Buffer - Backfill
THM
+
Other processes

1. Background, Scope & Limitations

Buffer - THM + Other processes

3. External Scenarios.

2. Basic Behavior

4. Internal Scenarios

6. The Real World *(Building the repository)*

5. Other Processes - Piping and Erosion

1. Background, Scope & Limitations

THM
+ other processes

3. External Scenarios.

a. Earthquakes – ***Shear***
b. Earthquakes – Liquefation
c. Freezing

2. Basic Behavior

a. Theoretical development
b. Laboratory testing
c. Full scale tests
d. ***Unanswered questions***

6. The Real World

4. Internal Scenarios

a. Uplift
b. Settlement
c. ***Homogenisation and saturation***

Buffer + Backfill

QA

Mining

Transportation

Preparation

Compressing

Transp + storing

Placing

Maintaining

Closing

5. Other Processes - ***Piping and Erosion***

THM
+ other
processes

2. Basic Behavior

Task: *Understand and predict the* ***basic behavior*** *of Bentonite*

1. Define properties: Retention, Deformation, Strength, Hydraulic, Thermal
2. Postulate: a number of Constitutive Models/ Global Model
3. Determine model parameters
4. *Verify the models by element testing !*

THM
+ other processes

2. Basic Behavior

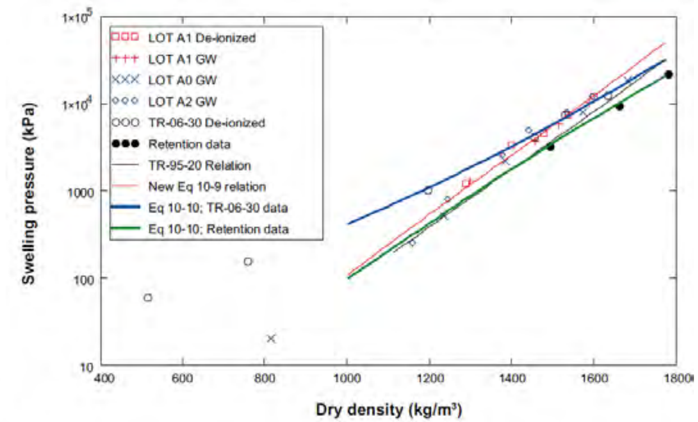
Task: *Understand and predict the **basic behavior** of Bentonite*

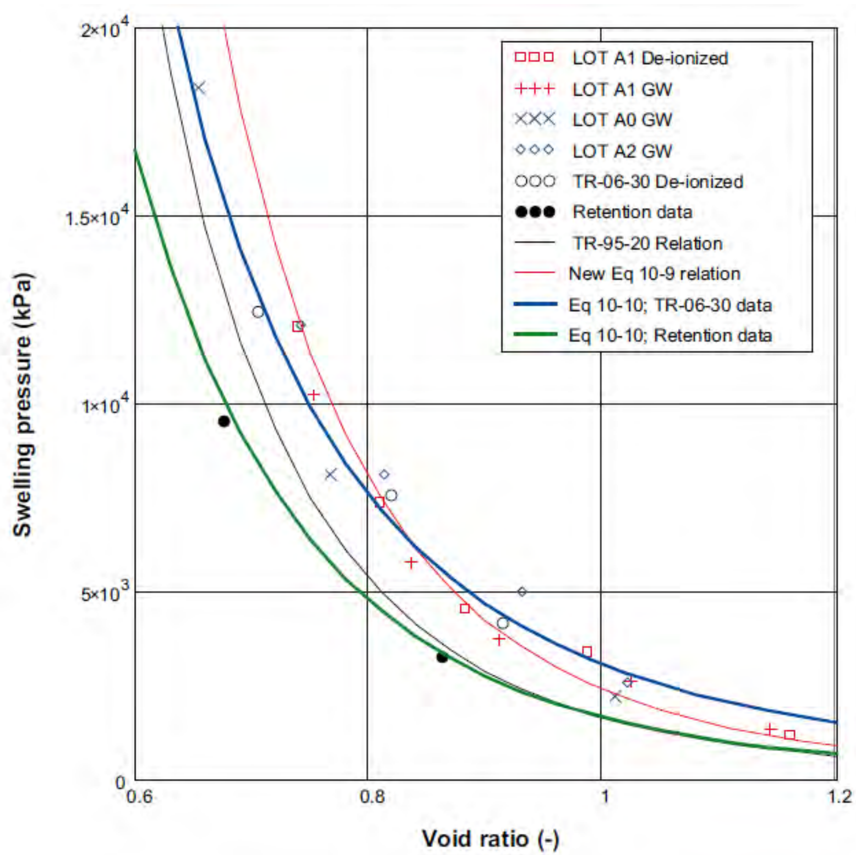
1. Define properties: Retention, Deformation, Strength, Hydraulic, Thermal
2. Postulate: a number of Constitutive Models/ Global Model
3. Determine model parameters
4. *Verify the models by element testing !*

