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# SOIL PERMEABILITY AND CAPILLARITY

# ABSTRACT

This paper presents a study into Soil Permeability and Capillarity. Soils are permeable materials because of the existence of interconnected voids that allow the flow of fluids when a difference in energy head exists. Good knowledge of soil permeability and capillarity is needed for estimating the quantity of seepage under dams and dewatering to aid underground construction. Soil permeability or Hydraulic conductivity, is measured using several methods that include constant and falling head laboratory tests on intact or reconstituted specimens. Alternatively, permeability can be measured in the field using in situ borehole permeability testing, piezocone penetration tests and field pumping tests. In this paper, the importance of soil permeability, factors affecting soil permeability and tests for soil permeability are discussed. Also, effects of capillary rise in soils and the relationship between soil permeability and capillarity are discussed.

# INTRODUCTION

Soils are permeable materials because of the presence of interconnected voids that allow the flow of fluids from high level locations to low level locations. In soil mechanics and foundation engineering, we must know the amount of water flowing through a soil in unit time. Soil permeability needs to be evaluated properly to accurately calculate the seepage under hydraulic structures and water quantities during dewatering activities. Soil Permeability is affected by many factors. This paper discusses these factors, importance of soil permeability and tests. Also discussed are the effects of capillary rise in soils and the relationship between soil permeability and capillarity.

## SOIL PERMEABILITY

Permeability (commonly symbolized as k) can be defined as the measure of the ability of a porous material (often, a rock or an unconsolidated material) to allow fluids to pass through it. The permeability of a medium is related to the porosity, but also to the shapes of the pores in the medium and their level of connectedness

Soil permeability is the property of the soil to transmit water and air. A permeable soil allows water to flow through it easily because the spaces between the inorganic particles are large and well connected. Soils with sandy textures have large pore spaces that allow rainfall to drain very quickly through the soil. Sandy soils are known to have high permeability, which results in high infiltration rates and good drainage. Clay textured soils have small pore spaces that cause water to drain very slowly through the soil. Clay soils are known to have low permeability, which results in low infiltration rates and bad drainage.

The size of the soil pores is of great importance with regard to the rate of infiltration (movement of water into the soil) and to the rate of percolation (movement of water through the soil). Pore size and the number of pores closely relate to soil texture and structure, and also influence soil permeability.

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### PERMEABILITY VARIATION ACCORDING TO SOIL TEXTURE

Usually, the finer the soil texture, the slower the permeability, as shown below:

|  |  |  |
| --- | --- | --- |
| **SOIL** | **TEXTURE** | **PERMEABILITY** |
| Clay soil | Fine | From very slow to rapid |
| Loamy soil | Moderately fine |
| Moderately coarse |
| Sandy soil | Coarse |

### PERMIABILITY VARIATION ACCORDING TO SOIL STRUCTURE

Structure may greatly modify the permeability as follows:

|  |  |
| --- | --- |
| **STRUCTURE TYPE** | **PERMEABILITY** |
| Platy | -greatly overlapping | From very slow to rapid |
| -slightly overlapping |
|  Blocky |
|  Prismatic |
|  Granular |

##

## IMPORTANCE OF PERMEABILITY

It is very important to study the permeability of soil because:

1. Almost all the civil engineering structures are constructed on the soil and if the soil below them is pervious, it may result in the percolation of the water, and may also result in the piping action, which will reduce the strength of the soil to take the structural weight.
2. Soil embankments are likely to get failed if the soil used to construct them is of high permeability, because it will reduce their shear strength. So it important to study the permeability of the soil to be used for the pavement construction.

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

4) The earth dams use the 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.

6) Filters made of soils are designed based on their permeability.

7) Permeability influences the rate of settlement of a saturated soil under load.

## FACTORS AFFECTING SOIL PERMEABILITY

A number of factors affect the permeability of soils, from particle size, impurities in the water, void ratio, the degree of saturation, and adsorbed water, to entrapped air and organic material.

### PARTICLE SIZE

It was studied by Allen Hazen that the coefficient of permeability (k) of a soil is directly proportional to the square of the particle size (D). Thus permeability of coarse grained soil is very large as compared to that of fine grained soil. The permeability of coarse sand may be more than one million times as much that of clay.

### VOID RATIO (e)

The coefficient of permeability varies with the void ratio as e/sup>/(1+e). For a given soil, the greater the void ratio, the higher the value of the coefficient of permeability. Here 'e' is the void ratio. Based on other concepts it has been established that the permeability of a soil varies as e2 or e2/(1+e). Whatever may be the exact relationship, all soils have e versus log k plot as a straight line.

### IMPURITIES IN WATER

The presence of impurities in soil decreases the permeability of soil.

