LARGE-SCALE BACKFILLING SIMULATIONS AT ÄSPÖ HRL AND APPLICABILITY OF RESULTS TO CANADIAN REPOSITORY CONCEPTS

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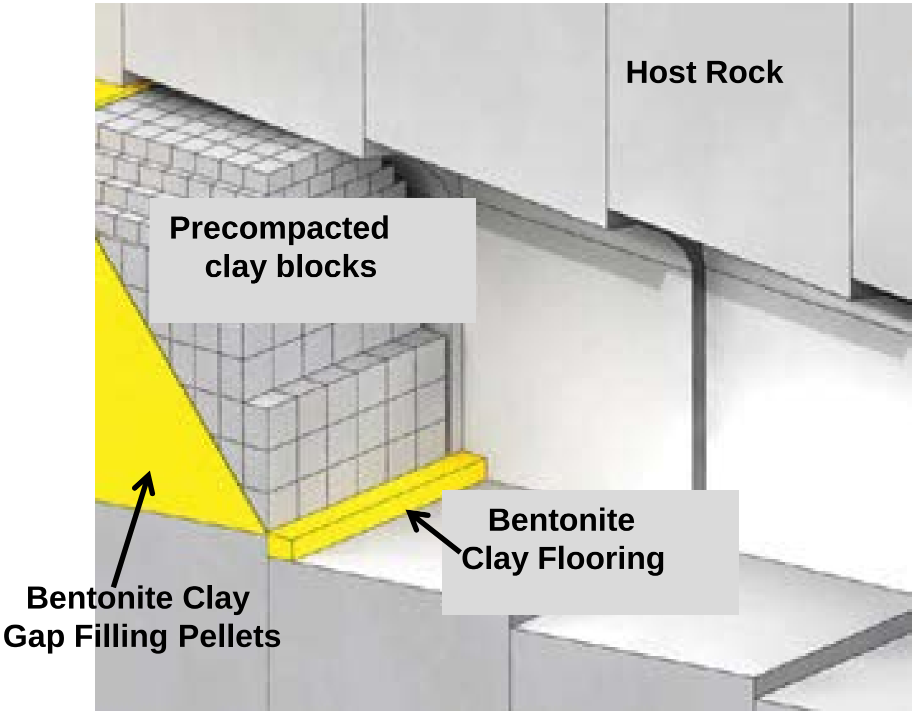
Background

- NWMO's APM approach to permanent disposal of used nuclear fuel includes ongoing evaluation of placement geometries and host media,
- Options considered by NWMO includes granitic host rock and in-floor borehole (IFB) placement of containers holding used nuclear fuel.
- SKB (Sweden) and Posiva (Finland) have selected IFB option as their reference design.
- As part of design process, SKB and Posiva are evaluating effect of water inflow on backfill behaviour.

Testing of Backfilling Concept

- SKB and Posiva have active research programs focused on development of backfill and backfilling technologies.
- One activity is evaluation of backfill in the period immediately following its installation.
- NWMO provided in-kind contributions to the SKB-Posiva BACLO project as part of its ongoing concept evaluation work (Results from small-scale backfilling simulations completed in Canada by AECL).
- Results of several subactivities have been published by SKB, Posiva, NWMO and/or presented at international conferences.

Tunnel Backfilling Using Blocks and Pellets



•Crushed or pelletized swelling clay is used to level floor,
•Precompacted clay blocks are then installed,
•Blocks fill the majority of the room volume (>70%), and
•Remaining gaps are filled with clay pellets.

Purpose of Studies

Evaluate materials and methods for placement tunnel backfilling in a repository in crystalline rock.

Determine the effect of inflowing water on system performance immediately after backfilling.

Regardless of Geological Medium: Backfill needs to be:

- Technically feasible to install (5-8 m/day SKB & Posiva concepts)
- Able to resist disruption by inflowing water during ongoing backfilling operations.
- Able to accommodate inflow of water without having its long-term behaviour compromised (swelling, hydraulic and mechanical)
- Safe, not result in development of conditions that might be dangerous to closure or repository operation.