Understand, Model and ***predict*** material behavior

Mechanical properties

Deformation properties
- swelling pressure



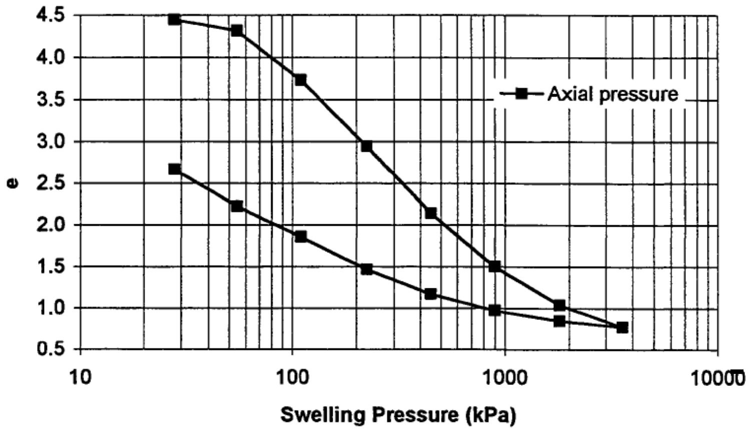


Unique values, but depends on
- retention data
- measured at full saturation

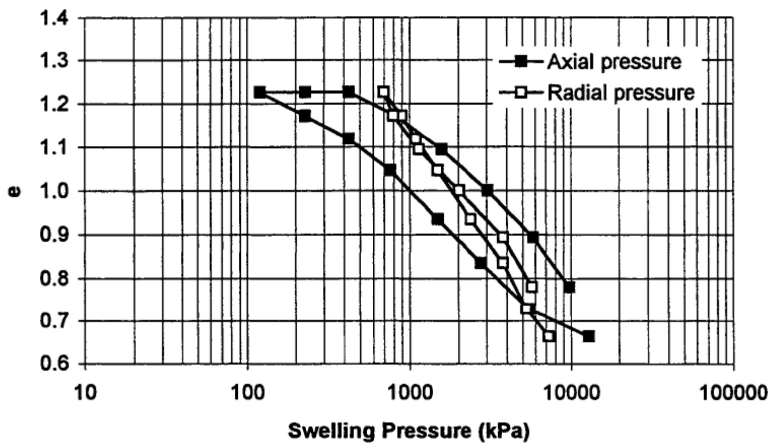
Mechanical properties

Deformation properties

- modulus (loading and unloading)

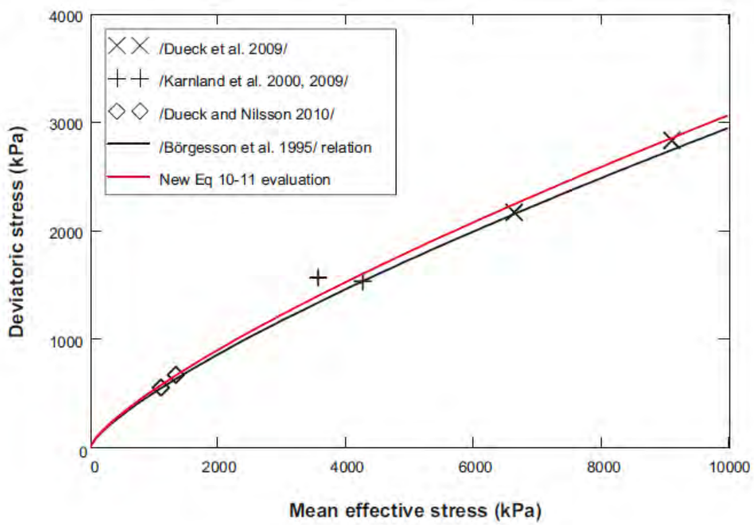


Well understood for oedometer testing (fixed ring)

