the soil.

(12) Connect the flexible tube from the tail of the funnel to the bottom outlet of the permeameter and keep the valves on the top of the permeameter open

(13) Place tubing from the top outlet to the sink to collect any water that may come out.

(14) Open the bottom valve and allow the water to flow into the permeameter.

(15) As soon as the water begins to flow out of the top control (de-airing) valve, close the control valve, letting water flow out of the outlet for some time.

(16) Close the bottom outlet valve and disconnect the tubing at the bottom. Connect the funnel tubing to the top side port.

(17) Open the bottom outlet valve and raise the funnel to a convenient height to get a reasonable steady flow of water.

(18) Allow adequate time for the flow pattern to stabilize.

19) Measure the time it takes to fill a volume of 750 – 1000 ml using the graduated cylinder, and then measure the temperature of the water. Repeat this process three times and compute the average time, average volume, and average temperature. Record the values as **t**, **Q**, and **T**, respectively.

(20) Measure the vertical distance between the funnel head level and the chamber outflow level, and record the distance as **h**.

(21) Repeat step 17 and 18 with different vertical distances.

(22) Remove the pan from the drying oven and measure the final mass of the pan along with the dry soil.

1.4 HYDRAULIC CONDUCTIVITY

Hydraulic conductivity is the ease with which water moves through porous spaces and fractures in soil or rock. It is subject to a hydraulic gradient and affected by saturation level and permeability of the material. Hydraulic conductivity is generally determined either through one of two approaches. An empirical approach correlates hydraulic conductivity to soil properties. A second approach calculates hydraulic conductivity through experimentation

2.0 WHAT IS SOIL CAPILLARY

Capillary action is also known as capillarity can be defined as the ability of a liquid to flow in narrow spaces without the assistance or even the opposition of external forces like gravity. It can also be defined as the elevation or depression of part of a liquid surface coming in contact with a solid. It is the phenomenon by which water rises in a cylindrical column. The narrower the column the higher the capillarity; similarly, the denser the substratum present in the column, the higher the capillary effect. In soil, there are millions of vertical channels – pipes – these are called <capillary tubes>.

2.1EFFECT OF CAPILLARY RISE IN SOIL

Capillary rise in the soil strata may saturate the soil and it has the effect of the effective stress. If the water table is below the soil strata saturated due to the capillary action then the effective stress is increased by an amount equal to the depth of the water table multiplied by the density of the water risen to that soil strata.

So the water pressure becomes negative here so, instead of decreasing the effective stress, this increase the effective stress in the saturated region by an amount equal to the surcharge weight of the water of the same depth.

If 'h' is the capillary rise of water above the water table, then the soil will have its effective stress increased by an amount equal to "h.dw".. where dw is the density of the water.
If the water table reaches the soil strata, the capillary meniscus gets destroyed and so the negative water pressure will disappear.

2.2 SURFACE TENSION IN SOILS

Surface tension is the tendency of liquid surfaces to shrink into the minimum surface area possible. Surface tension allows insects (e.g. water striders), usually denser than water, to float and slide on a water surface.

At liquid–air interfaces, surface tension results from the greater attraction of liquid molecules to each other (due to cohesion) than to the molecules in the air (due to adhesion). The net effect is an inward force at its surface that causes the liquid to behave as if its surface were covered with a stretched elastic membrane. Thus, the surface comes under tension from the imbalanced forces, which is probably where the term "surface tension" came from.[1] Because of the relatively high attraction of water molecules to each other through a web of hydrogen bonds, water has a higher surface tension (72.8 millinewtons per meter at 20 °C) than most other liquids. Surface tension is an important factor in the phenomenon of capillarity. Surface tension has the dimension of force per unit length, or of energy per unit area. The two are equivalent, but when referring to energy per unit of area, it is common to use the term surface energy, which is a more general term in the sense that it applies also to solids. Due to the cohesive forces a molecule is pulled equally in every direction by neighbouring liquid molecules, resulting in a net force of zero. The molecules at the surface do not have the *same* molecules on all sides of them and therefore are pulled inward. This creates some internal pressure and forces liquid surfaces to contract to the minimum area. The forces of attraction acting between the molecules of same type are called cohesive forces while those acting between the molecules of different types are called adhesive forces. The balance between the cohesion of the liquid and its adhesion to the material of the container determines the degree of wetting, the contact angle and the shape of meniscus. When cohesion dominates (specifically, adhesion energy is less than half of cohesion energy) the wetting is low and the meniscus is convex at a vertical wall (as for mercury in a glass container). On the other hand, when adhesion dominates (adhesion energy more than half of cohesion energy) the wetting is high and the similar meniscus is concave (as in water in a glass).

2.3 PROPERTIES WHICH CONTRIBUTES TO CAPILLARITY

Water is good at capillary action, better than most liquids. How well a liquid can perform the feat of capillary action depends on cohesion and adhesion.

Cohesion is the attraction btw particles of the same type. There is strong cohesion in water and ones water molecules is strongly attracted to another.

Adhesion is the attraction btw two different particles. The adhesion btw water molecules and a plastic straw is also pretty strong.

Note: Capillary action occurs when adhesive forces outweigh cohesive forces.

2.4 FACTOR USED TO DETERMINE CAPILLARY RISE

The factor needed for determining capillary rise includes;

1 Diameter of capillary tube, Which represent the diameter of pores in a soil

2 Density of the liquid

3 Viscosity of the liquid.

4 Surface tension