

Soil Mechanics(CVE306) TERM PAPER

ON

SOIL PERMEABILITY AND CAPILLARITY

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**Abstract**

The paper reviews the meaning, purpose,functions and importance of soil capillarity and permeability and how they both are important factors in soil mechanics. The paper shows the relationship between them and ways in which some tests and calculations can be carried out to be able to indicate the level of permeability and capillarity properties of a soil and to know if the soil contains a high or low percentage of the 2 properties.

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**What is Soil Permeability?**

Firstly permeability of soil can be defined as a soil property which permits the flow of water . It can also be defined as the property of a porous material which allows the seepage of water into its interconnecting voids. It is a very important Civil Engineering property. Soils are made up of different layers and each of their qualities may vary from one layer to the next. The amount, distribution, and movement of water in soil have an important role on the properties and behavior of soil. A civil engineer should be able to put into practice the principles of fluid flow because conditions that involve groundwater are frequently experienced or encountered on a construction project. The data which is gotten from a field permeability test are used in the design of various works as a Civil Engineer, some include the design of cut-off walls for earth dams, dewatering and excavation to obtain aquifer constants and to ascertain the pumping capacity for dewatering excavations. The permeability of soils has a decisive effect on the stability of foundations, seepage loss through embankments of reservoirs, drainage of subgrades, excavation of open cuts in water bearing sand, and rate of flow of water into wells. Proper measurement/evaluation of soil permeability is required for calculating the [seepage](https://www.sciencedirect.com/topics/engineering/seepage) under [hydraulic structures](https://www.sciencedirect.com/topics/engineering/hydraulic-structures) and water quantities during dewatering activities. 

Fig 1.1 Permeable soil allowing water to flow into soil

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Fig 1.2 Impermeable soil not allowing water to easily flow into soil

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## **Factors that affect Permeability of Soils**

There are many factors which affect soil permeability and must be thoroughly observed to be able to determine them. With these observations the Civil Engineer will be able to form the basis for the permeability measurements and know if they are likely to be representative. Each of the soils are to be studied separately to determine their permeability. The size of the soil pores is of utmost importance when paying attention to the movement of water into the soil and the movement of water through the soil. The size of the pores and the pore number relate to the soil texture and structure which as stated also influences soil permeability.

**Following are factors affecting permeability of soils.**

1. Void ratio
2. Absorbed water
3. Organic matter
4. Temperature
5. Water properties
6. Soil structures
7. Shape of soil particles
8. Size of soil particles
9. Specific surface area of soil particle
10. Degree of saturation

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### **1. Void Ratio**

From what's known an increase in void ratio also leads to an increase in permeability though this is not applicable to all soil types like clay which has a high void ratio compared to other types of soil but due the small flow paths through voids that does not permit water to pass through easily therefore makes permeability very low.

### **2. Adsorbed Water**

### Adsorbed water is said to be the layer of water which forms around the soil particles especially in cases involving fine grain soil. The absorbed water reduces the size of void space by 10% therefore leading to a reduction in permeability.

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### **3. Organic matter**

### Blockage of voids due to organic matter reduces the permeability of soil.

### **4. Temperature**

Temperature is also known to affect the permeability in soils. From equation ($k α\frac{1}{μ}α temperature$) permeability is shown to be inversely proportional to the viscosity of the liquid and the viscosity varies inversely to temperature therefore it can be said that temperature is directly related to permeability. So it can be said that the greater the temperature the higher the permeability. For this reason seepage happens more in hotter environments than in cooler places.

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### **5. Water Properties**

Different water properties of water such as viscosity and unit weight has effects on permeability. Unit weight may not affect much but when there is an increase in temperature viscosity rapidly decreases. Permeability increases when viscosity decreases.

**6. Soil Structure**

Structure of any two similar soil masses at the same void ratio need not be the same. It varies with respect to the level of compaction that is applied to them.If a soil contains a flocculated structure the particles are in random positions and leads to an increase in permeability. If a soil contains a dispersed structure the particles are in face to face orientation and leads to a reduction in permeability.



**Fig 1.3 flocculated and dispersed soil arrangement**

**7. Shape of Soil Particle**

Particles which are round will have more permeability than particles with angular shapes. The reason for this is the difference in their surface areas. Angular particles have higher surface areas than rounded particles which leads to a reduction in permeability.

**8. Size of Soil Particle**

Permeability varies according to the size of soil particles. 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 ($kαD^{2}^{}$) .

### **9. Specific Surface Area of Particles**

Specific surface area of soil particles also affects the permeability. Higher the specific surface area lower will be the permeability.$k α\frac{1}{Specific surface area}$

**10. Degree of Saturation**

Any partially saturated soil has to contain air voids which form due to air or gas which has been entrapped from fluid or going through the soil. are formed due to entrapped air or gas released from the percolating fluid or water. The air blocks the flow path which leads to a reduction in permeability of the soil. Fully saturated soil is more permeable than partially saturated soil.