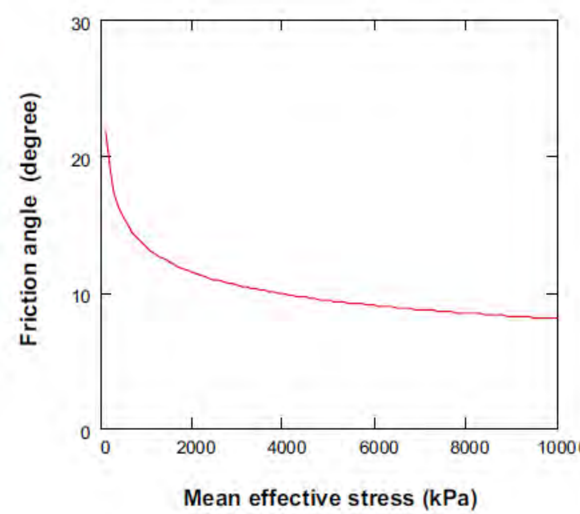


Mechanical properties

Strength properties

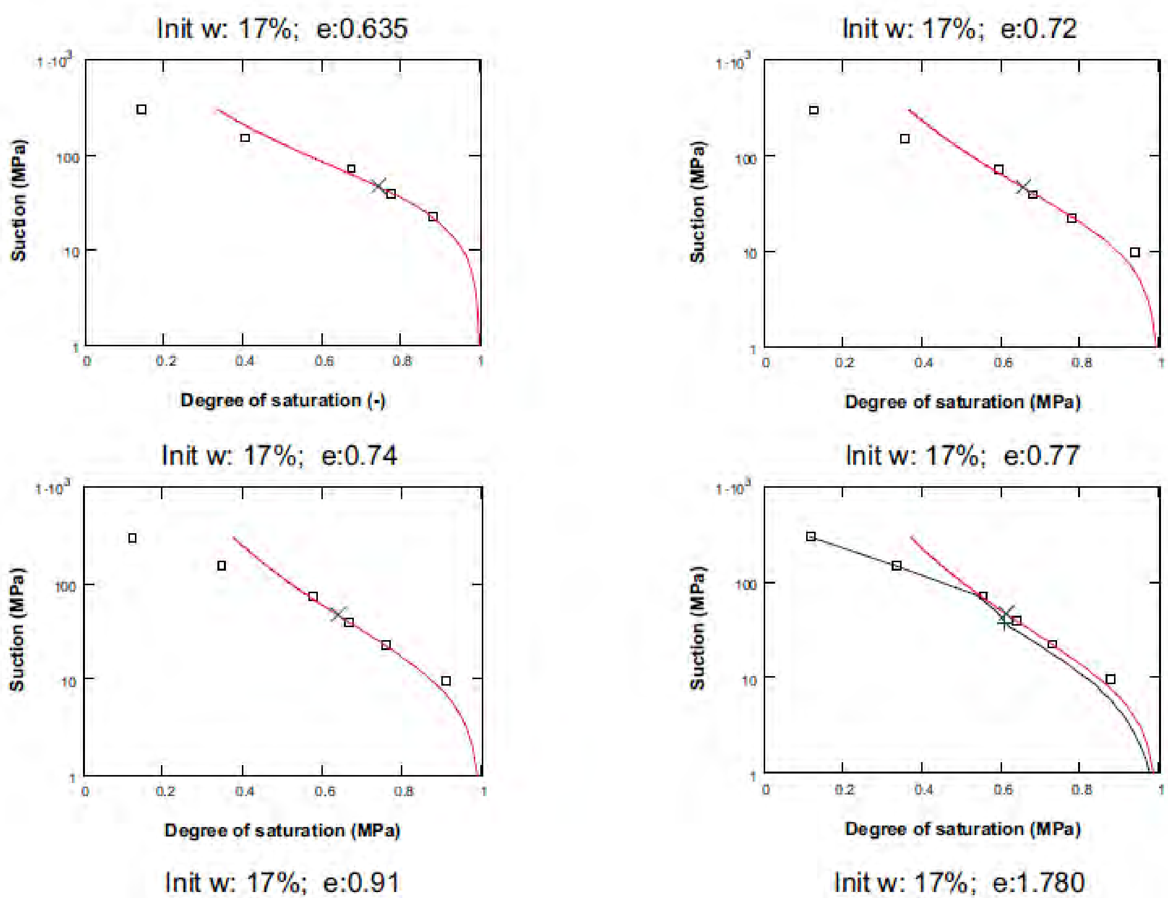


φ' decreases with increasing stress
c' increases, but neglected



Hydraulic properties

Retention properties

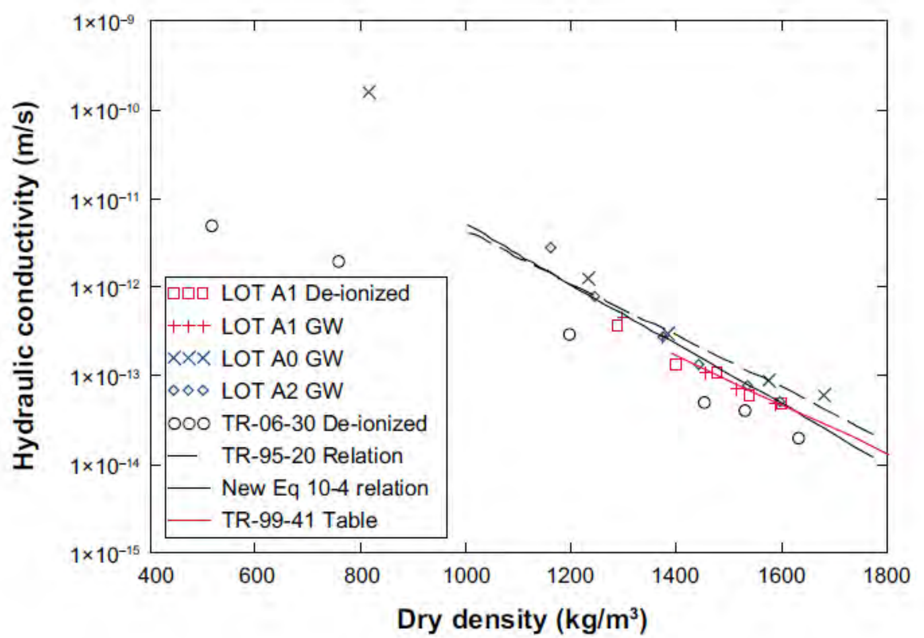


Van Genughten, modified

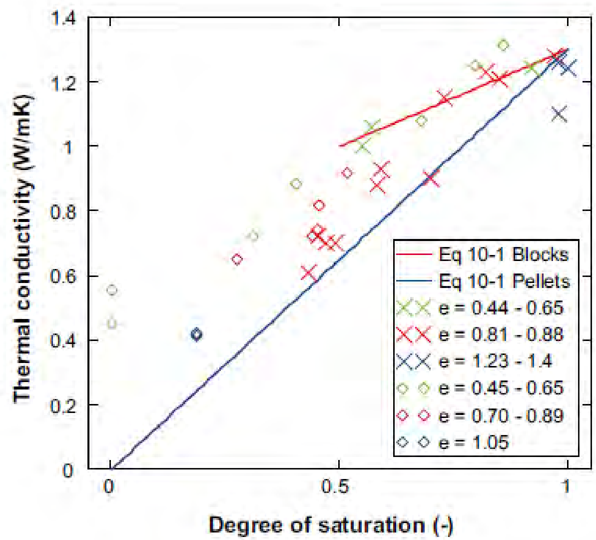
Observe! Suction in MPa

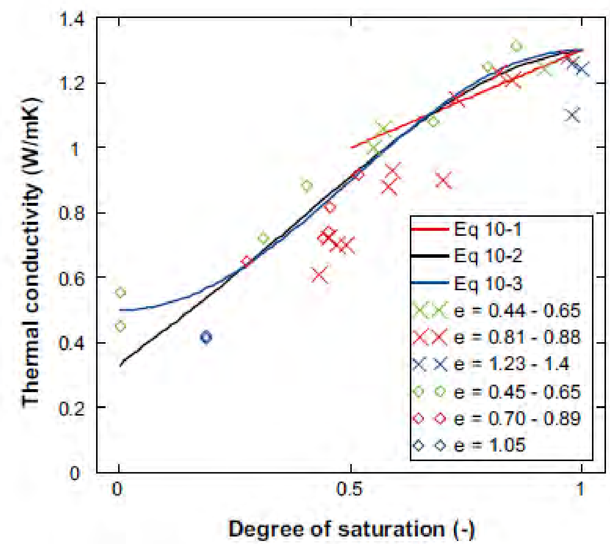
Red: Code Bright
Black: Claytech
Symbols: measured

