



UPSCALING HOMOGENIZATION EXPERIMENTS OF BLOCK-PELLET SYSTEM FOR KBS-3V FINLAND APPLICATION

Beacon Initial Workshop and Kick Off
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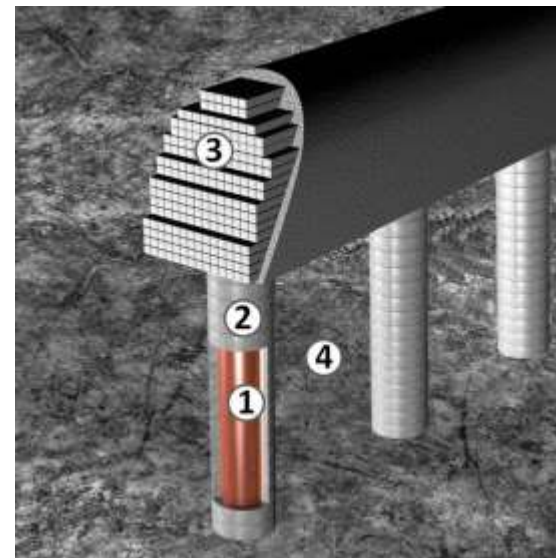
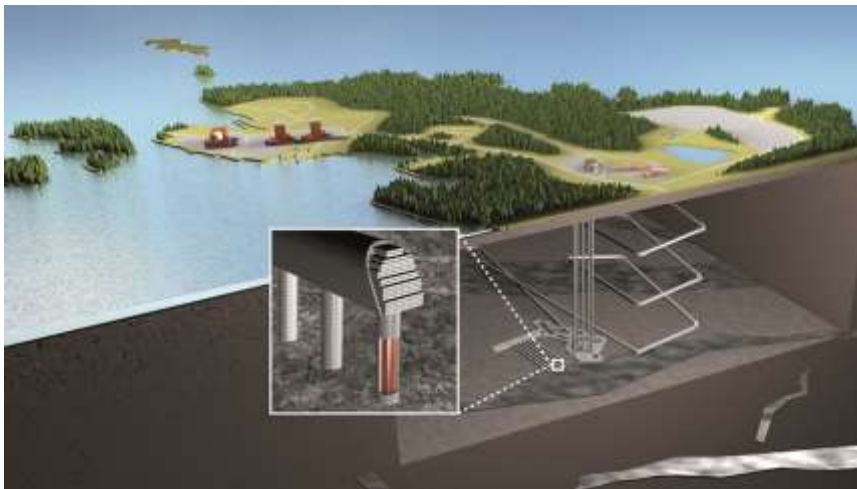


Presentation Overview

- Background
 - Medium scale
- 2 Large-Scale Experiments (dismantled already):
 - Buffer Backfill Interaction Test (laboratory, 1/6 scale)
 - 40% Scale Buffer Test (in-situ, ONKALO)
 - Both contain lesson applicable to BEACON

Introduction

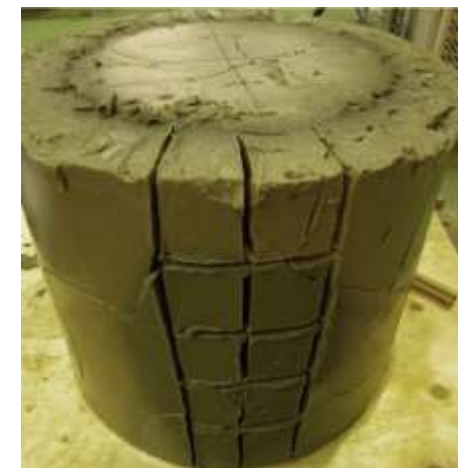
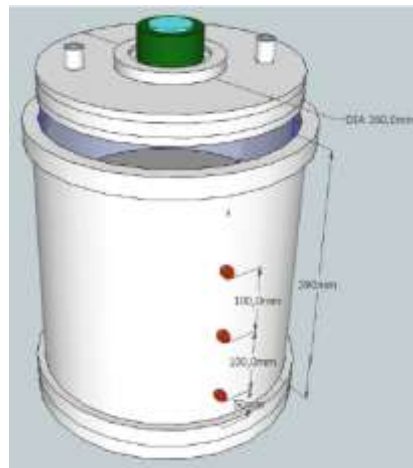
- Posiva's nuclear waste disposal technologies have been investigated since 1970s
- Start of final disposal scheduled in 2020s at Olkiluoto at a depth of 400-450 m
- Multi-barrier concept KBS-3V



