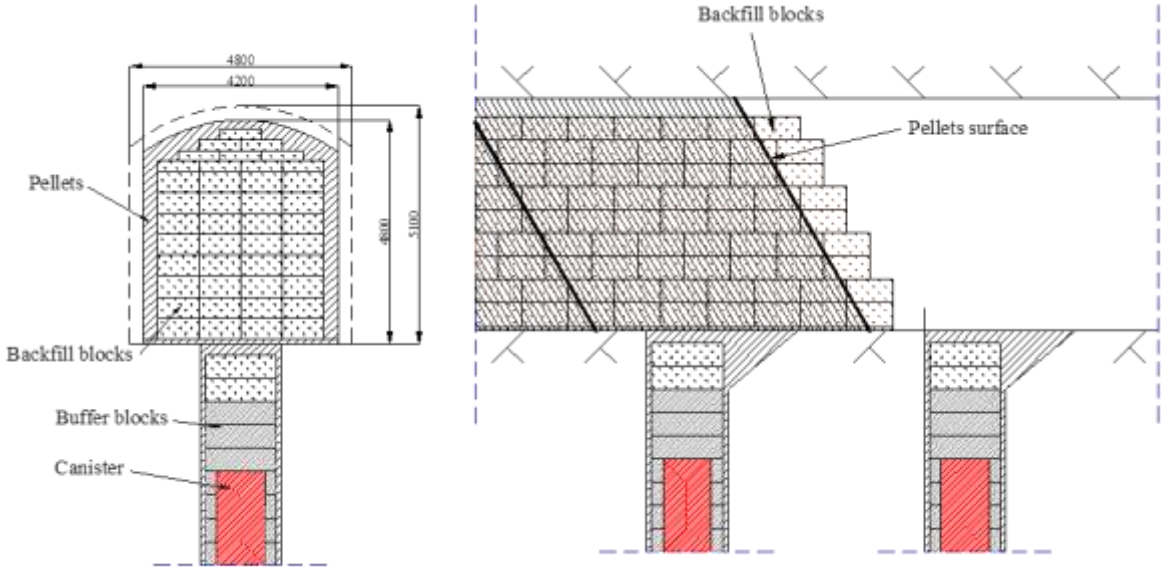
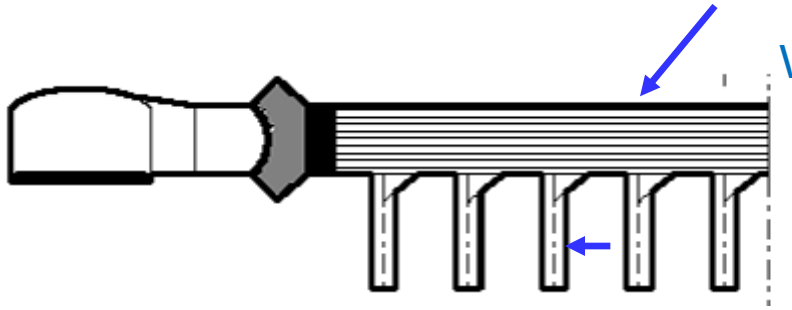
Piping and Erosion during the saturation stage
The Eva Project

The answer to Round 2 indicates that no performance confirmation activities related to bentonite piping and erosion are planned. Is this correct? Given the potential importance of SKB's assessment of these properties to overall performance, would it not be prudent that SKB provides multiple lines of evidence regarding their assessment

Background





Where does water enter?

