Appendix 7

Physical Erosion

Göran Sällfors

A number of SKB reports deal with the backfill, saturation, erosion and a number of practical problems … … …

Figure 6-6. Wetting along crown of Assembly 3 (Tests 5, 6). (Note dry (empty regions along walls) and wetting (darker regions) along crown.

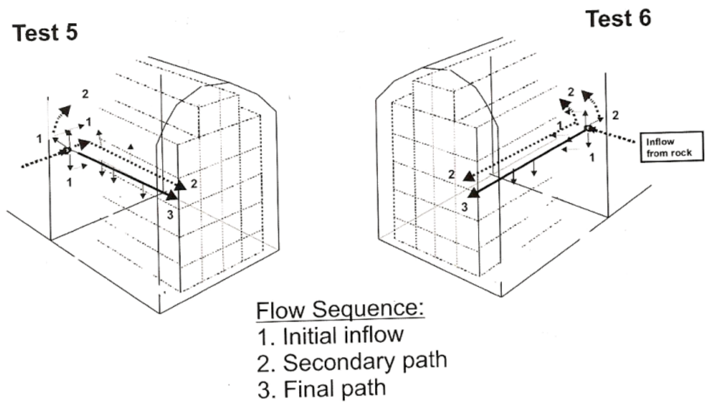


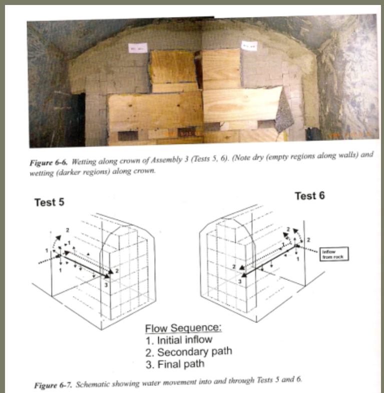
Figure 6-7. Schematic showing water movement into and through Tests 5 and 6.

Physical Erosion

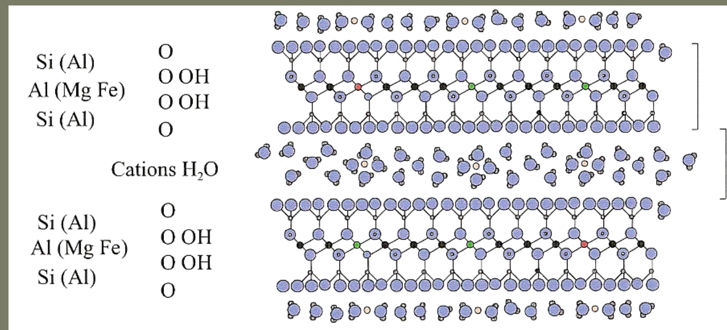
Physical Erosion

Can occur at different scales:

