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# ABSTRACT

This will present an outlook on soil capillarity and soil permeability

# CHAPTER 1

# INTRODUCTION

**Soil mechanics is a branch of soil physics and applied mechanics that describes the behavior of soils. It differs from fluid mechanics and solid mechanics in the sense that soils consist of a heterogeneous mixture of fluids (usually air and water) and particles (usually clay, silt, sand, and gravel) but soil may also contain organic solids and other matter. Along with rock mechanics, soil mechanics provides the theoretical basis for analysis in geotechnical engineering, a subdiscipline of civil engineering, and engineering geology, a subdiscipline of geology. Soil mechanics is used to analyze the deformations of and flow of fluids within natural and man-made structures that are supported on or made of soil, or structures that are buried in soils. Example applications are building and bridge foundations, retaining walls, dams, and buried pipeline systems. Principles of soil mechanics are also used in related disciplines such as engineering geology, geophysical engineering, coastal engineering, agricultural engineering, hydrology and soil physics.**

**Permeability** in [fluid mechanics](https://en.wikipedia.org/wiki/Fluid_mechanics) and the [Earth sciences](https://en.wikipedia.org/wiki/Earth_science) (commonly symbolized as *k*) is a measure of the ability of a [porous material](https://en.wikipedia.org/wiki/Porous_media) (often, a [rock](https://en.wikipedia.org/wiki/Rock_(geology)) or an unconsolidated material) to allow fluids to pass through it.

The permeability of a medium is related to the [porosity](https://en.wikipedia.org/wiki/Porosity), but also to the shapes of the pores in the medium and their level of connectedness.

Capillarity is the rate at which water is pulled upward from the water table into pore spaces by capillary action.

In general, particles with larger pore spaces have better permeability and poor capillarity.

# CHAPTER 2

# LITERATURE REVIEW

# PERMEABILITY

Permeability is the property of rocks that is an indication of the ability for fluids (gas or liquid) to flow through rocks. High permeability will allow fluids to move rapidly through rocks. Permeability is affected by the pressure in a rock. The unit of measure is called the darcy, named after Henry Darcy nc Permeabilities are more commonly in the range of tens to hundreds of millidarcies. A rock with 25% porosity and a permeability of 1 md will not yield a significant flow of water. Such “tight” rocks are usually artificially stimulated (fractured or acidized) to create permeability and yield a flow. It is measured in m2 .

# APPLICATION OF PERMEABILITY

1. In determining the flow characteristics of hydrocarbons in oil and gas reservoirs
2. In determining the flow characteristics of groundwater in aquifers

For a rock to be considered as an exploitable hydrocarbon reservoir without stimulation, its permeability must be greater than approximately 100 md (depending on the nature of the hydrocarbon – gas reservoirs with lower permeabilities are still exploitable because of the lower viscosity of gas with respect to oil). Rocks with permeabilities significantly lower than 100 md can form efficient *seals* . Unconsolidated sands may have permeabilities of over 5000 md.

Permeability is part of the proportionality constant in [Darcy's law](https://en.wikipedia.org/wiki/Darcy%27s_law) which relates discharge (flow rate) and fluid physical properties (e.g. [viscosity](https://en.wikipedia.org/wiki/Viscosity)), to a pressure gradient applied to the porous media [[3]](https://en.wikipedia.org/wiki/Permeability_(Earth_sciences)#cite_note-3):

 v = k μ Δ P Δ x {\displaystyle v={\frac {k}{\mu }}{\frac {\Delta P}{\Delta x}}} (for linear flow)

Therefore:

k = v μ Δ x Δ P {\displaystyle k=v{\frac {\mu \Delta x}{\Delta P}}} 

where:

v {\displaystyle v}  is the [superficial fluid flow velocity](https://en.wikipedia.org/wiki/Superficial_velocity) through the medium (i.e., the average velocity calculated as if the fluid were the only [phase](https://en.wikipedia.org/wiki/Phase_(matter)) present in the porous medium) (m/s)

k {\displaystyle k}  is the permeability of a medium (m2)