Aspects Evaluated

Evaluation of <u>behaviour of backfill immediately following its placement</u> has included:

- *Testing placement technologies and determining achievable as-placed backfill densities.*
- *Identifying conditions or processes causing instability of the backfill or that make backfilling operations problematic.*
- *Determining water inflow rate where backfill stability is compromised, specialized water handling, or remediation of adjacent rock is likely to be needed.*
- *Evaluating the effect of water inflow pattern (point sources, dispersed seepage) on backfill behaviour.*
- *Determining effect of isolated and pressurized sections on system behaviour prior to tunnel closure.*

Tests to Evaluate Materials and Interactions

Bench-Scale
(SKB and Posiva)

1/12th Scale
(NWMO)

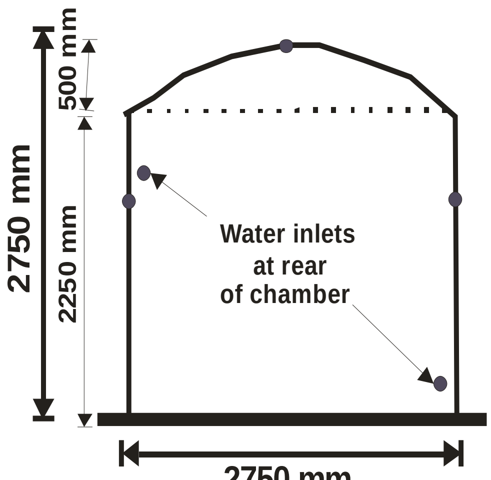
¼-Scale
(Posiva and SKB)

½ Scale Mockup
(at Äspö Sweden, Joint SKB/Posiva)

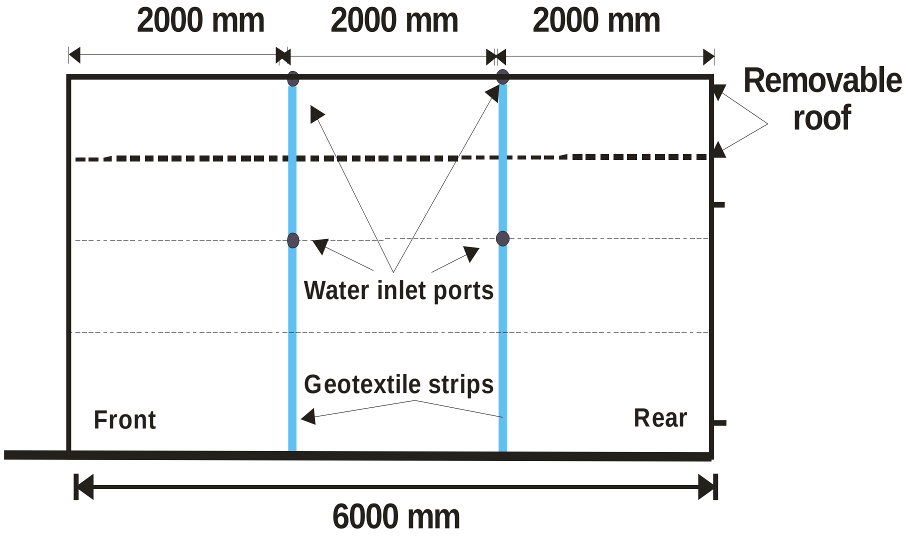
Results of Small-Scale Tests

- Laboratory and Bench-Scale tests undertaken by SKB, Posiva and NWMO indicate that backfill can develop preferential flowpaths
- Pathways are generally at interfaces (rock-pellet; pellet-block)
- At very low inflow (< ~0.1 l/min) these features were generally non-erosive and were not physically disruptive
- Small flow features can combine into a single pathway, causing increased erosion
- Removal (erosion) of clay can be affected by:
  - Water velocity (> velocity > erosion),
  - Salinity (higher salinity > erosion),
  - Clay block density, and
  - As-Placed density of backfill pellets.