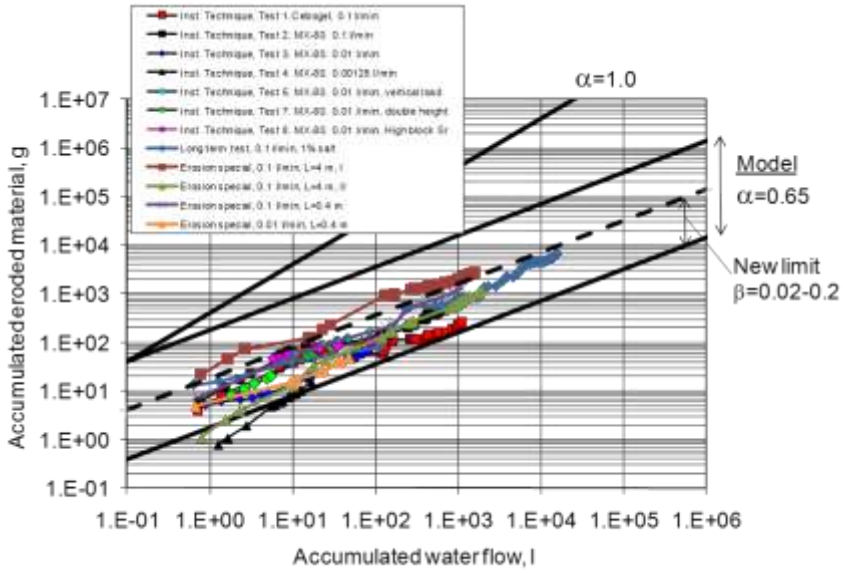
Erosion – inflow criteria

- Analyses of the consequences of expected erosion in the deposition holes
- SR-Site restrictions:
  - <100 kg erosion acceptable
  - Inflow restrictions into tunnels (<5 l/min) and dep holes (<0.1 l/min)
  - Total empty space in a tunnel (incl. 20% leakage) = 1250 m^3

Water inflow and acceptance table

		Inflow into dep. holes l/min				Erosion model
		>0,1	0,01 -0,1	0,001 -0,01	< 0,001	
Inflow into tunnel l/min	>10	35	22	58	864	SR-Site
						New model
	1-10	83	48	123	1626	SR-Site
						New model
	0,1-1	16	62	167	2566	SR-Site
						New model
	<0,1	0	7	31	1208	SR-Site
						New model

