3.2 RELATIVE PERMEABILITY

- $k_{r_{nw}} + k_{r_w} \neq 1 \Rightarrow k_{r_{nw}} + k_{r_w} < 1$

  Most effective transmission is at 100% saturation (if accessible). Interference.

- Usually $k_{r_{nw}}$ closer to 1 than k_{r_w}
- Steep decline of k_{r_w} with increasing S_{nw} indicates large pores occupied first by nonwetting phase.

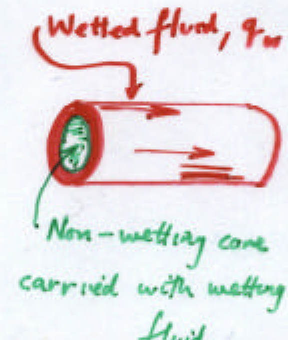
  Nonwetting phase occupies larger pores preferentially due to capillary pressure arguments.

- k to wetting fluid is always larger for open pored unconsolidated material.

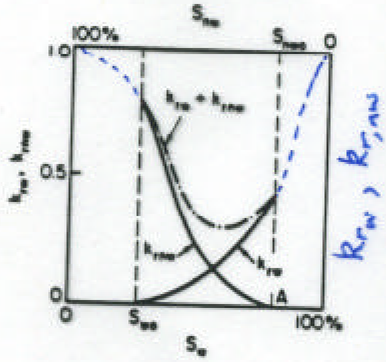
- k to non-wetting fluid is always smaller for open-pored unconsolidated material.

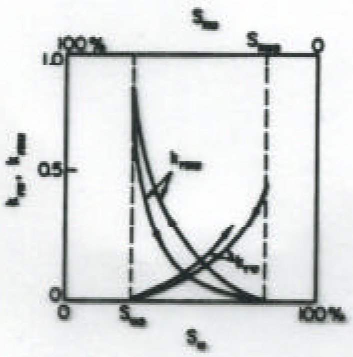
Hysteresis:

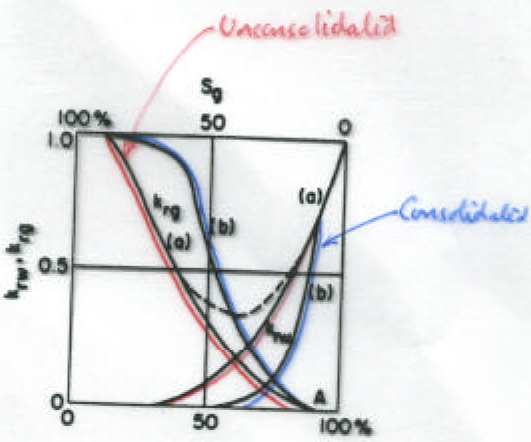
1. Wetting fluid surrounds grains and non-wetting fluid ∴ may move nw fluid even if no pressure gradient in nw fluid.



2. Since change in saturation requires change in wetted grain surface – wettability is hysteretic. ∴ permeabilities are hysteretic.



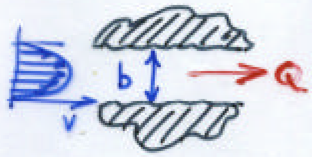




Curves switch over
- nw fluid saturates
largest pores first.

PERMABILITY/CONDUCTIVITY OF FRACTURES

Flow in fractures



$$\bar{v} = -\underbrace{\frac{gb^2}{12\nu}}_{k}\frac{dh}{dx}$$

$\bar{v}$ = average velocity.

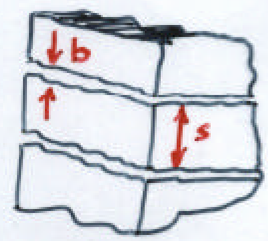
ν = kinematic viscosity of fluid

$\nu = \mu/\rho$

Equivalent flow rate per unit width: for single fracture

$$Q = b\,\frac{gb^2}{12\nu}\,\frac{dh}{dx}$$

Multiple fractures arranged in parallel:



Total of N fractures per unit height:

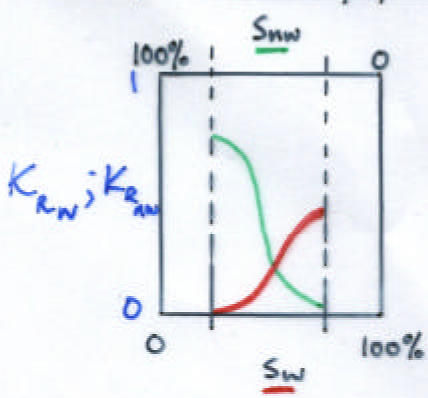
$N = 1/s$

$$Q = \underbrace{\frac{gb^3}{12\nu}\,\frac{1}{s}}_{K_b}\,\frac{dh}{dx}$$

Equivalent conductivity for multiple sets: $K_b = \frac{gb^3}{6\nu s}$

Enables b to be evaluated if K known (measured).

Relative permeability of fractures



- Similar behavior to porous medium
- Distribution of apertures 

  Large apertures saturate first

Capillary pressure or head $h_c = \frac{2\sigma}{b\gamma_w}$

FRACTURE PERMEABILITIES AND CAPILLARY PRESSURES

$$k = \frac{b^2}{12}$$ single fracture permeability (1)

$$k_b = \frac{b^3}{12s}$$ bulk permeability

Permeabilities and capillary pressures related.

$$h_c = \frac{2\sigma}{b\gamma_w} \quad \text{or} \quad h_c\gamma_w = \frac{2\sigma}{b} = P_{c_b} \qquad (2)$$

From (1) and (2)

$$P_{c_b} = \frac{2\sigma}{\sqrt{12k}}$$

General relation for fractures and porous media

$$P_c \propto \sqrt{\frac{1}{k}}.$$

e.g. Leverett 'J' function –

$$J = \frac{P_c}{\sigma}\sqrt{\frac{k}{n}}$$

$$\therefore \; P_c = J\sigma\sqrt{\frac{n}{k}}$$