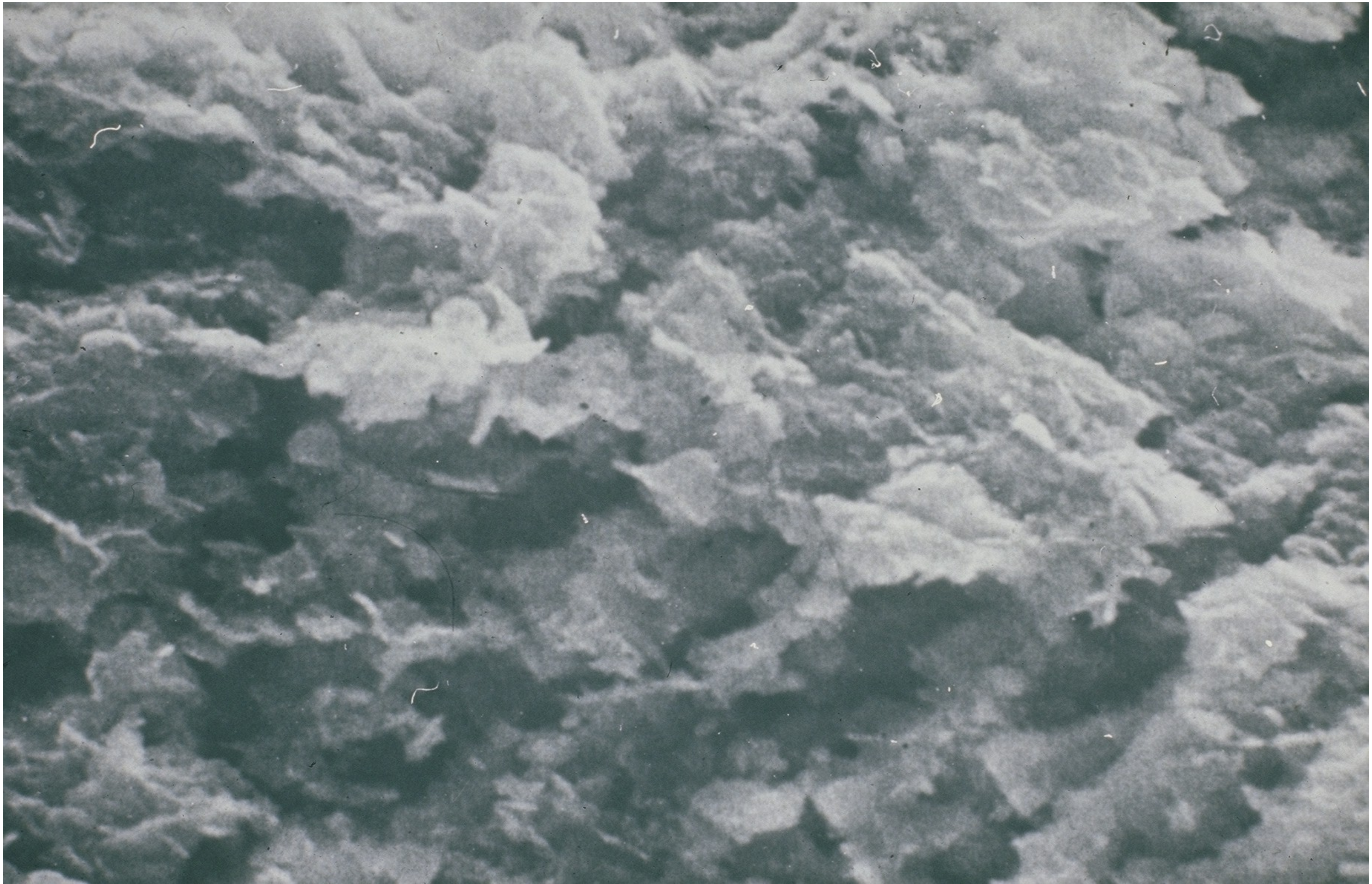
macro scale



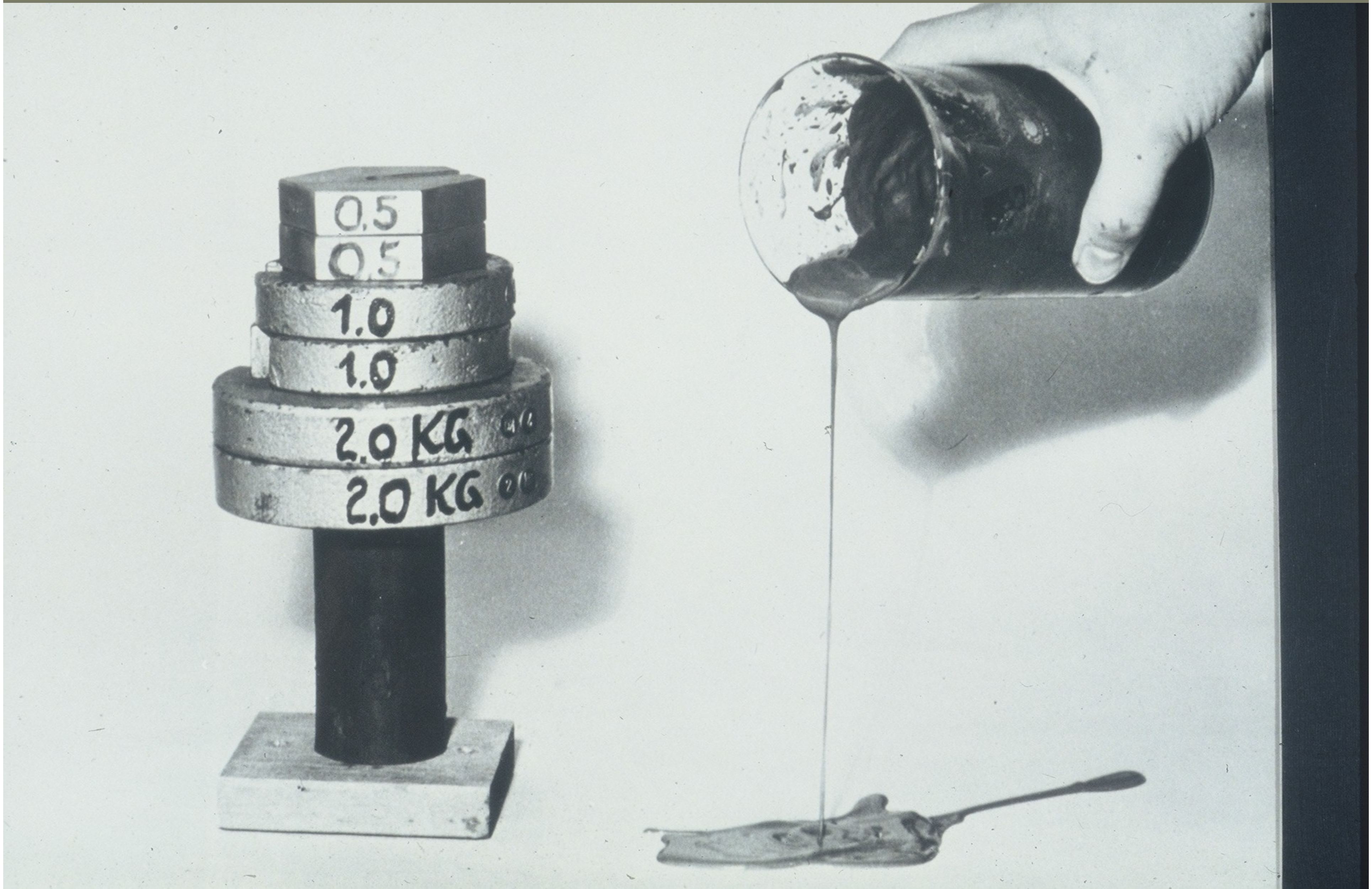
micro scale



Physical Erosion



Physical Erosion



Physical Erosion

In the Tunnel

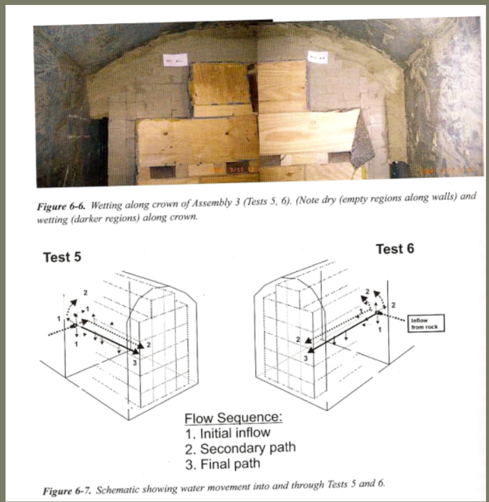
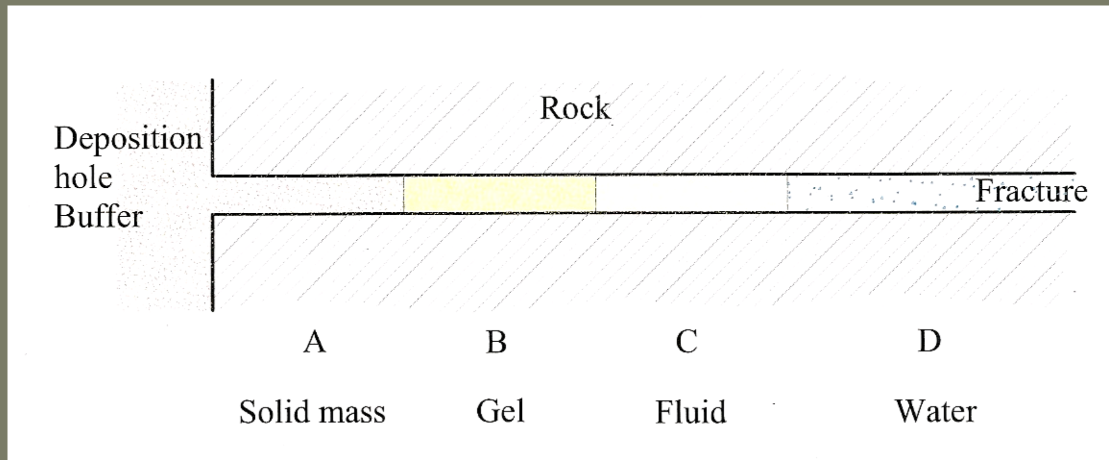


Figure 6-6. Wetting along crown of Assembly 3 (Tests 5, 6). (Note dry (empty regions along walls) and wetting (darker regions) along crown.

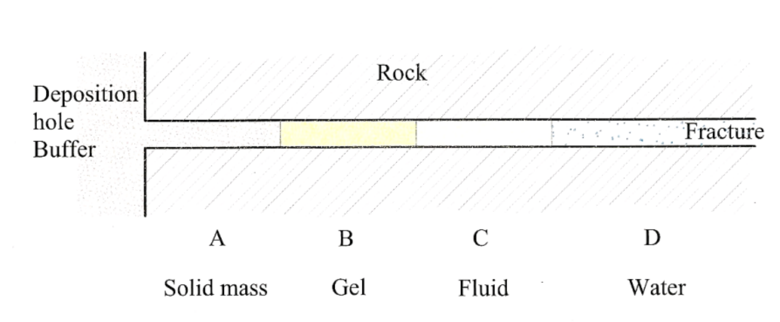
Figure 6-7. Schematic showing water movement into and through Tests 5 and 6.