Hydraulic properties



Thermal properties



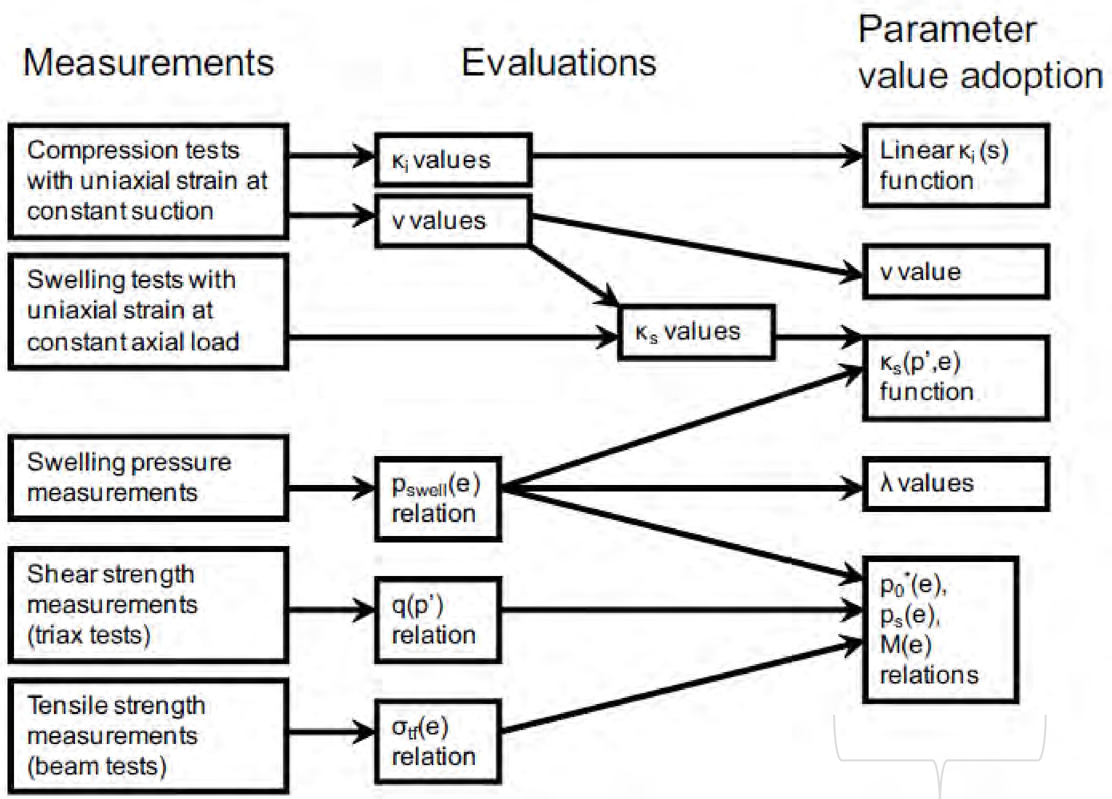


1. $$\lambda(S_r) = \lambda_{dry}(1 - S_r) + \lambda_{sat} \cdot S_r$$

2. $$\lambda(S_r) = \lambda_{sat}^{S_r^{\,n}} \lambda_{dry}^{(1-S_r)^{\frac{1}{n}}}$$

3. $$\lambda(S_r) = \lambda_{dry} \cos^2(\pi S_r / 2) + \lambda_{sat} \sin^2(\pi S_r / 2)$$

Measurements - Evaluations - Parameter value adoption

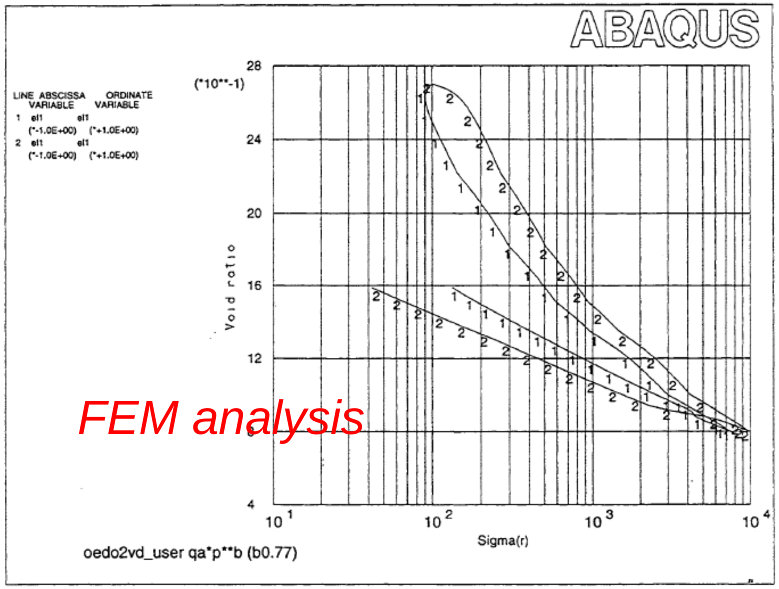


Parameters for advanced constitutive model – ***Code_Bright***

Strategy for adoption of mechanical parameters (= compromise)

Success ?

Proof is needed !