All cases OK	
Some cases OK	
No cases OK	
Inflow restrictions	



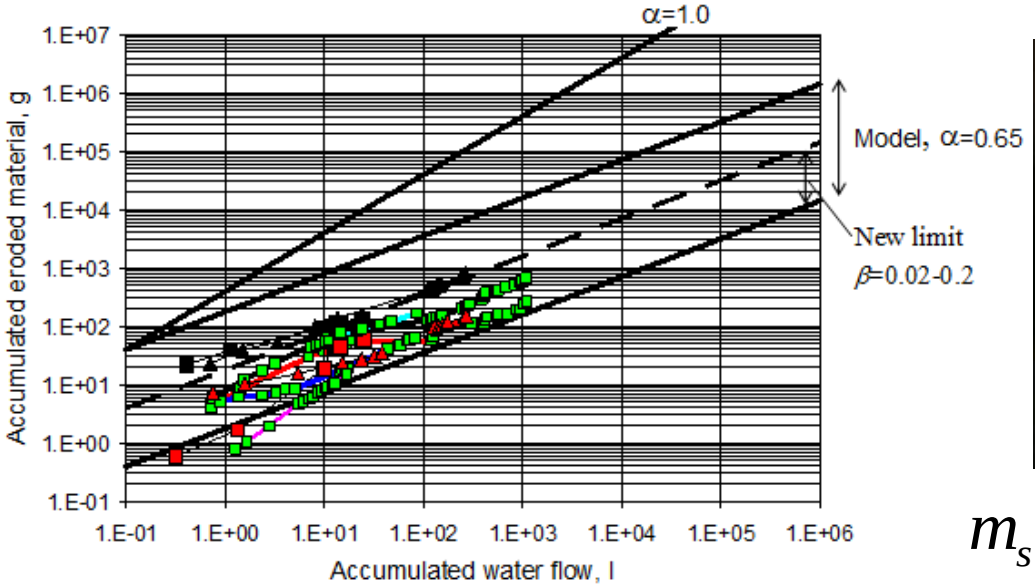
Objectives

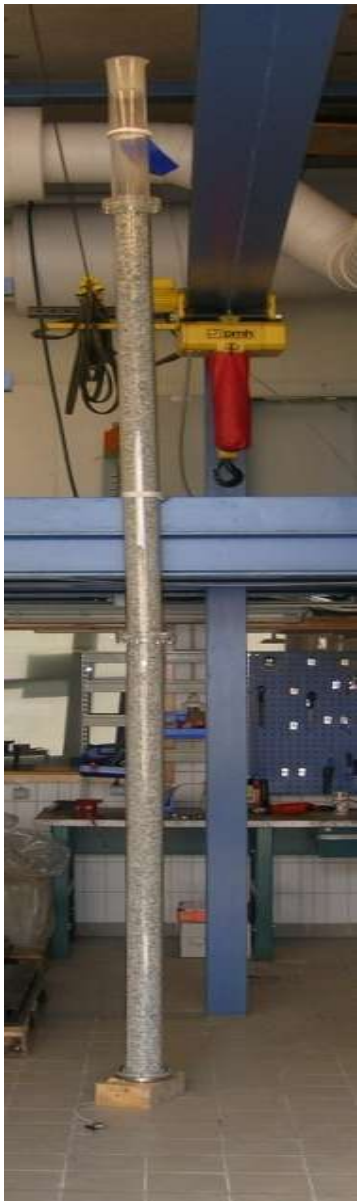
- The purpose of the project is to develop an improved model for the processes:
  - Piping
  - Erosion
  - Water filling of pellets filled slots
  - early water absorption and resulting water pressure increase against the plug.
- This project intends to study the effects of water inflow in deposition holes and deposition tunnels and the emergence of piping and erosion during installation and wetting of the buffer and backfill until slots and pellets have been water filled and piping and erosion have ceased, which means that the plug takes water pressure gradient
- Create a quantifiable conceptual model, based on a detailed description of the system with elements of theoretical and empirical submodels (semi-empirical)

Process	Model	Investigations
Erosion	Function associated with the different dependencies v_e = f (a, b, c, d, …). Probably empirical, but if possible supported by a theoretical model	Laboratory tests and theoretical analyses
Piping	Conceptual model possibly combined with theoretical models	Laboratory experiments, theoretical analyses and mechanical HM-modelling
Water flow in pellet filled slots	Conceptual model. If possible an empirical model	Laboratory studies
Sealing ability	Conceptual model of process understanding possibly combined with theoretical models	Laboratory experiments, theoretical analyses and mechanical HM-modelling
Water absorption of bentonite blocks	Numerical FEM-model	Modelling of various cases and checking with laboratory experiments
Formation of water or gel pockets in pellet filled slots	Numerical FEM-model or conceptual model	Laboratory experiments and numerical modelling of some case where this happens (if!)
Outflow of bentonite gel	Numerical FEM-model or conceptual model	Laboratory experiments and modelling of some case where this happens (if!)
Buffer swelling before placement of backfill	Conceptual model	Made in another project

Erosion during the saturation phase

- In SR-Site an empirical model for erosion was used
  - Model based on a number of tests
- In Eva, the following effects will be measured:
  - Erosion magnitude as function of time
  - The material composition of the eroded bentonite
  - The location of the erosion
    - will it be at the inflow point or along the entire channel?