In a fracture

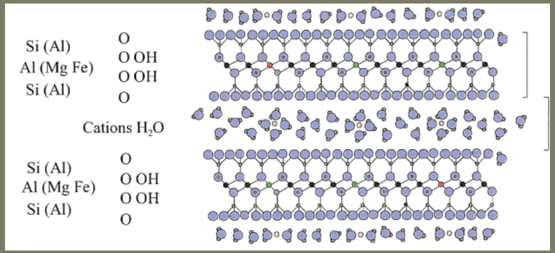


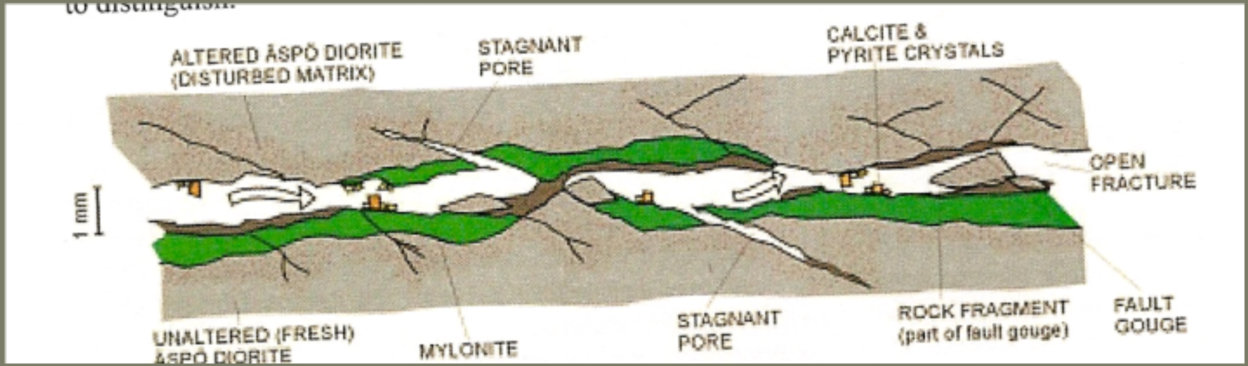
Physical Erosion

Ideal fracture

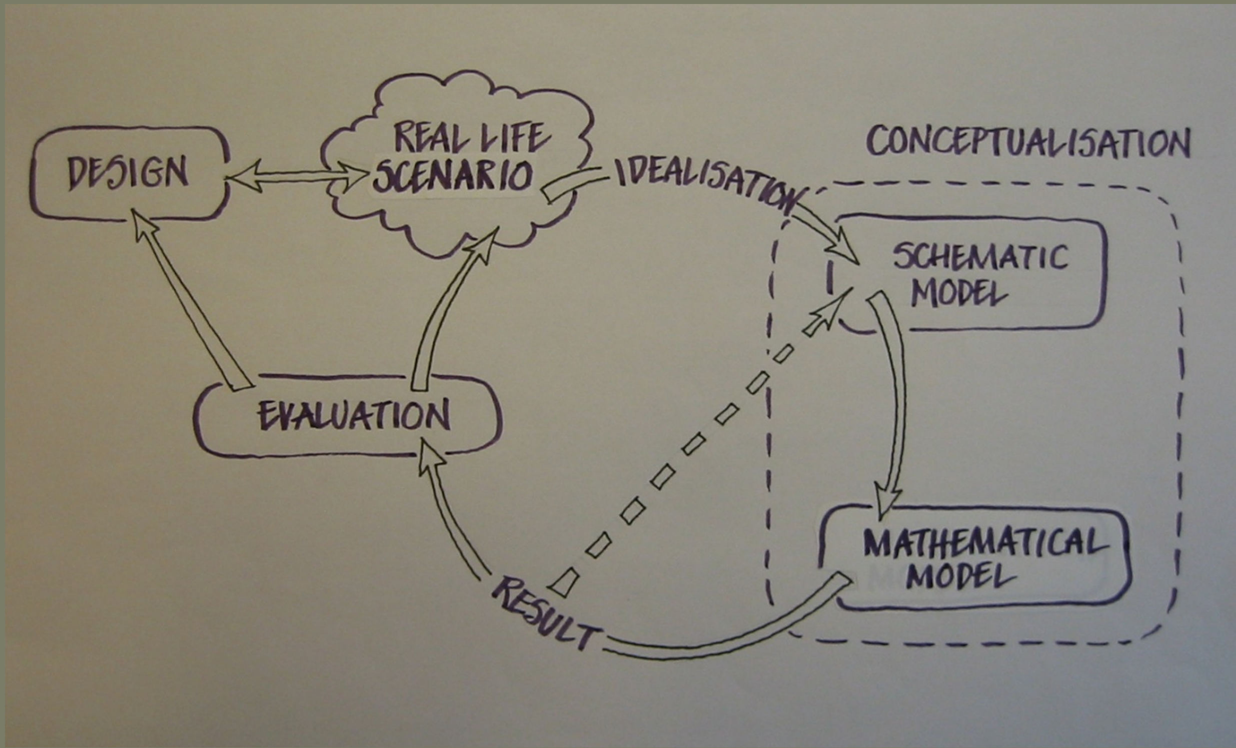


Idealized Prototype fracture

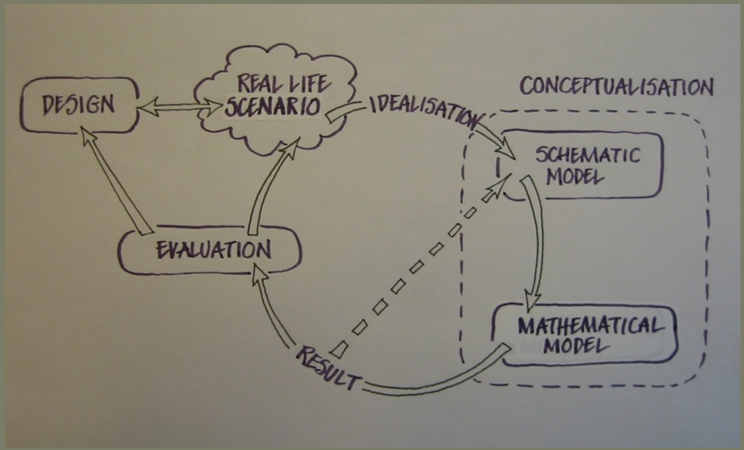


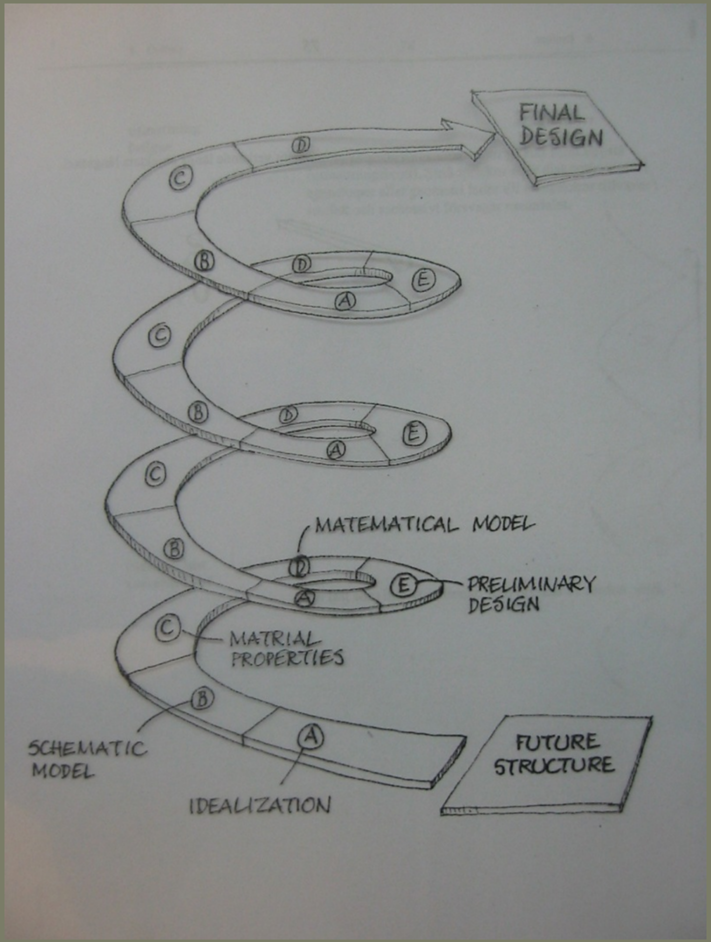


Physical Erosion

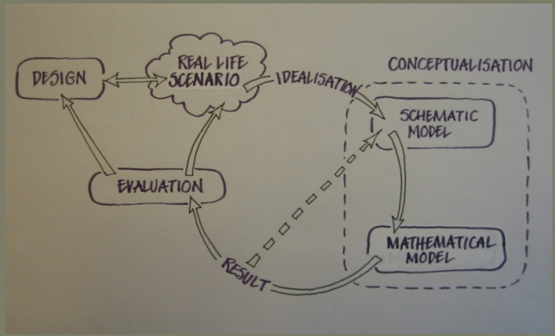


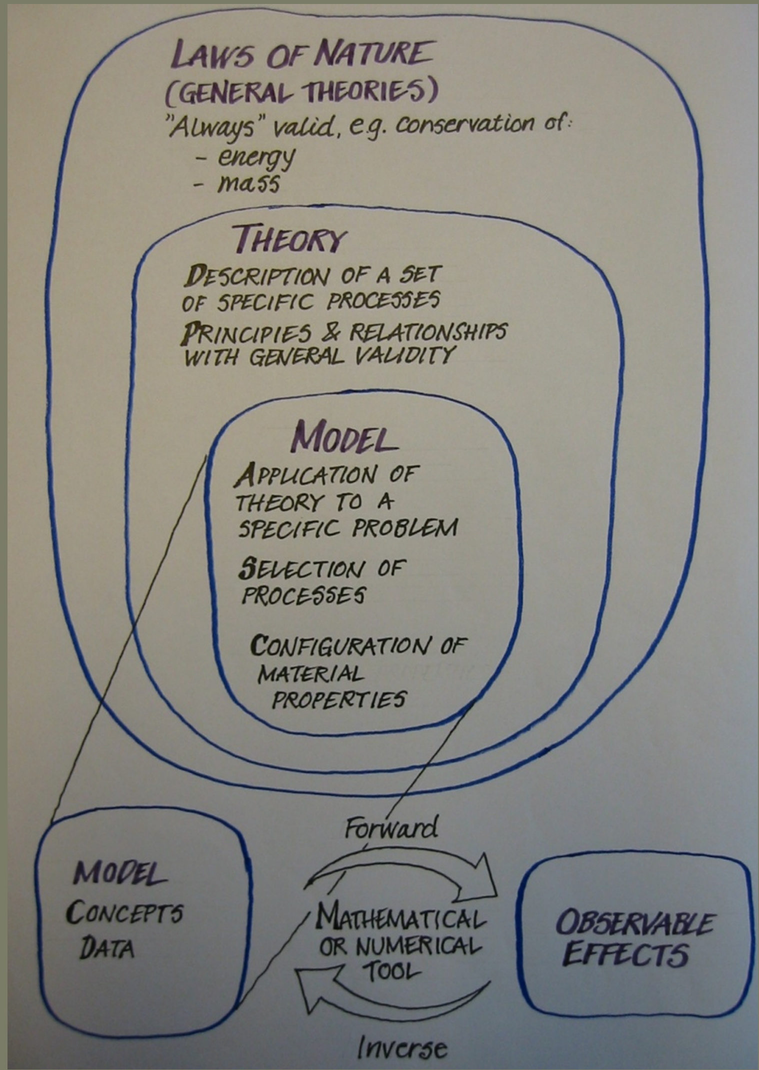
Physical Erosion

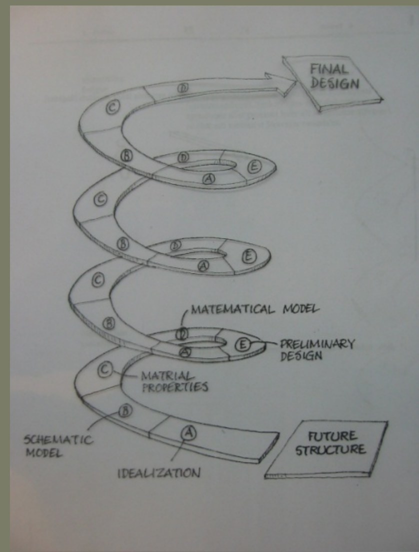




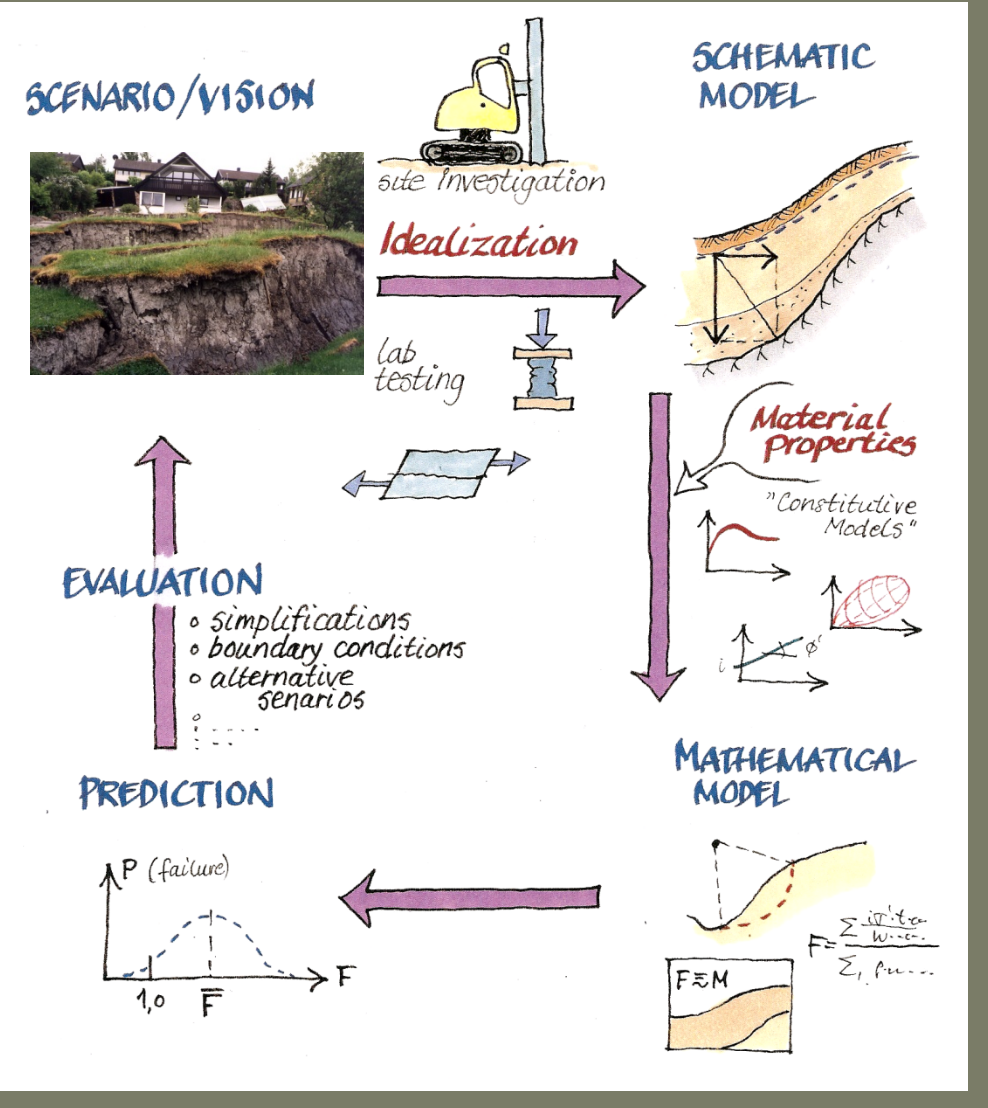
Physical Erosion



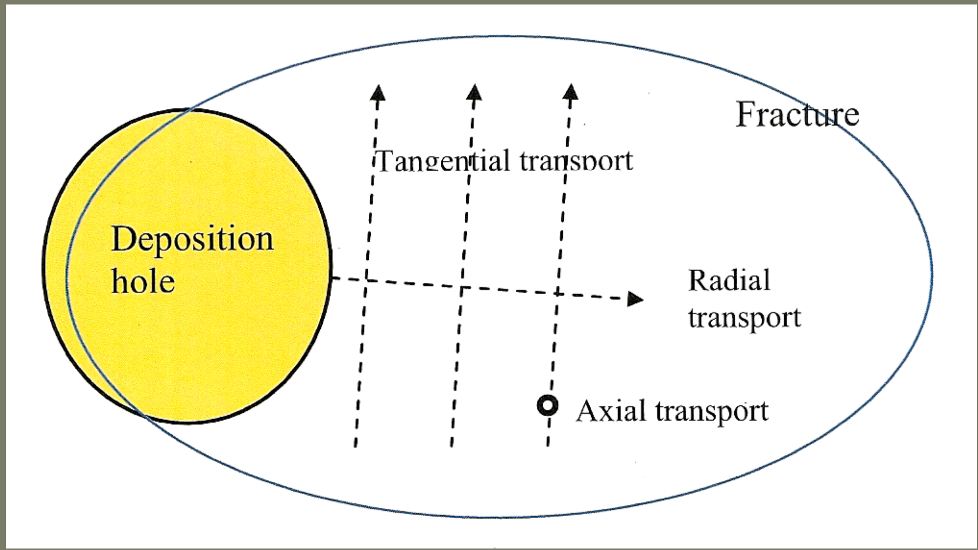




Physical Erosion



Physical Erosion



Börgesson et al deal with *swelling* (radial transport) and *erosion* (tangential transport) *sedimentation* (axial tranport)

Physical Erosion

Penetration depth of bentonite determineed
by the *swelling pressure* and *friction* bentonite/wall
and the *aperture*

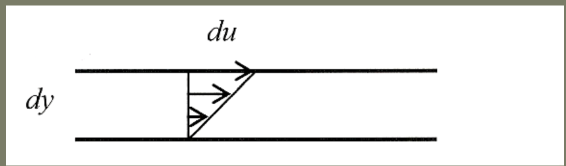
$$\sigma = \sigma_1 \cdot e^{-2 \tan \phi \left(\frac{z}{a}\right)}$$

Physical Erosion

$$\sigma = \sigma_1 \cdot e^{-2\tan\phi\left(\frac{z}{a}\right)}$$

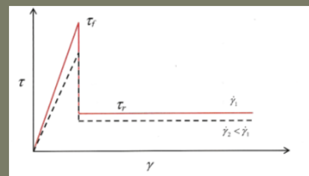
Rheology needed for calculating the penetration depth and velocity