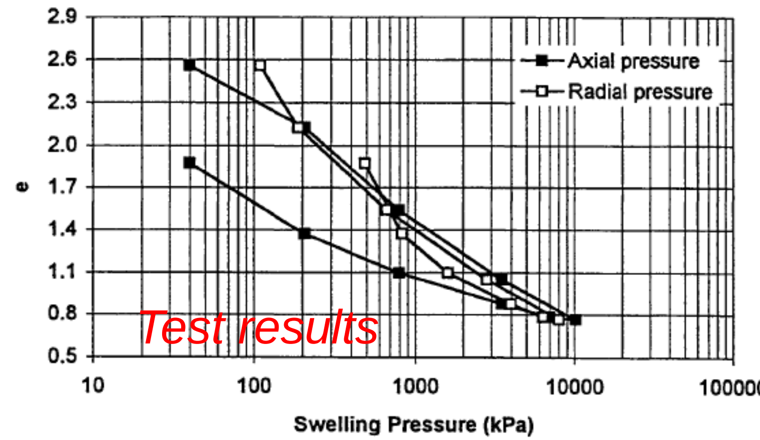
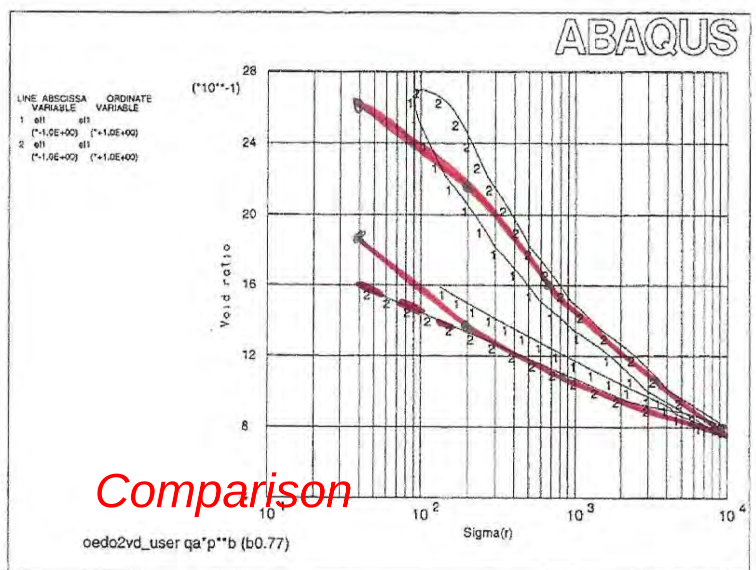
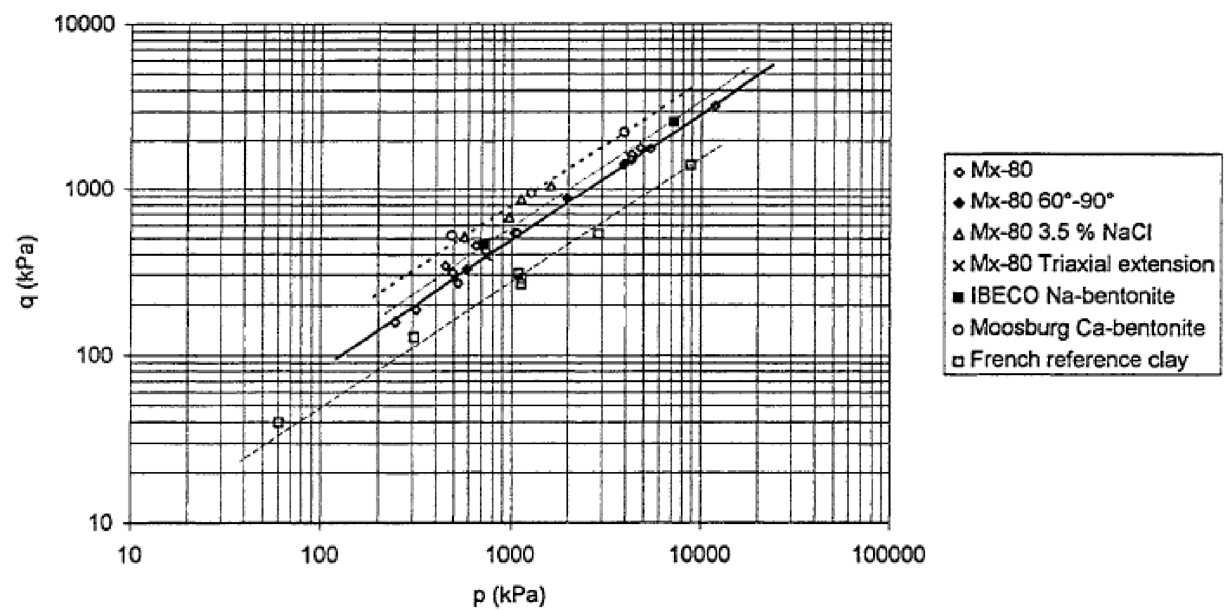


Figure 5-9. Measured pressures at a compression-swelling test on MX-80 made in the laboratory (KMXAR4).



Prediction and Performance

- Failure occurs at the correct Mises stress (according to Fig 3-6).
- The stress-strain curve is non-linear in the same way as in the real test.
- The void ratio decreases from 0.65 to at minimum 0.626 and then starts to increase slowly. The corresponding volume decrease is 1.5%, which is in the same range as achieved in the measurements (1%-3%).



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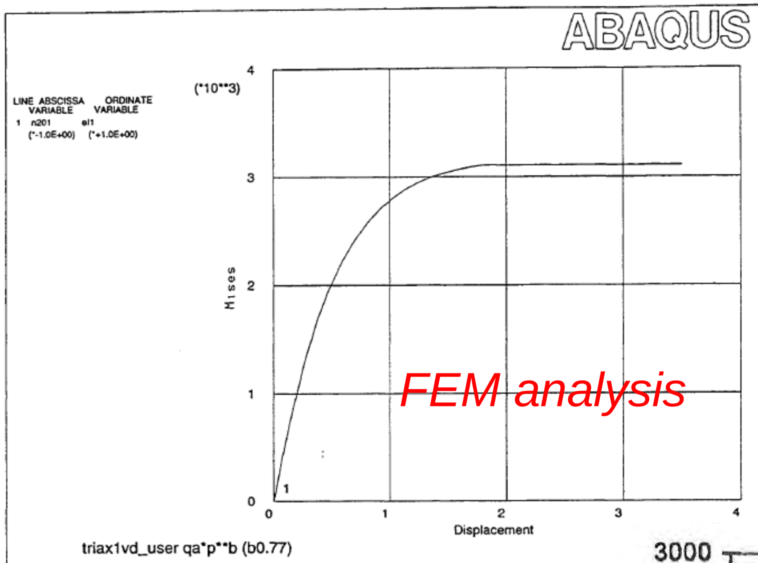