½-Scale Chamber Used to Evaluate Post-Placement Backfill Behaviour



Front View

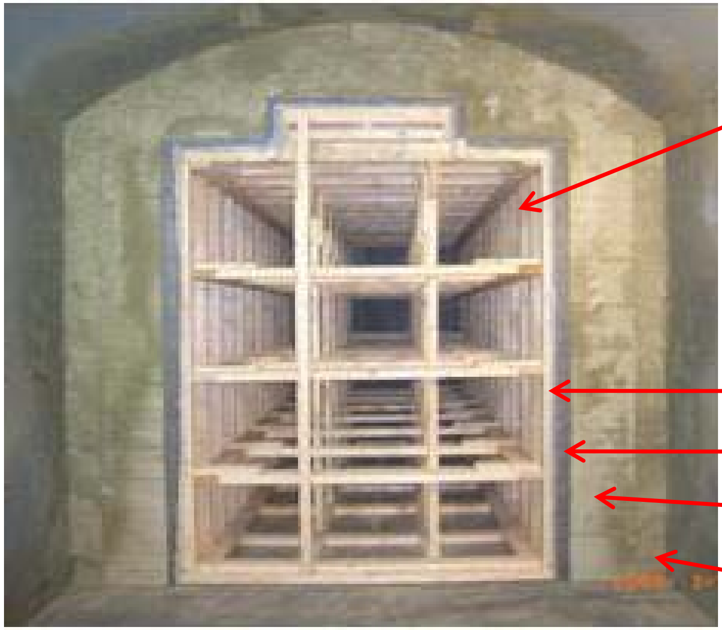


Side View

Construction of ½-Scale Tests

½-Scale test design took into account results of previously completed, smaller-scale tests, Specifically that:

- Initial flow is controlled by pellet fill,
- Interior block-fill generally plays little role in water movement.
- Substantial swelling pressures can develop in pellet-filled regions.



Mockups consist of:

- Robust wooden formwork occupying tunnel core,

-Internal formwork protects the test chamber by ability to fail should swelling pressures approach ~ 500 kPa.

- Heavy plastic internal liner

-Bentonite geotextile outer liner,

-300 mm of precompacted clay blocks,

-100+ mm of pellet fill at perimeter.

Water Movement and Clay Erosion Caused by Point-Source of Inflow

Initial Appearance

Inflow 0.25 l/min left, 0.5 l/m right
Test duration 168 h,
Initial outflow @ 24 h

Inflow 2.5 l/min right side
Test duration 65 h
Initial outflow @ 0.5 h

Path length ~4 m
Water supplied to rear of chamber

½-Scale Test Results: Part 1: Point Inflow to Tunnel

Incoming water prefers to move along "rock" – clay interface:

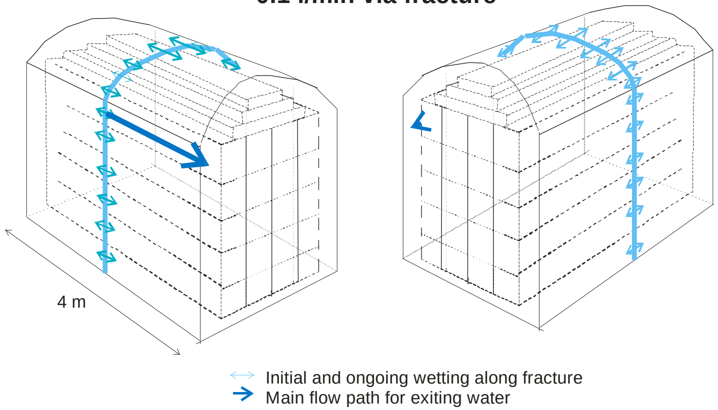
- At < ~0.1 L/min,
  - Water movement gradually into pellets (and blocks)
  - Exiting water had essentially no suspended or entrained solids.
- At ~0.1 to ~0.25 L/min,
  - Water movement and erosive action increased with inflow rate.
  - Erosion rate was low, decreasing with time (stabilised flow path).
- For point or combined inflows >0.5 L/min,
  - Water moves rapidly downstream, only localized water uptake.
  - Considerable erosion of the backfill pellets.
- At > ~2.5 L/min,
  - Water moves rapidly towards open section of tunnel,
  - Substantial erosion of pellet materials,
  - Erosion of blocks can also occur.