1. Newtonian flow $\tau = \mu \dfrac{du}{dy}$

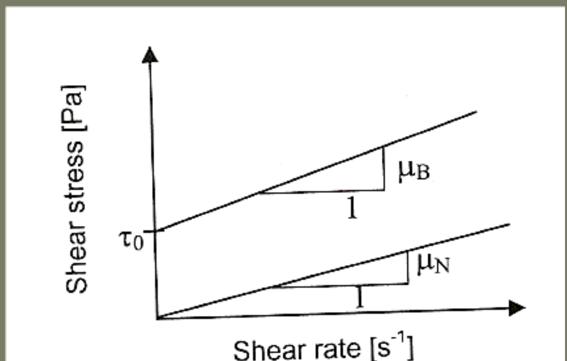


2. Power law $\tau = m\left(\dfrac{\dot{\gamma}}{\dot{\gamma}_0}\right)^n$

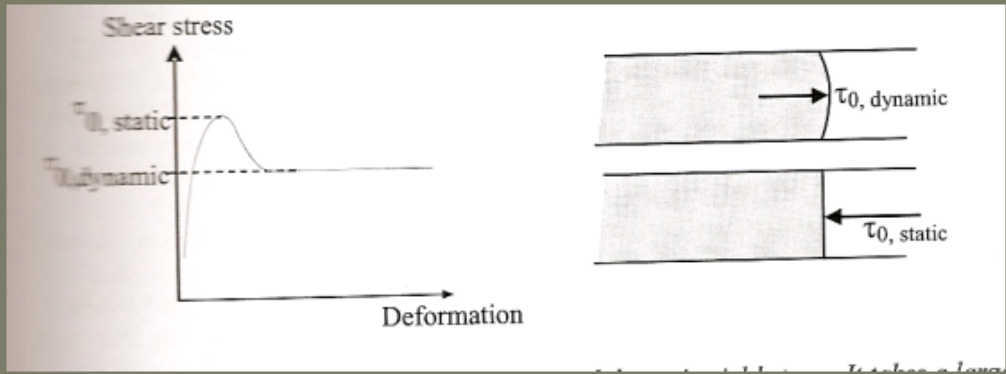
3. Stress-strain relations

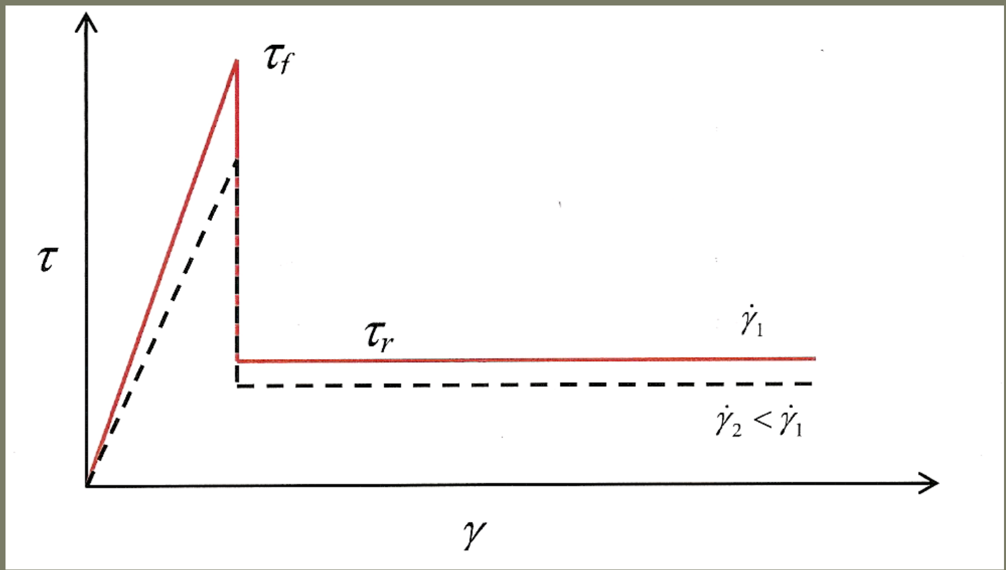


4. Bingham-flow



Physical Erosion

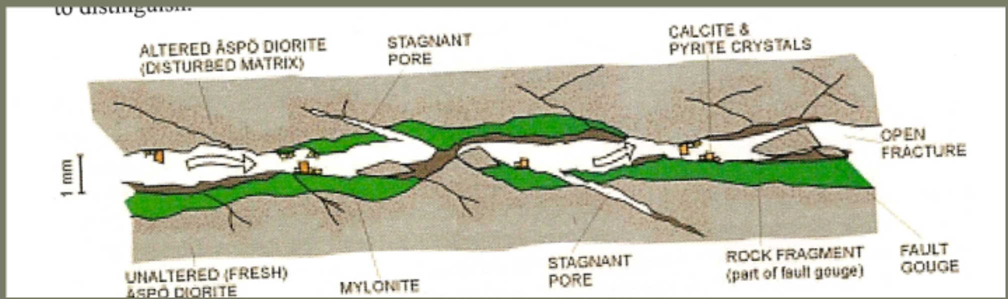




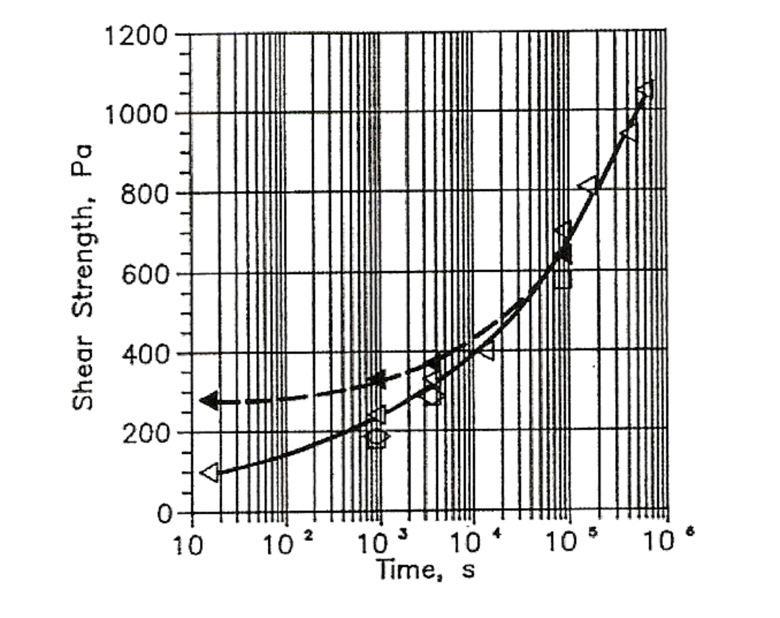
Strong idealization

Sedimentation

(Mason and Weaver, 1924)



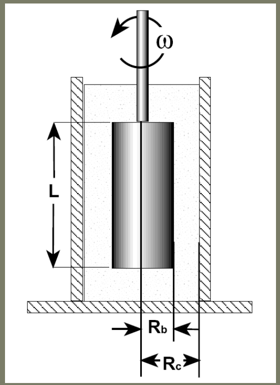
Tixotropy



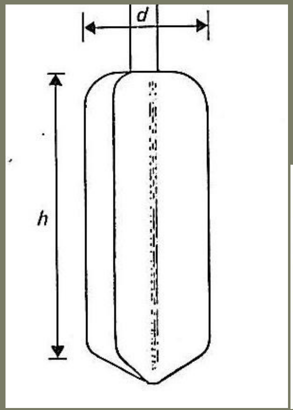
Shear Strength, Pa
1200
1000
800
600
400
200
0
10
10 2
10 3
10 4
10 5
10 6
Time, s

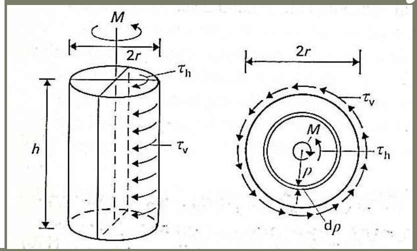
Laboratory equipment

Viscometer



Laboratory vane





Physical Erosion

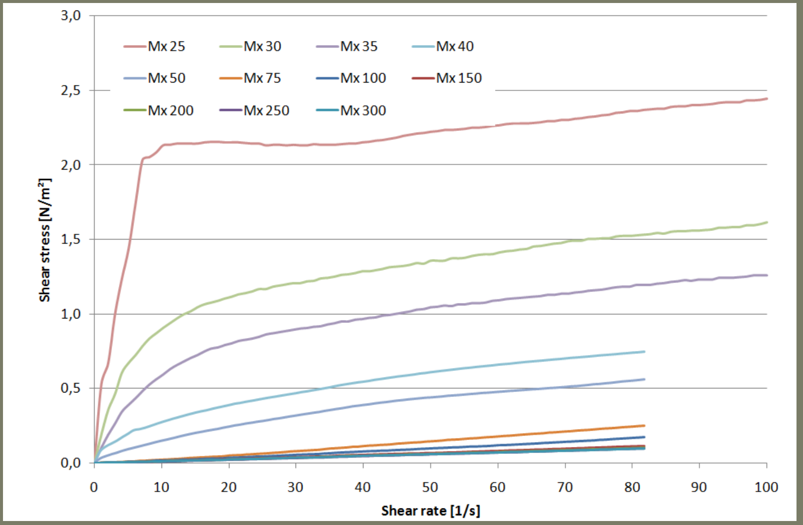
Extensive testing with

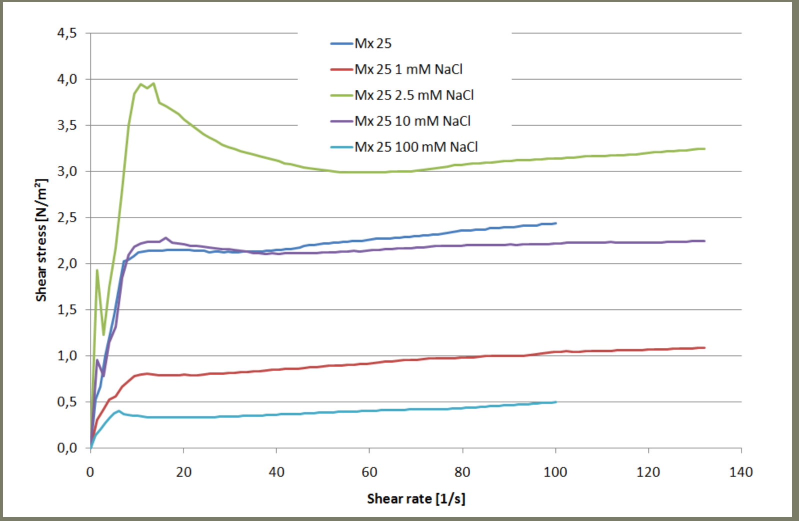
- Rate of deformation
- Time after preparation
- Bentonite composition
- Water ratios
- Water composition

In order to determine suitable model and model parameters

Extensive testing with

- ***Rate of deformation***
- Time after preparation
- Bentonite composition
- Water ratios
- ***Water composition***