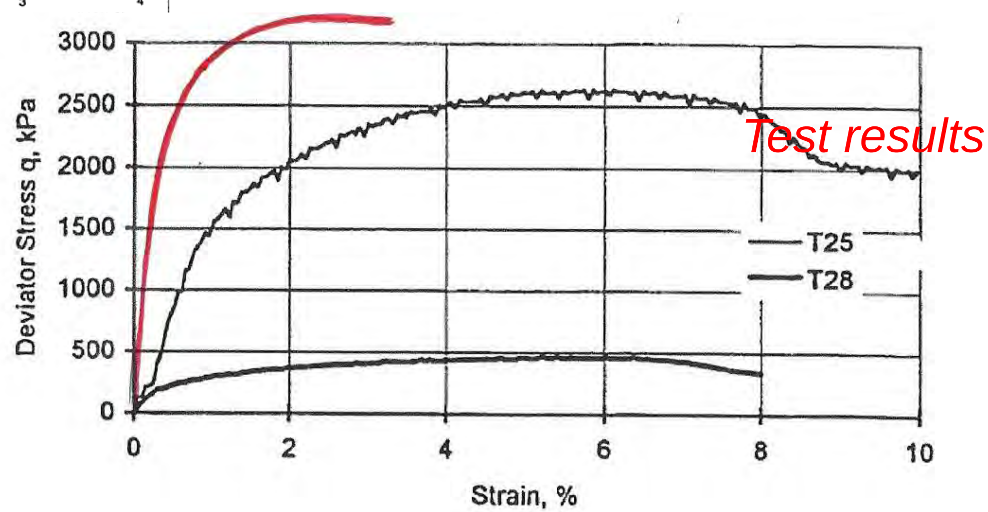

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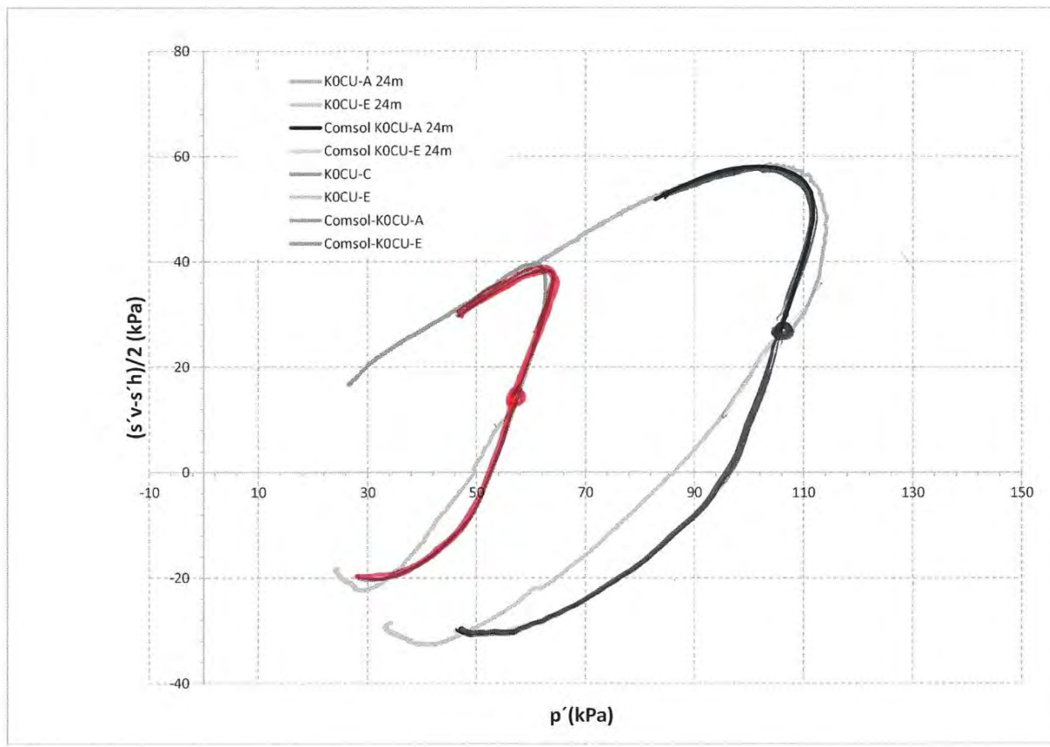
(Not given in chapter 2)

A similar scheme for Clay/tech model is not available

An example from the geotechnical field:
triaxial tests on soft clay



It is evident that:

- all data exhibit some or substantial scatter
- several equations are not suited for describing behavior over a wide range of values
- the number of influencing factors is large
-

Necessary additional verification/information:

Prediction of and comparison with tests with different boundary conditions Several of the tests used for evaluating the parameters, should be predicted by the model and again compared with real performance.
This should also be done for the tests on which the evaluation was based.

Based on the above suggested testing, some kind of optimization of the parameters could probably be made

In TR-10-44, Sections 10.8 -10.10 parameters describing the mechanical behavior are given for the Code Bright and Abaqus models. Similar strategies should be illustrated for hydraulic and thermal properties

It is desirable with some kind of quantification of to what degree the constitutive model is able to predict basic behavior. Ranges for suitable choice of parameters can probably be given

Necessary additional verification/information:

I could "design" or suggest a number of tests and test series that could be used as bench mark examples related to:

- deformation and swelling
- strength
- resaturation
- homogenisation
- homogenisation when a block is missing
- flow characteristics
-
-

THM
+ other processes

2. Basic Behavior

*Task: Model and predict behavior for a **complex model***

Test performance
- model scale
- full scale

Prove the prediction capability

Not until then can it be used for Predicting outcome of Critical Scenarios not possible to model in a physical model