Part 2: Water Inflow Via Intersecting Fractures

- Effect of a dispersed wetting (e.g. intersection of tunnel by water-bearing fractures)
- Tests simulated the effect of water supply by fracture-only and also effect of subsequent upstream wetting of a hydraulically isolated section of tunnel.
  - Geotextile strips simulated an intersecting fracture,
  - Water was supplied to geotextile-only or in combination with point source(s) at rear of chamber,
  - Resistance of isolated pocket to water entry was monitored as were conditions at the “fracture” features.
  - Ability of the pellet-filled region to “store” water was evaluated.
  - How water moved past gaskets formed by seeping fracture features was monitored.

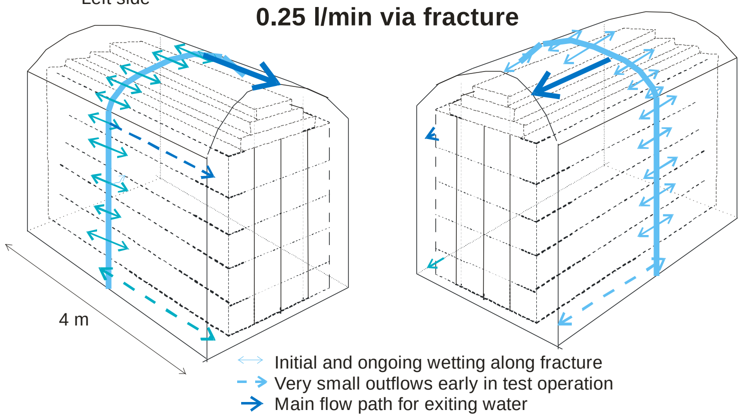
Water Inflow From Intersecting Fracture (inflows 0.1 and 0.25 l/min for ~ 300 h)

Test 1
0.1 l/min via fracture



Relatively uniform water uptake; water movement via a single pathway; no erosion at 0.1 l/min and discernible erosion at 0.25 l/min

Test 2
0.25 l/min via fracture



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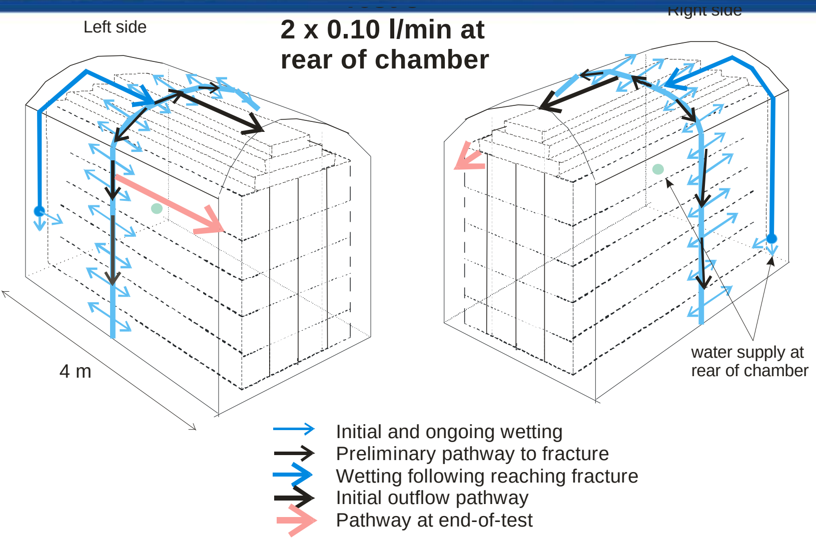
Water Movement Past A Seeping Fracture