- 1.Canister
- 2.Bentonite buffer
- 3.Tunnel backfill
- 4.Bedrock

Background: Previous medium-scale research

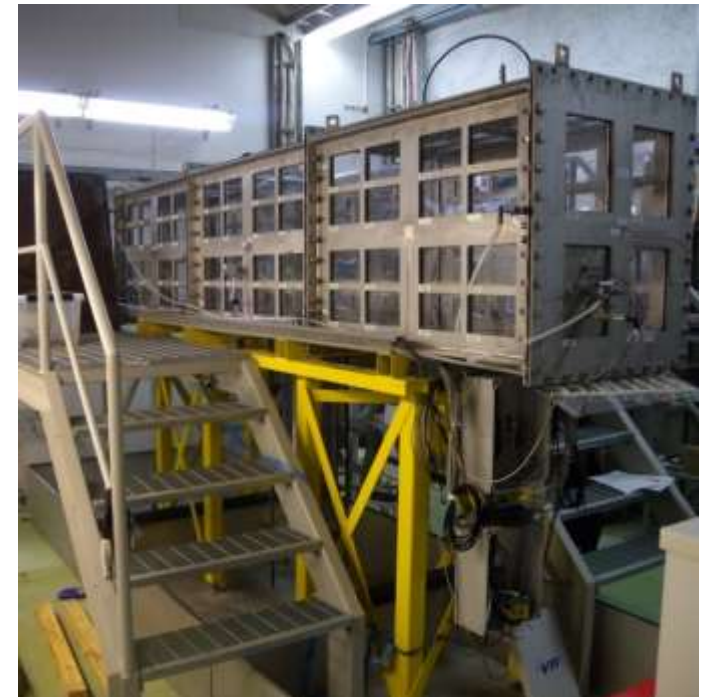
- Initial & early age focus
- Single & combined components
 - Buffer block swelling tests
 - Pellet filtration tests (glass/tube)
 - Gap filling tests (small/large scale)
 - Artificial wetting tests



Buffer-Backfill-Interaction (BBI) test

Research goals:

- Understanding of early phase processes (test duration 62 days)
- Water flow and its distribution
- Heaving/uplift of the buffer
- Erosion of bentonite materials
- Support earlier modelling results (uplift, water flow paths, pressures)
- More information for future larger scale in-situ EBS demonstration