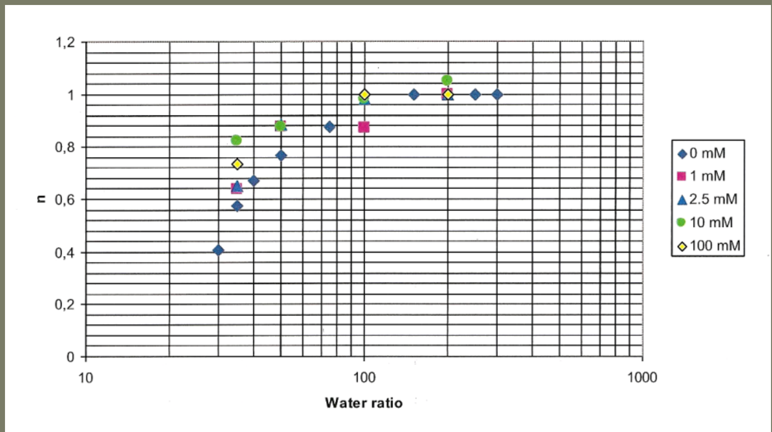


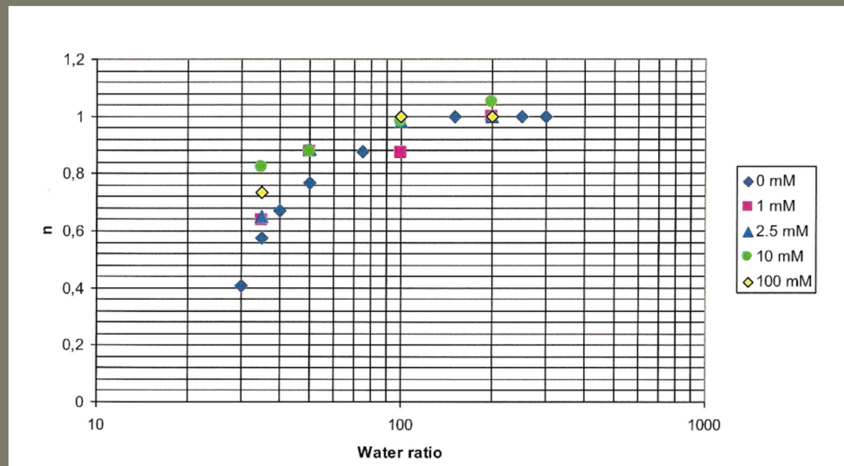


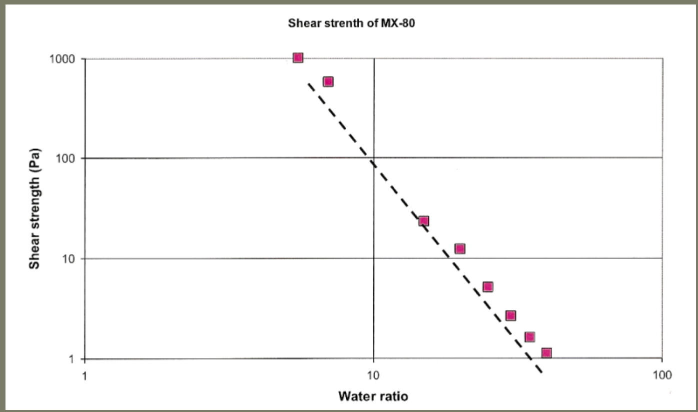
Physical Erosion

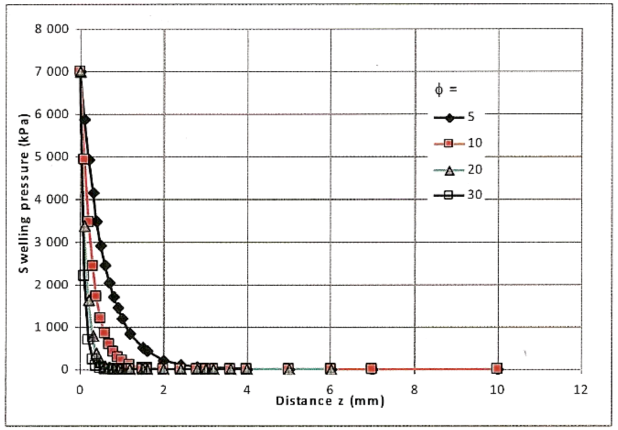
Evaluation of the parameters in eq 3.6, ***m*** and ***n***

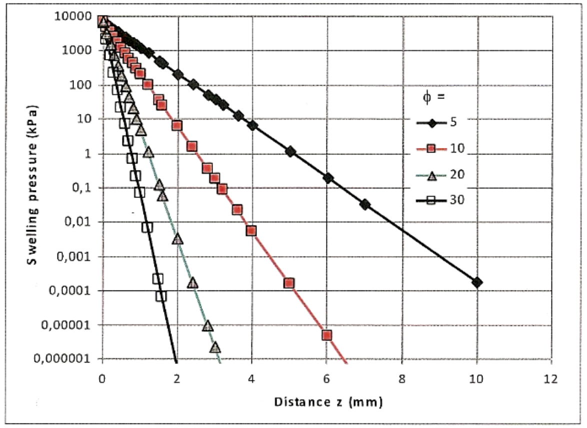
$$\tau = m\left(\frac{\dot{\gamma}}{\dot{\gamma}_0}\right)^n$$





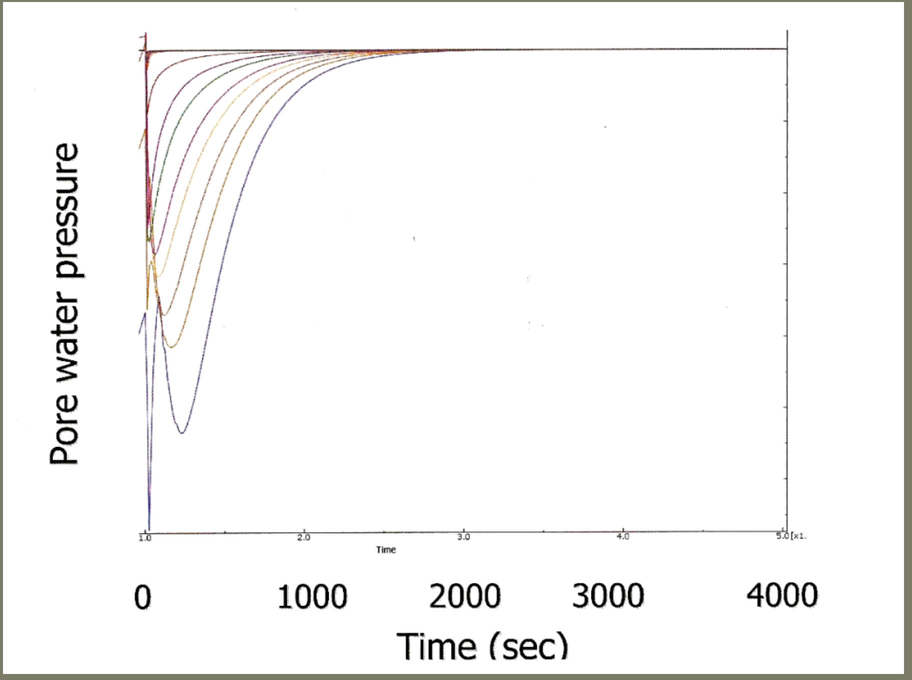






Physical Erosion

Swelling time (aperture 0.1 mm)
Assumptions:
w<30 - penetration = f(swelling pressure only)
w>30 - penetration = f(colloid dispersion, erosion, settlement)
- colloid dispersion faster than swelling



I kg in 85 years ?

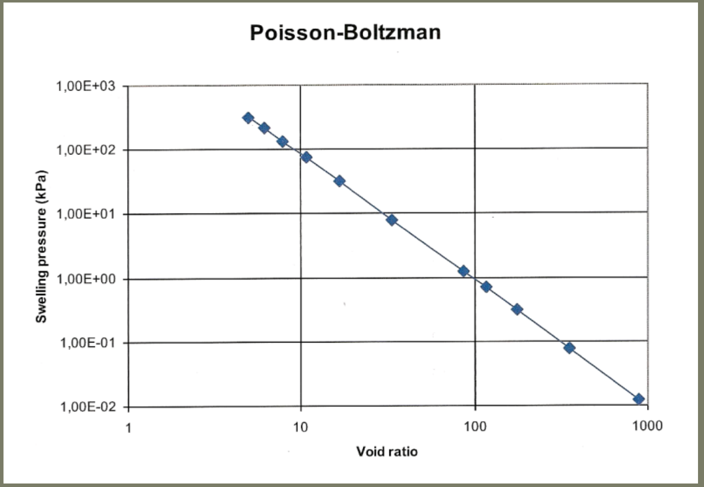
Physical Erosion

Physical Erosion

Same amount of benotine will be lost independent of aperture width (according to this model)

Higher friction angle gives higher loss of bentonite
(in the example 1 kg lost in 6.5 years instead of 85 years
If friction angle 30 instead of 10)