μ {\displaystyle \mu }  is the dynamic [viscosity](https://en.wikipedia.org/wiki/Viscosity) of the fluid (Pa·s)

Δ P {\displaystyle \Delta P}  is the applied [pressure](https://en.wikipedia.org/wiki/Pressure) difference (Pa)

Δ x {\displaystyle \Delta x}  is the thickness of the bed of the porous medium (m)

In naturally occurring materials, the permeability values range over many orders of magnitude

Permeability is typically determined in the lab by application of Darcy's law under steady state conditions or, more generally, by application of various solutions to the [diffusion equation](https://en.wikipedia.org/wiki/Diffusion_equation) for unsteady flow conditions.[[4]](https://en.wikipedia.org/wiki/Permeability_(Earth_sciences)#cite_note-4)

Permeability needs to be measured, either directly (using Darcy's law), or through [estimation](https://en.wikipedia.org/wiki/Estimation_theory) using empirically derived formulas. However, for some simple models of porous media, permeability can be calculated.

# Permeability model based on conduit flow

Based on the Hagen–Poiseuille equation for viscous flow in a pipe, permeability can be expressed as:

k I = C ⋅ d 2 {\displaystyle k\_{I}=C\cdot d^{2}}

where:



k I {\displaystyle k\_{I}}  is the intrinsic permeability [length2]

C {\displaystyle C}  is a dimensionless constant that is related to the configuration of the flow-paths

d {\displaystyle d}  is the average, or effective pore [diameter](https://en.wikipedia.org/wiki/Diameter) [length].

# Absolute permeability (aka intrinsic or specific permeability)

*Absolute permeability* denotes the permeability in a porous medium that is 100% saturated with a single-phase fluid. This may also be called the *intrinsic permeability* or *specific permeability.* These terms refer to the quality that the permeability value in question is an [intensive property](https://en.wikipedia.org/wiki/Intensive_and_extensive_properties) of the medium, not a spatial average of a heterogeneous block of materialand that it is a function of the material structure only (and not of the fluid). They explicitly distinguish the value from that of [relative permeability](https://en.wikipedia.org/wiki/Relative_permeability).

# Permeability to gase

Sometimes permeability to gases can be somewhat different than those for liquids in the same media. One difference is attributable to "slippage" of gas at the interface with the solid[[5]](https://en.wikipedia.org/wiki/Permeability_(Earth_sciences)#cite_note-5) when the gas [mean free path](https://en.wikipedia.org/wiki/Mean_free_path) is comparable to the pore size (about 0.01 to 0.1 μm at standard temperature and pressure). See also [Knudsen diffusion](https://en.wikipedia.org/wiki/Knudsen_diffusion) and [constrictivity](https://en.wikipedia.org/wiki/Constrictivity). For example, measurement of permeability through sandstones and shales yielded values from 9.0×10−19 m2 to 2.4×10−12 m2 for water and between 1.7×10−17 m2 to 2.6×10−12 m2 for nitrogen gas. Gas permeability of [reservoir rock](https://en.wikipedia.org/wiki/Reservoir_rock) and [source rock](https://en.wikipedia.org/wiki/Source_rock) is important in [petroleum engineering](https://en.wikipedia.org/wiki/Petroleum_engineering), when considering the optimal extraction of [shale gas](https://en.wikipedia.org/wiki/Shale_gas), [tight gas](https://en.wikipedia.org/wiki/Tight_gas), or [coalbed methane](https://en.wikipedia.org/wiki/Coalbed_methane).