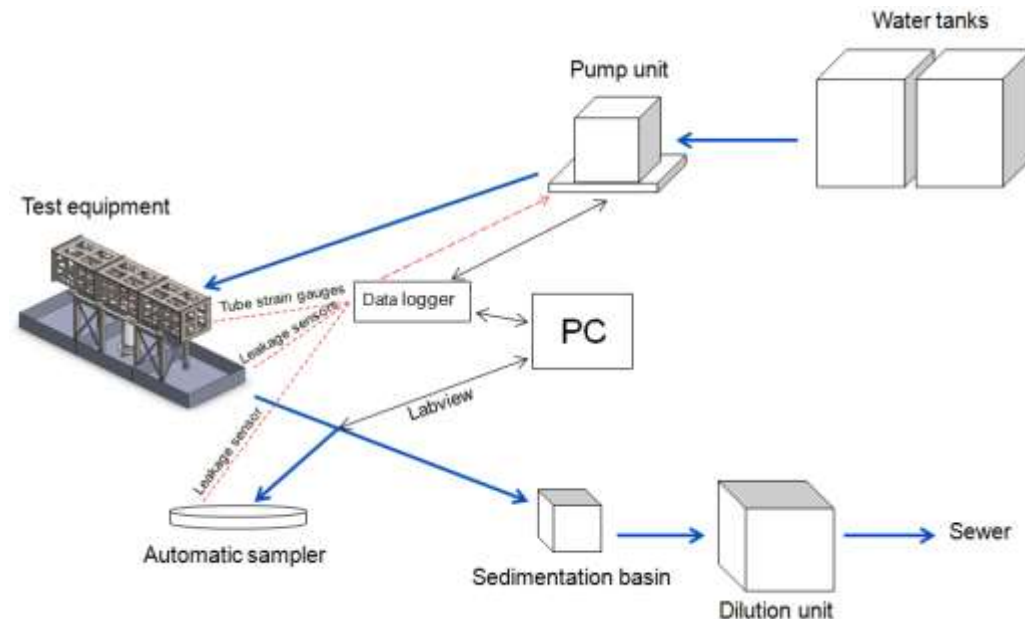
BBI test – set-up

- Test equipment (tube and tunnel) at $\sim 1/6$ scale simulating the deposition hole and the tunnel of the KBS-3V concept (substantial design work)
 - Buffer: cylindrical blocks (MX-80), 50 mm wide pellet filled gap (MX-80)