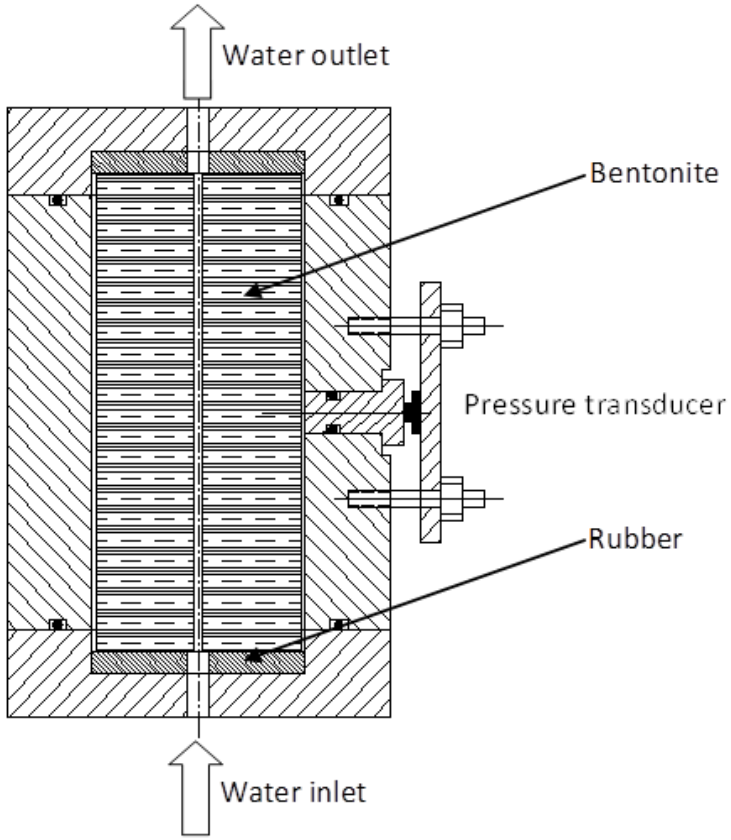




$$m_s = \beta \times (m_w)^{\alpha}$$

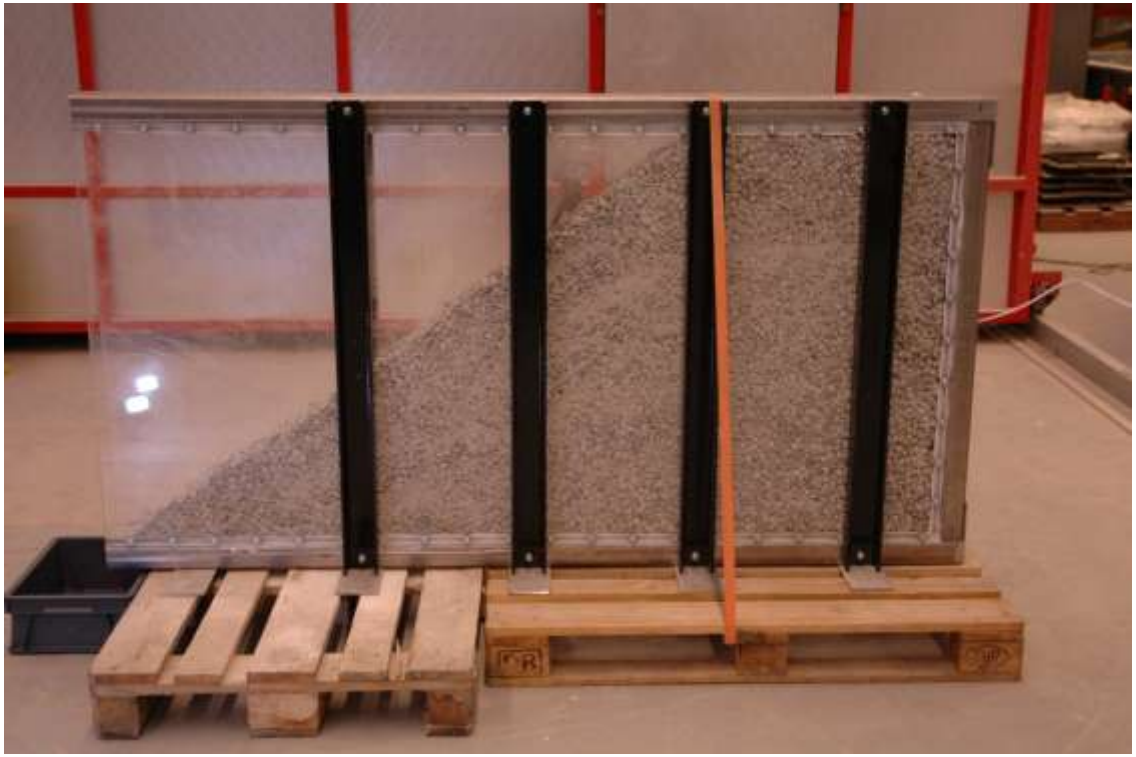
Piping

- The piping tests aim at studying:
  - When piping occurs
- The process is connected to :
  - Water uptake,
  - The swelling
  - Erosion