# Tensor permeability

To model permeability in [anisotropic](https://en.wikipedia.org/wiki/Anisotropic) media, a permeability [tensor](https://en.wikipedia.org/wiki/Tensor) is needed. Pressure can be applied in three directions, and for each direction, permeability can be measured (via Darcy's law in 3D) in three directions, thus leading to a 3 by 3 tensor. The tensor is realised using a 3 by 3 [matrix](https://en.wikipedia.org/wiki/Matrix_(mathematics)) being both [symmetric](https://en.wikipedia.org/wiki/Symmetric_matrix) and [positive definite](https://en.wikipedia.org/wiki/Positive-definite_matrix) (SPD matrix):

* The tensor is symmetric by the [Onsager reciprocal relations](https://en.wikipedia.org/wiki/Onsager_reciprocal_relations).
* The tensor is positive definite as the component of the flow [parallel](https://en.wikipedia.org/wiki/Parallel_(geometry)) to the pressure drop is always in the same direction as the pressure drop.

The permeability tensor is always [diagonalizable](https://en.wikipedia.org/wiki/Diagonalizable) (being both symmetric and positive definite). The [eigenvectors](https://en.wikipedia.org/wiki/Eigenvectors) will yield the principal directions of flow, meaning the directions where flow is parallel to the pressure drop, and the [eigenvalues](https://en.wikipedia.org/wiki/Eigenvalues) representing the principal permeabilities.

These values do not depend on the fluid properties; see the table derived from the same source for values of [hydraulic conductivity](https://en.wikipedia.org/wiki/Hydraulic_conductivity), which are specific to the material through which the fluid is flowing.[[7]](https://en.wikipedia.org/wiki/Permeability_(Earth_sciences)#cite_note-7)

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Permeability** | **Pervious** | | | | **Semi-pervious** | | | | **Impervious** | | | | |
| **Unconsolidated sand and gravel** | Well sorted [gravel](https://en.wikipedia.org/wiki/Gravel) | | Well sorted [sand](https://en.wikipedia.org/wiki/Sand) or sand and gravel | | | Very fine sand, silt, [loess](https://en.wikipedia.org/wiki/Loess), [loam](https://en.wikipedia.org/wiki/Loam) | | | |  | | | |
| **Unconsolidated clay and organic** |  | | | | [Peat](https://en.wikipedia.org/wiki/Peat) | | Layered [clay](https://en.wikipedia.org/wiki/Clay) | | | Unweathered clay | | | |
| **Consolidated rocks** | Highly fractured rocks | | | | [Oil reservoir](https://en.wikipedia.org/wiki/Petroleum_geology) rocks | | | Fresh [sandstone](https://en.wikipedia.org/wiki/Sandstone) | | Fresh [limestone](https://en.wikipedia.org/wiki/Limestone), [dolomite](https://en.wikipedia.org/wiki/Dolomite_(rock)) | | Fresh [granite](https://en.wikipedia.org/wiki/Granite) | |
| ***k* (cm2)** | 0.001 | 0.0001 | 10−5 | 10−6 | 10−7 | 10−8 | 10−9 | 10−10 | 10−11 | 10−12 | 10−13 | 10−14 | 10−15 |
| ***k* (millidarcy)** | 10+8 | 10+7 | 10+6 | 10+5 | 10,000 | 1,000 | 100 | 10 | 1 | 0.1 | 0.01 | 0.001 | 0.0001 |

# **SOIL CAPILLARITY**

Capillary action (sometimes capillarity, capillary motion, capillary effect, or wicking) is the ability of a liquid to flow in narrow spaces without the assistance of, or even in opposition to, external forces like gravity. The effect can be seen in the drawing up of liquids between the hairs of a paint-brush, in a thin tube, in porous materials such as paper and plaster, in some non-porous materials such as sand and liquefied carbon fiber, or in a biological cell. It occurs because of intermolecular forces between the liquid and surrounding solid surfaces. If the diameter of the tube is sufficiently small, then the combination of surface tension (which is caused by cohesion within the liquid) and adhesive forces between the liquid and container wall act to propel the liquid.

# CONCLUSION

In conclusion I was able to discuss soil permeability and capillarity and its application

# Reference

* Wang, H. F., 2000. Theory of Linear Poroelasticity with Applications to Geomechanics and Hydrogeology, Princeton University Press.