 - Backfill: cuboid blocks (Ibeco RWC BF), pellet layers (Cebogel) around (thickness between ~ 100 -200 mm)

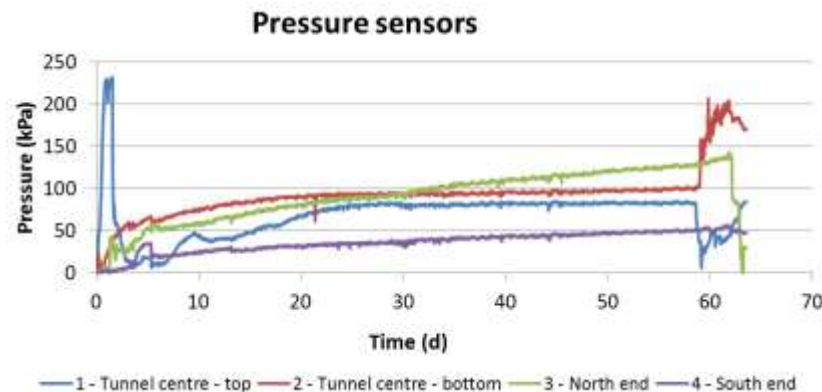
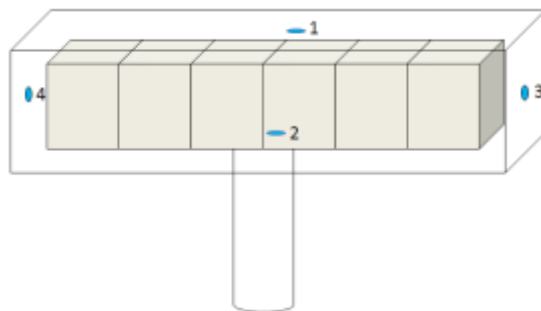
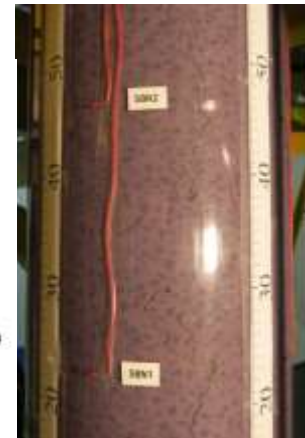
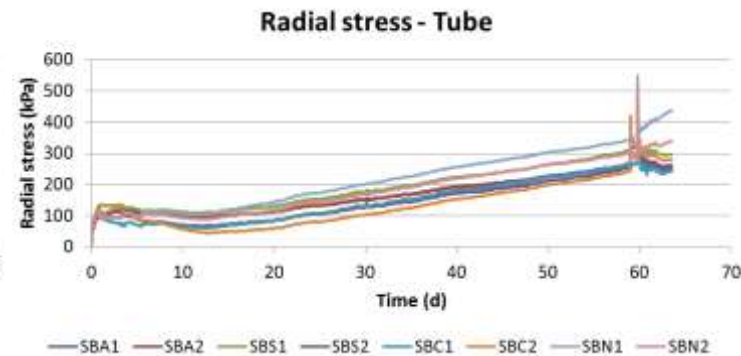
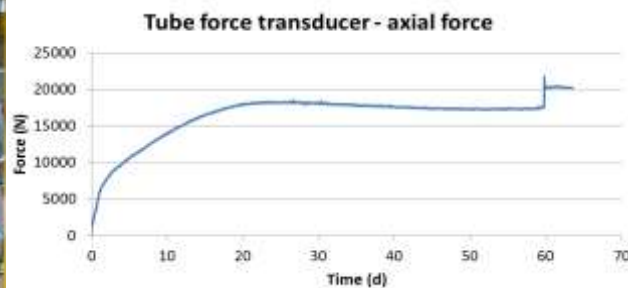