Downstream of fracture no block wetting

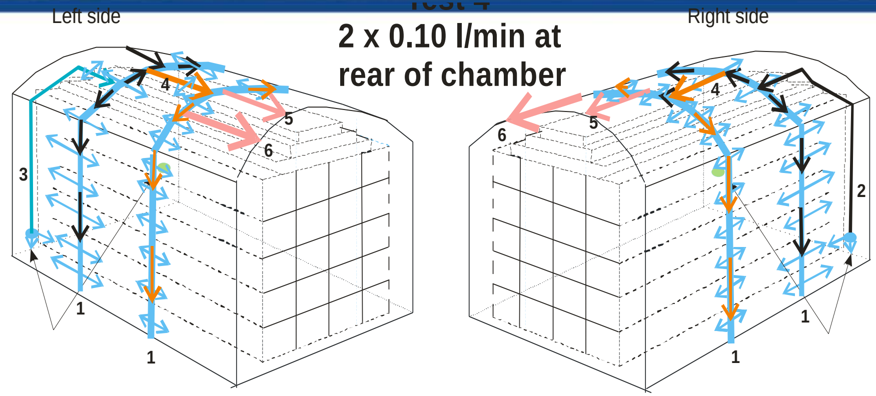
Block wetting at fracture location

Upstream of fracture, extensive block wetting

Summary of 270 h Test

- Presence of a fracture-isolated section of tunnel resulted in pressurization of trapped air,
- Outflow was delayed (~5 days) by “gasket” feature,
- Substantial water storage upstream of fracture
- Breaching involved sudden expulsion of air-water-clay mix.
- A highly conductive and erosive flow path was formed.

Water Movement Past Successive Isolating Features



1 Initial and ongoing wetting via fractures
2 Preliminary pathway to fracture via right side
3 Preliminary pathway to fracture via left side
4 Pathway from inner to outer fracture
5 Pathway from outer fracture to front of chamber
6 Pathway at end-of-test

Dry blocks at downstream

Limited wetting at inner fracture

Extensive wetting behind inner fracture

Summary of ~325 h Test

- Wetting by fracture isolated a section of tunnel, resulting in pressurized of trapped air,
- Start of outflow was noticeably delayed (~5 days)
- Water storage upstream of inner fracture but not outer,
- Breaching involved sudden expulsion of air-water-clay mix.
- A highly conductive and erosive flow path was formed.

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Summary

- Inflowing water has potential to disrupt newly installed backfill,
- Pellet-rock interface seems to be the preferred flow path. For low flow (<0.1 L/min), this does not result in substantial erosion,
- Disturbance is likely at > ~0.25 L/m inflow via a single pathway,
- Where pellet thickness is low, water may enter block-filled volume, generate flow paths at clay-block or block-block interfaces,
- Seepage from fractures can lead to development of isolated sections of tunnel where pressurized air pockets form,
- Uncontrolled air release prior to installation of the mechanical plug at end of the placement room can cause backfill disruption,
- After plug installation piping, interface flow or trapped air movement should not be a problem.

Relevance to NWMO Repository Concept

- Backfill formulations and installation methods developed and demonstrated in SKB-Posiva Tests have potential for use in NWMO DGR concept.
- Potentially disruptive processes have been identified (high point inflow, development of isolated pockets of compressed air).
- Relevant to NWMO concepts as they have potential to exist in any geological medium where water is entering excavations.
- Reinforces importance of pre-screening deposition tunnels for high-inflow features.
- Highlights importance of inflow water-management during backfilling operations.

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