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## **Importance of Permeability of Soil**

1. The stability of slopes as well as retaining structures are greatly affected by the permeability of the soil involved.
2. Permeability influences the rate of settlement of a saturated soil under load.
3. The design of earth dams is very much based upon the *permeability of soil* used.
4. Filters made of soils are designed based upon their permeability.
5. Permeability plays a big role in the development of plants.

## **Types of Soil Permeability Test**

Soil permeability measurements help determine the rate of soil settling, which you need to know before constructing buildings or determining how much water will flow toward an excavation. Some permeability tests include:

1. **Constant Head Permeability Test:** The constant head test is a laboratory test done on sandy or granular soil samples. Under constant pressure, a piston forces water through a column of water-saturated soil to determine the flow rate of water. The water in the test is de-aired and kept at a constant temperature. The test apparatus has a water reservoir on top and an outlet reservoir on the bottom. The permeability of the soil sample is calculated from the height of the soil sample, the sample's cross section, pressure measurements, the volume of passed water and the time interval.

## **Falling Head Permeability Test:** The falling head permeability test is for low permeability soils, such as silts and clays. A relatively small soil sample is used, because water flow will be slow. After tamping down the sample and saturating it with water, a standpipe is connected to the container holding the soil. The standpipe is filled with water, and the initial water level is measured. The decline in water level in the standpipe is measured again after the water flows through the sample in a specified time. The permeability of the soil sample is calculated from the size of the soil sample, the cross section of the standpipe, the drop in water level and the time taken.

## **Percolation Test**: For the percolation test, a field test done in the area of interest, a tester digs a series of holes in the ground and fills them with water for a few hours or overnight to saturate the soil. Sandy or gravelly soils take shorter than silt or clay soils to become saturated. After water has saturated the soil surrounding the test holes, the tester adds new water and records the time it takes for the water level in the holes to drop. The permeability, or more accurately the percolation rate, is calculated from the drop in water level in inches or centimeters per specified time.

**What is Soil Capillarity?**

Capillary action 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". Whenever there is a downpour, excess water runs underground through these capillary tubes. When it is dry, these same tubes transport water to the surface. Trees have their roots in these capillary tubes - which also contain threads of fungi which are hygroscopic (attracting water); and with their lateral roots, they soak up capillary water when it is hot and dry. This is how a tree survives heat and drought. Even in rocks, minuscule and invisible fissures function as capillary tubes.

Capillary action is an important ability of water to move through other materials. Water is not the only liquid that can do this, but its properties make it better at capillary action than most other substances.

Examples of capillary action include:

1. If you put a narrow straw into a glass of water, what can you observe about the level of water in the straw as compared to in the glass? You should see that the water has climbed up the straw and is higher than the level of water in the glass. It seems to have defied gravity by moving up the straw. This is capillary action - the movement of a liquid through or along the surface of another material in spite of other forces, such as gravity.
2. When a paper towel is used to mop up a spilled drink or a towel is used to dry yourself after a shower, you are using capillary action.
3. When cut flowers are put into a vase, capillarity water is able to keep them fresh.

#### **What is Surface Tension**

At the interface between water and solids or other fluids (e.g., air), water molecules are exposed to different forces than are molecules within the bulk fluid. For example, water molecules in the bulk liquid are subjected to uniform cohesive forces whereby [hydrogen bonds](https://www.sciencedirect.com/topics/earth-and-planetary-sciences/hydrogen-bonds) are formed with neighboring molecules on all sides. In contrast, molecules at the [air–water interface](https://www.sciencedirect.com/topics/earth-and-planetary-sciences/air-water-interface) experience net attraction into the liquid because of the lower density of water molecules on the air side of the interface, with most hydrogen bonds formed at the liquid side. The result is a membrane-like water surface that has a tendency to contract and reduce the amount of its excess surface energy. The surface tension reflects the amount of [interfacial energy](https://www.sciencedirect.com/topics/earth-and-planetary-sciences/interfacial-energy) per unit area, or the energy required to bring molecules from the bulk liquid to increase the surface (it is also useful to express surface tension as force per unit length of interface).

Note: Different liquids vary in their surface tension σ

##  **Properties which contribute 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 between particles of the same type. There is strong cohesion in water. One water molecule is strongly attracted to another.

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

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

### **Capillary action and permeability relationship**

Capillary action relationships are dimensional functions that range from large negative to large positive values. (Capillary action is often defined as the pressure of the less-dense phase minus the pressure of the more-dense phase.) Relative permeabilities and capillary action are usually viewed as functions of the saturation of phases in the porous sample—so, for oil/water flow in the absence of a gas phase, we have:

* *kro*(*Sw*)
* *krw*(*Sw*)
* *Pc*(*Sw*)

Saturation is the fraction of pore space that is occupied by a phase. In the present example of oil/water flow, *Sw* +*So* =1.

**Conclusion**

In conclusion it can be said that both soil permeability and capillarity are important factors any engineer must use in the course of his profession. The interactions among different geotechnical properties of soils can help the researchers while designing the foundations for different types of civil engineering structures and these two can be said to be very important parts of the operation.

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