BBI – test set-up

- Water simulating Olkiluoto's groundwater (1% salinity)
- Inflow rate 0.1 l/min (rock suitability criteria), 1 inflow location in buffer
- 8 outflow locations, channelled to one collecting pipe
- Monitoring of bentonite swelling
 - 40 strain gauges, 4 pressure sensors, 2 dual gauges, 1 force transducer

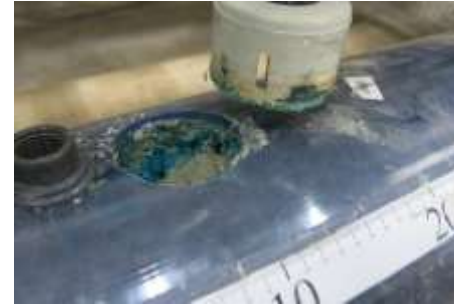


BBI – example of monitoring results



BBI – post-mortem sampling

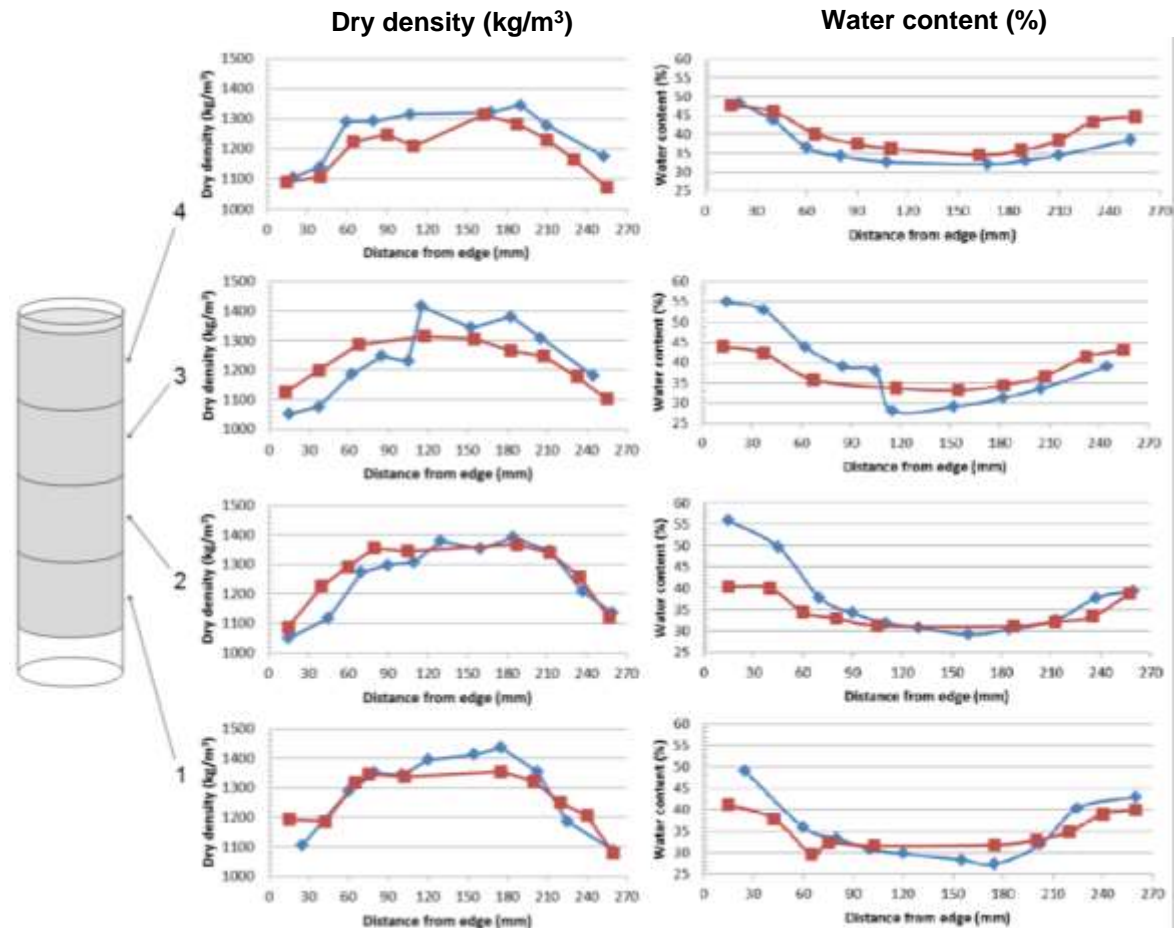
- Block and pellet fill samples for water content (oven drying) and density analyses (water immersion)
- Investigation of possible water flow paths (tracer)



- 6 backfill block samples
- 117 backfill pellet samples
- 8 buffer samples
- 9 buffer-backfill-interface samples

BBI – example post-mortem sampling results (buffer)

- Samples from 4 height levels
- 2 sampling directions
- Level 1 was right above the water inlet
- Inner tube diameter was 270 mm
- Gap width 50 mm
- Indications of homogenization processes