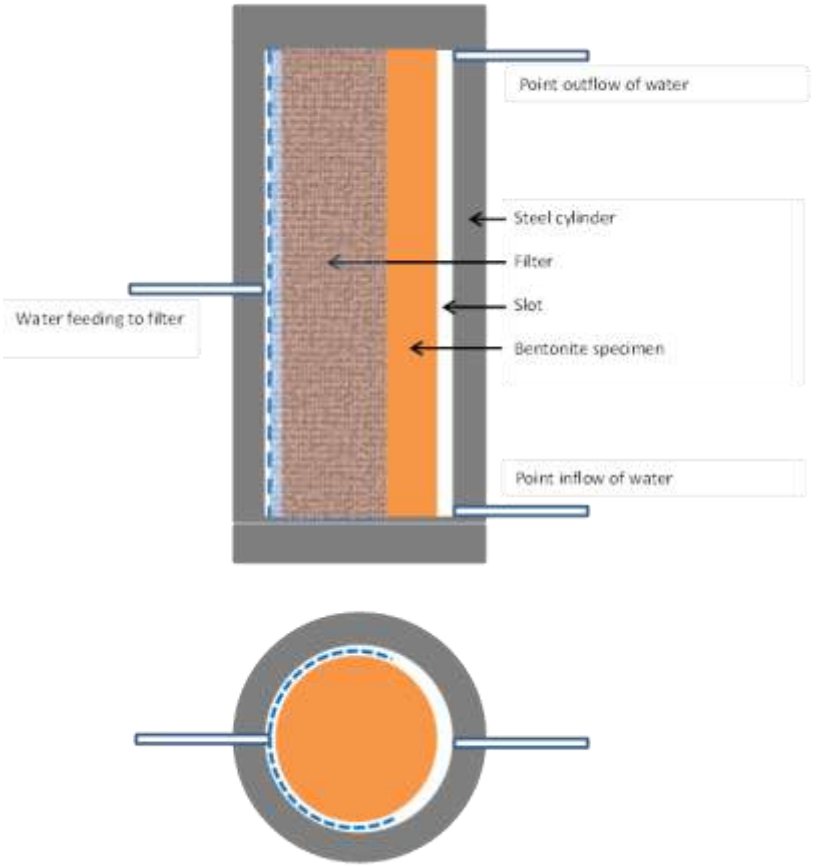
Water flow in pellet filled slots

- Several tests was done in the past
- The scatter in observations is large
- Repetition of tests



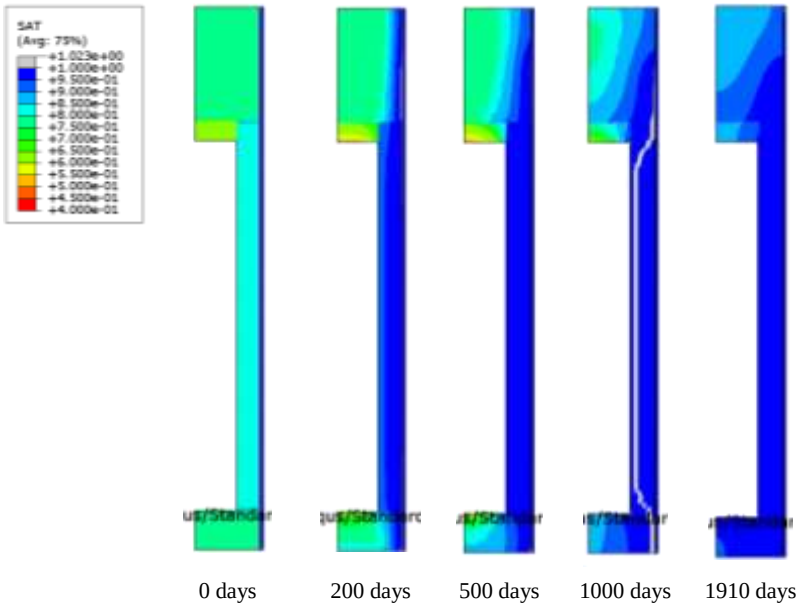
Sealing ability

- The swelling pressure in the pellet filling is too low to prevent piping
  - The water pressure that builds up when inflow is prevented can be several MPa
- Other sub-processes can cause sealing:
  - The bentonite blocks swell and compresses the pellet filling
  - Vault formation in the pellet filled slot



Water absorption in bentonite blocks

- Good models of water absorption in bentonite
- Can be studied theoretically by FEM-modeling
- Possibly a scale test can be done to verify the modelling results
- Field tests at Äspö can also be used



Formation of water or gel pockets in pellet filled slots

- If piping does not occur because the bentonite seals
- A water pressure from the inflowing rock water will be generated
- If the water pressure produces a slight displacement in the pellet filling an opening that provides a large total pressure against a surface may occur
- Which can give rise to further displacements that increases the size of the opening
- This process can result in large parts of the pellet filling is displaced and that large water or gel pockets are formed

Outflow of bentonite gel

- Cannot take place unless piping is prevented
- Also requires either:
  - Gel formation in a water pocket that is squeezed through unwetted pellets filling
  - That the pellets filling has been wetted (but not consolidated by the swelling blocks) so that it forms a loose gel that can be squeezed out through unwetted pellets filling

Self-sealing of cracks by eroding water