Compare with requirement

Important to

Model and predict behavior

for a

Complex model

in order to bench mark
the capabilities of the model

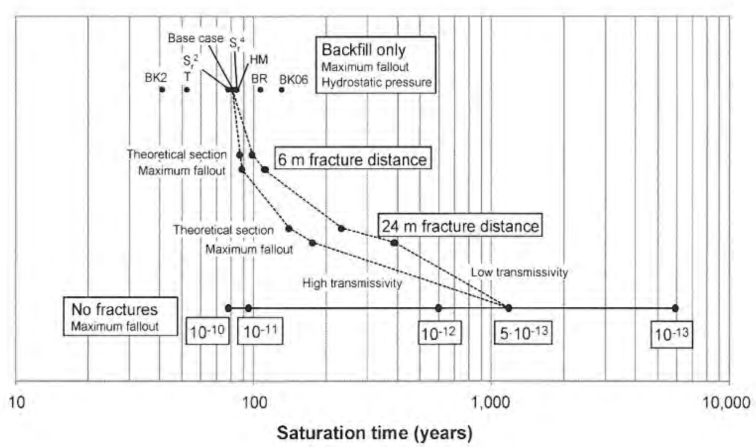
CRT - Canister Retrieval Test

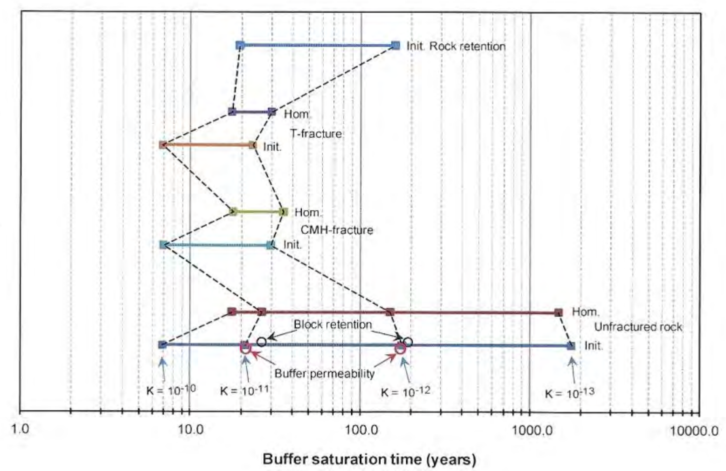
THM
+ other processes

2. Basic Behavior

*Task: Model and predict behavior for a **complex model***

Prediction of saturation of buffer and backfill





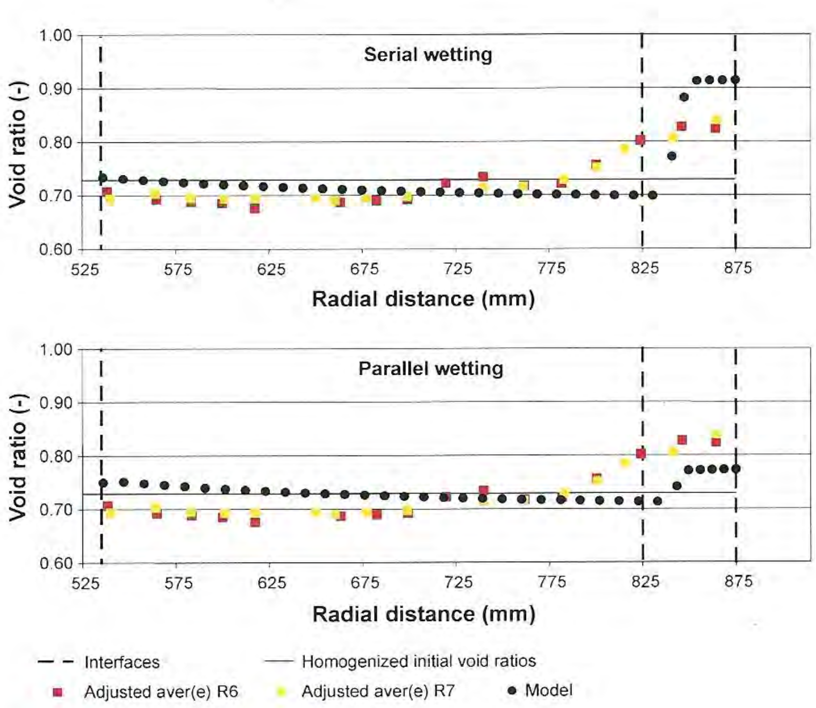
Time to saturation: 10 to approx. 2 000 years
Conclusion: Rock conditions/properties constitute the main influence

THM
+ other
processes

2. Basic Behavior

Task: Model and predict behavior for a ***complex model***

Prediction of saturation of buffer and backfill



The ***uncertainties*** are mainly the ***material models***, which are very complicated,
And the ***parameter values***

1. Background, Scope & Limitations

THM
+ other processes

3. External Scenarios.

a. Earthquakes – Shear
b. Earthquakes – Liquefation
c. Freezing

2. Basic Behavior

4. Internal Scenarios

6. The Real World

5. Other Processes - Piping and Erosion

THM
+ other processes

3. External Scenarios

3.a Earthquakes - Shear

THM assumption

- Base case
- Variations of critical parameters within wide ranges
- Complemented with rate dependent stiffness

- Local yielding will occur in the canister
- Numerous results, but lacking generalizing conclusions

Uncertainties pointed out by the authors

- Properties of the cemented buffer (**Na**/Ca)
- Old data on copper properties (yield properties)
- Contact elements no cohesion at tensile stress
- The size of the element mesh might affect the results.
- Scatter in material properties not accounted for
- c=0 for wall friction which is low

THM
+ other processes

3. External Scenarios

3.b Earthquakes - Liquefaction

THM assumption

- Base case
- Variations of critical parameters within wide ranges

A major conclusion is hence that there is no risk of liquefaction of the engineered soil barriers in a KBS-3 repository even for very significant earthquakes.