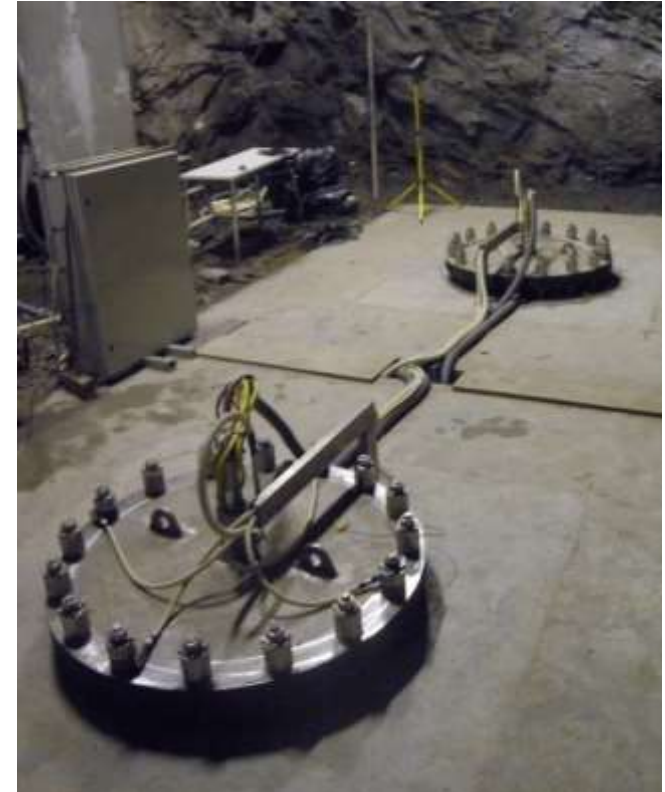


BBI – summary/conclusions

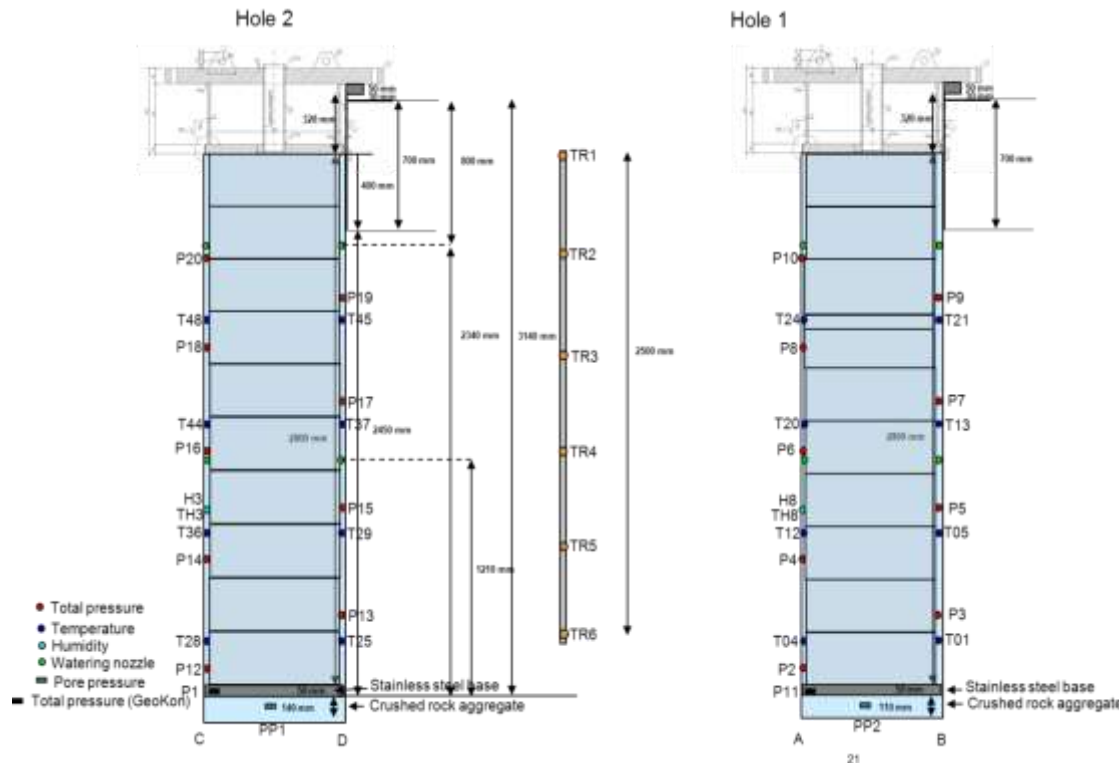
- Water was not uniformly distributed - water finds "the easiest path"
- Stop in water inflow caused sealing of previous (and opening of new) channels
- Follow-up of the hydromechanical evolution (large number of sensors)
- Extensive post-mortem sampling data
- Non-wetted zones were found, especially in the backfill
- No samples having saturation degrees $> 90\%$ were found (too short duration)
- Persistence of heterogeneities in the system
- Approx. 40 mm vertical displacement of the buffer block