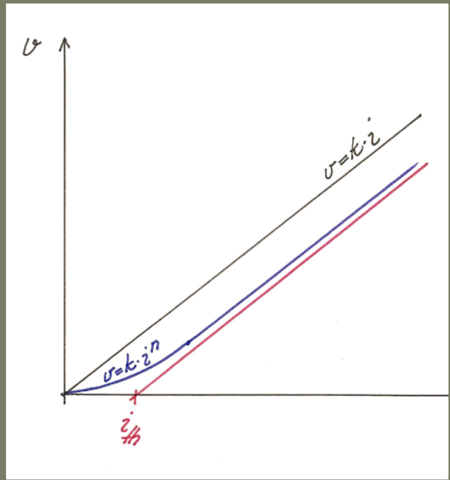
Swelling pressure higher at low water ratios
Larger losses
Big question: swelling pressure = f(w)



k measured up o w=20 and then extrapolated
Loss = f(k)
Boudary for swelling pressure 10Pa, if 1/1000 only 2,5 higher loss

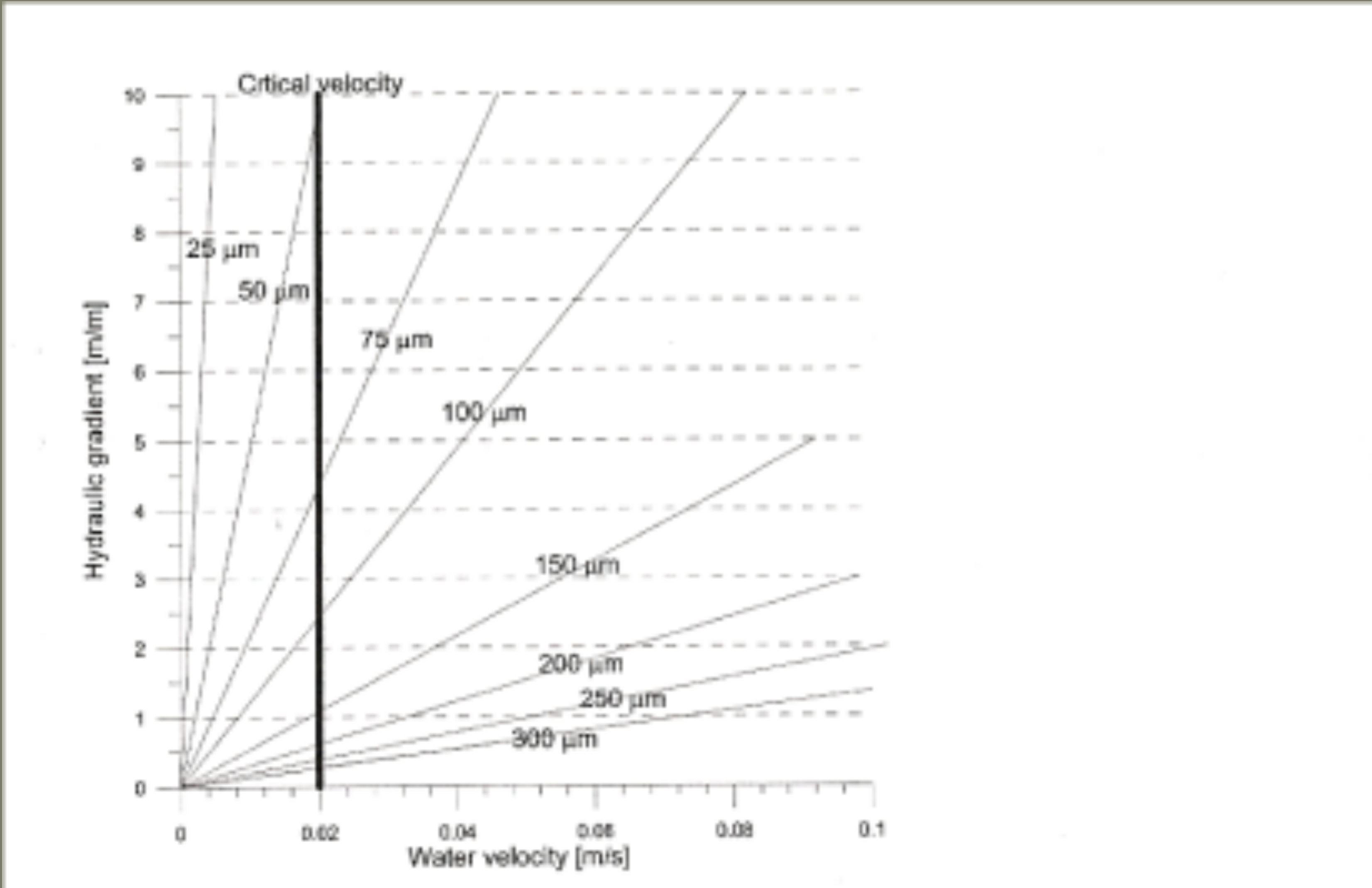
Physical Erosion

Phase		Properties		Bentonite transport model		
		WyNa in distilled water	**MX-80 in distilled water**	**Radially (swelling)**	**Tangentially (viscous flow and erosion)**	**Axially (sedimentation)**
A	Solid mass τ_f >1 kPa	w<10	w<5	A_R. Hydro-Mechanical Friction	A_T. None	A_A. None
B	Gel 1 Pa < τ_f < 1 kPa	10<w< 35	5<w<35	B_R. Hydro-Mechanical Friction	B_T. Rheological Stress/strain relation	B_A. None?
C1	Semi-fluid	35<w< 100	35<w<70	$C1_R$ Hydro-Mechanical Friction (?)	$C1_T$ Power law	$C1_A$ Diffusion controlled aggregation?
C2	Fluid	100 <w< 1000	70 <w< 500	$C2_R$ Diffusion?	$C2_T$ Viscosity, Newtonian	$C2_A$ Diffusion controlled aggregation
D	Water	w>1000	w>500	D_R. Diffusion?	D_T. Water viscosity	D_A. None?

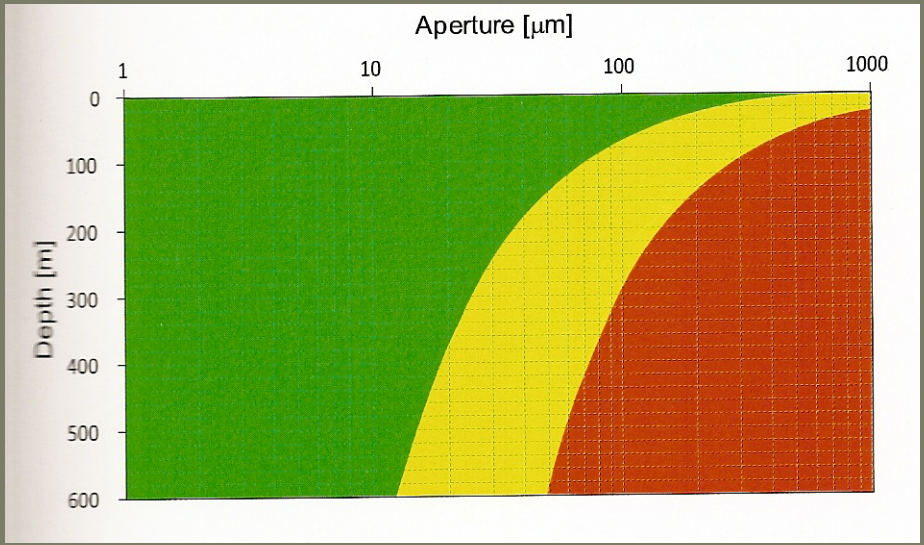


Darcy's law

Valid for small gradients ?



Physical Erosion



Physical Erosion

Laws - rheological models

Darcy's law

Water ratios

Swelling pressure

Different phenomena

Fracture width/continuity

Testing - extrapolation

Nereetniks blobb-tests elementary
What do we learn.
Aperture 1,8 mm
Clay Technology 0,2 – 0,01