### DEGREE OF SATURATION

If the soil is not fully saturated, it contains air pockets. The permeability is reduced due to the presence of air which causes a blockage to the passage of water. Consequently, the permeability of a partially saturated soil is considerably smaller than that of fully saturated soil. In fact, Darcy's Law is not strictly applicable to such soils

### ABSORBED WATER

Fine grained soils have a layer of adsorbed water strongly attached to their surface. This adsorbed layer is not free to move under gravity. It causes an obstruction to the flow of water in the pores and hence, it reduces the permeability of soils. According to Casagrande, it may be taken as the void ratio occupied by absorbed water and the permeability may be roughly assumed to be proportional to the square of the net voids ratio of (e - 0.1).

### ENTRAPPED AIR AND ORGANIC MATTER

Air entrapped in the soil and organic matter block the passage of water through soil, hence permeability considerably decreases. In permeability tests, the sample of soil used should be fully saturated to avoid errors.

### TEMPERATURE

As the viscosity of the pore fluid decrease with temperature, permeability increases with temperature, as unit weight of pore fluid does not change much with change in temperature

## TESTS FOR PERMEABILITY

In the laboratory, we can find the coefficient of permeability by two methods:

### CONSTANT HEAD TEST

In the constant head method, the available head for the flow of water through soil is kept constant by the arrangement of the steady inflow of the water in the storage tank.

### FALLING HEAD TEST

In the falling head test, the head of the water is not constant. The initial head and final head are noted with respect to the time taken by it.

## SOIL CAPILLARITY

Capillarity is the action by which waters moves against the downward pull of gravity. Water is able to travel upwards and sideways within rock material. Surface tension created by the forces of cohesion (attraction between water molecules) and adhesion (attraction between water molecules and the rock material) allow small migration within pore spaces between rock particles.

Capillarity is best when sediments are round and small. The smaller the pore space, the better the capillarity. Capillarity is worst when sediments are poorly sorted with angled particles and mixed sizes and shapes present. The angled particles prevent ample pore space between rock fragments so there is no space available through which water can migrate.

Soil capillarity can be defined as the primary force that enables the soil to retain water, as well as to regulate its movement. Capillarity is as a result of surface or interfacial forces. Clay soils have the highest capillarity, followed by loamy soils and then lastly, sandy soils. This is because clay soils have the smallest particles. Therefore, it retains water best. The smaller the spaces, the higher the water rises in the soil. This means that clay soil allows water rise highest compared to sand and loamy soils. Water tends to rise very fast in sand soil but after a while, it slows down.

## CAPILLARY RISE IN DIFFERENT SOILS

Capillary rise is a well-known unsaturated soil phenomenon that describes the movement of pore water from lower elevation to higher elevation driven by the hydraulic head gradient acting across the curved pore air/pore water interface.

The importance of knowing the capillary rise of a material varies depending on the application and the industry. Understanding the capillary rise value for different soils affects various industries such as environmental remediation, construction, and farming.

In the construction industry, capillary rise in important to know the rising moisture in building materials. A building’s foundation may be above the water table but may be within the capillary fringe. Building within the capillary fringe can increase the moisture in a building’s foundation, which can lead to mould problems, weakening of the building’s structure, and weakening of the building’s foundation. Knowing the capillary rise of the materials used within a building is equally as important as knowing the capillary zone around the building. Every material has a unique capillary rise. For example, fluids will rise in wood creating mould and causing the wood to swell and warp. In areas where water use is common, such as kitchens and bathrooms, materials with a low capillary rise should be selected to prevent damage within those rooms.

Also, knowledge of the capillary rise in farming is important. Knowing the capillary rise for different soils is essential for water irrigation management. Capillary rise can also affect the salinity of soil used for farmland. If the water at the water table is brackish, capillary rise may bring the capillary fringe close enough to the surface to evaporate, leaving salt deposits.

## RELATIONSHIP BETWEEN PERMEABILITY AND CAPILLARITY

|  |  |  |  |
| --- | --- | --- | --- |
| **PARTICLE AND SEDIMENT COMPARISON** | **ROUND** | **MIXED** | **ANGULAR** |
| **SMALL** | -GOOD PERMEABILITY-BEST CAPILLARITY | -POOR PERMEABILITY-POOR CAPILLARITY | -POOR PERMEABILITY-POOR CAPILLARITY |
| **MEDIUM** | -GOOD PERMEABILITY-GOOD CAPILLARITY | -POOR PERMEABILITY-POOR CAPILLARITY | -POOR PERMEABILITY-POOR CAPILLARITY |
| **LARGE** | -BEST PERMEABILITY-FAIR CAPILLARITY | -POOR PERMEABILITY-POOR CAPILLARITY | -POOR PERMEABILITY-POOR CAPILLARITY |

# CONCLUSION

In conclusion, I would like to state the importance of the study of Soil Permeability and Capillarity has not been fully stressed in this paper due to the lack of thorough experimental data but I hope the issues discussed above are relevant enough and ignites interest in the topic.