Conclusion: ***Liquefaction under the canister is Not an issue!***

THM
+ other processes

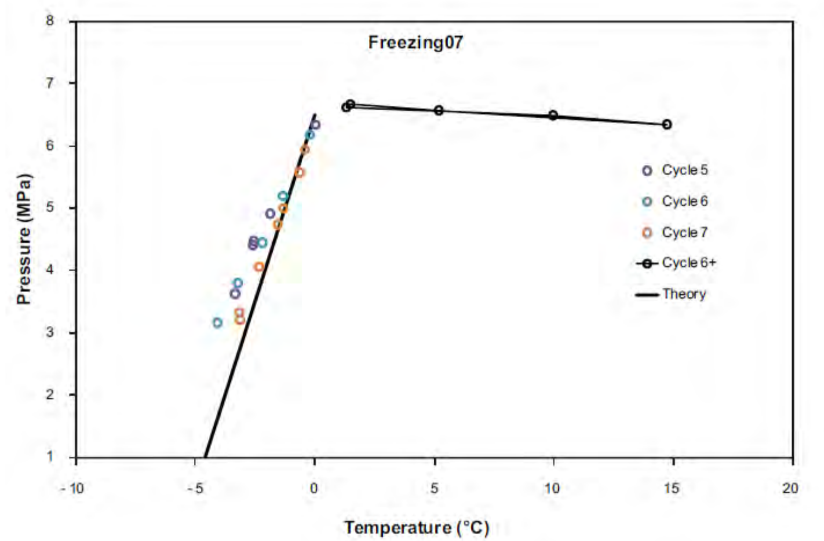
3. External Scenarios

3.c Freezing

THM assumption

- Base case
- Variations of critical parameters within wide ranges
- Temperature > -2 degrees C

$$P_s(w,\Delta T) = P_s(w,0°C) + \frac{\Delta s(w)}{v_{clay}(w)} \cdot \Delta T$$



Conclusion: ***Freezing of the buffer and backfill is Not an issue!***
(At least not for the temperature scenarios given)

1. Background, Scope & Limitations

THM
+ other processes

3. External Scenarios.

2. Basic Behavior

4. Internal Scenarios

a. Uplift
b. Settlement
c. Homogenisation

6. The Real World

5. Other Processes
- Piping and Erosion

THM
+ other processes

4. Internal Scenarios

4.a Swelling/Uplift

THM assumption

- Base case
- Variations of critical parameters within wide ranges

Buffer/backfill

- wet/wet
- wet/dry
- (dry/dry)
- (dry/wet)

Advanced Abaqus calculations show that the safety functions will be upheld.

Uncertainties:
- mobilization of friction at rock surface
- homogenisation

THM
+ other processes

4. Internal Scenarios

4. b Settlement of the canister

THM assumption

- Base case
- Variations of critical parameters within wide ranges

- •Creep model (Singh and Mitchel)
- Bearing capacity failure only if φ' <0,5 degrees

no problem

Result: Settlement < 2 cm for the worst case

Conclusion: ***Settlement of the canister is Not an issue!***

THM
+ other processes

4. Internal Scenarios

4. c Missing blocks - homogenisation

THM assumption

- Base case
- Variations of critical parameters within wide ranges

Ample modeling of several missing blocks

Very little testing under idealized conditions
And no testing for actual assumed geometry

It is evident that:

- all data exhibit some or substantial scatter
- sinking of the canister is not a problem
- liquefaction is not a problem

Necessary additional testing and verification:

Tests of homogenization under ideal conditions (element tests) where a void exists

Tests of homogenization with relevant geometry (model tests) where a block is missing

Comparison of model prediction and test performance

1. Background,
Scope & Limitations

THM
+ other processes

3. External Scenarios.

2. Basic
Behavior

4. Internal Scenarios

6. The Real World

5. Other Processes
- Piping and Erosion

THM
+ other processes

5. Other Processes

5.a Erosion/Piping

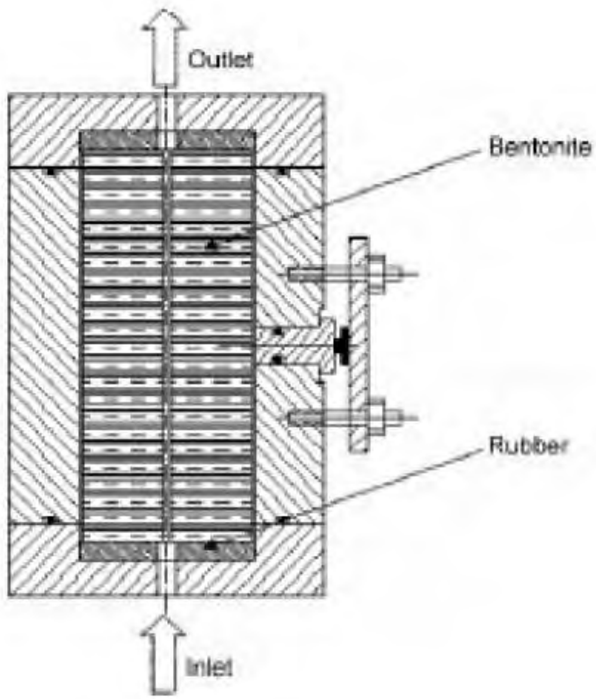


Figure 4-1. *Design of the basic tests and example of piping channel in tests with an outer slot.*

THM
+ other processes

5. Other Processes

5.a Erosion/Piping

Some testing done

R-06-80:

-"Piping, erosion and subsequent sealing is a complicated process … much depending on the hydraulic properties of the rock"

"The uncertainties are considerable …

"The knowledge of when piping and and erosion occur and the consequences are not enough known today"

5. Other Processes

5.a Erosion/Piping

Some testing done, but

- More “real world” tests are necessary
- internal piping must be provoked
- testing of the ability of self-healing due to swelling missing
- Pressure or gradient dependent
-
-

1. Background,
Scope & Limitations

3. External Scenarios.

THM
+ other processes

2. Basic
Behavior

4. Internal Scenarios

6. The Real World

5. Other Processes
- Piping and Erosion

THM

+ other processes

6. The Real World

Mining

Transportation

Preparation

Buffer
+
Backfill

Compressing

Transp + storing

Placing

Maintaining

Closing

THM

6. The Real World

- Premises
- Reference design
- Conformity of reference design to premises
- ***Production***
- Initial state

Production

- A large number of equipment, methods and procedures still remains to be developed and tested.

- Inspection methods and strategies need to be developed

- Sampling strategies and acceptance criteria for each stage of production needs to be developed

- QA … .. . organization and book-keeping