40 % Scale Buffer Tests

- 140 m underground at ONKALO
- Two test holes:
 - Natural water inflow (11/2011 - 09/2013)
 - Artificial wetting (11/2011 - present)
 - Diameter 800 mm, depth 3000 mm
 - 4 m apart
- Buffer blocks and pellets
 - Posiva's Buffer Design 2012
 - Constrained lid to confine uplift
- Heated canister dummy
 - Surface temperature +90 °C



40 % scale Buffer tests – monitoring



Sensor locations and quantities

Instrumentation tubes:

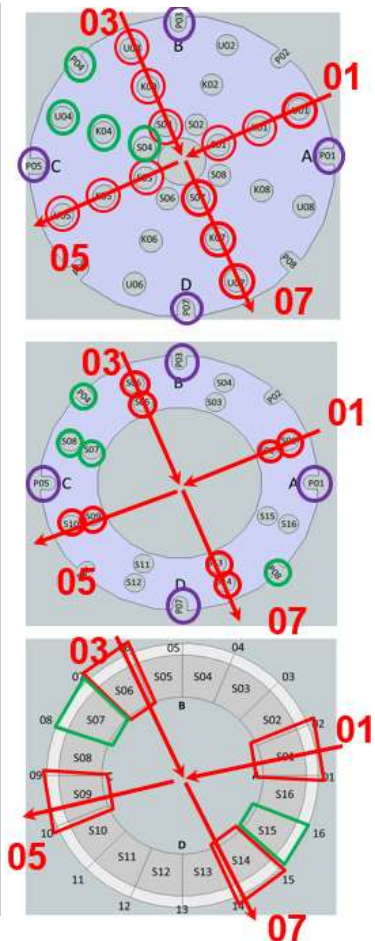
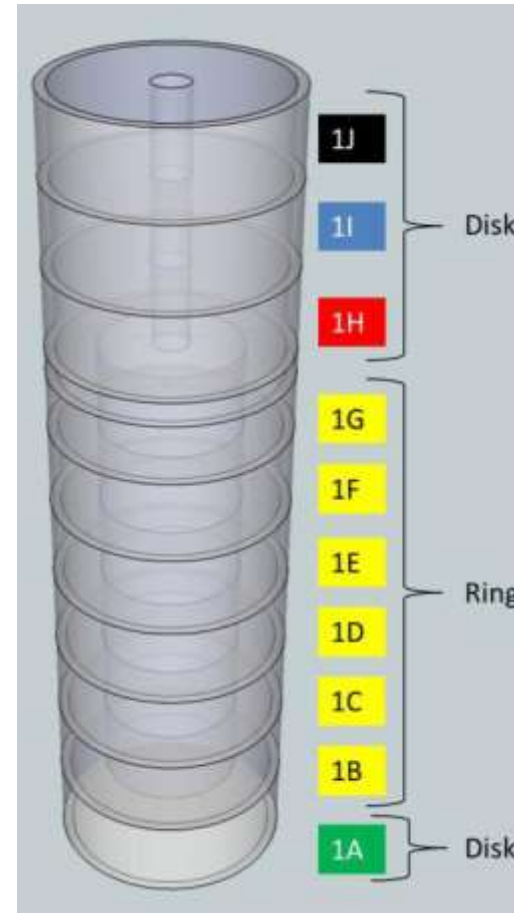
- Total pressure 20
- Pore pressure 2
- Temperature 22
- Humidity RH 2

Bentonite blocks, canisters and pistons:

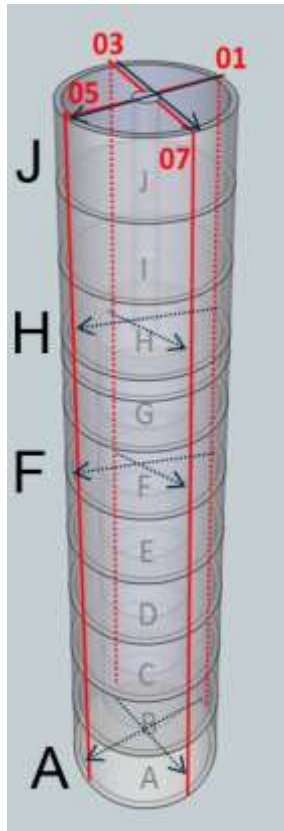
- Temperature 44
- Humidity RH 14
- Force 8
- Displacement 2

40 % scale Buffer tests – De-commissioning and post-mortem sampling

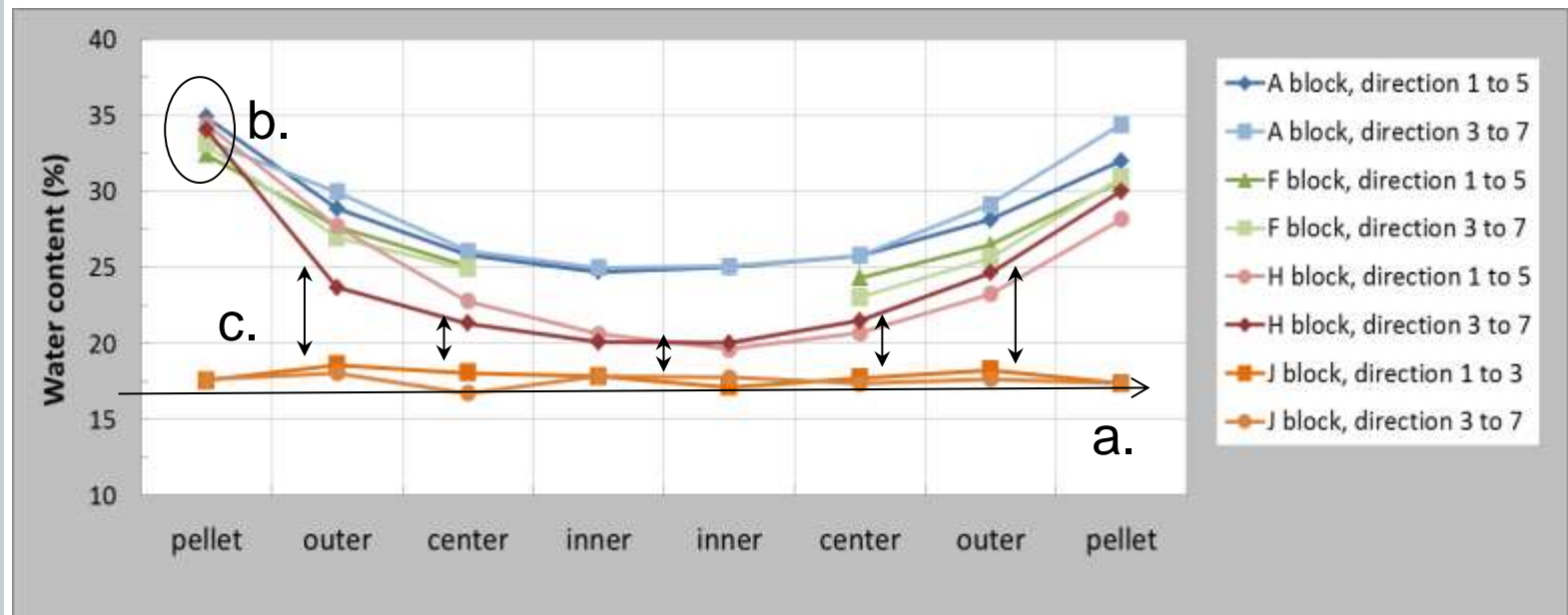
- Hole 1 (natural water inflow)
- Approx. 2 years test duration
- > 1000 samples
- Water content and densities



40 % scale Buffer tests – Example radial water content distribution (blocks A, F, H and J)

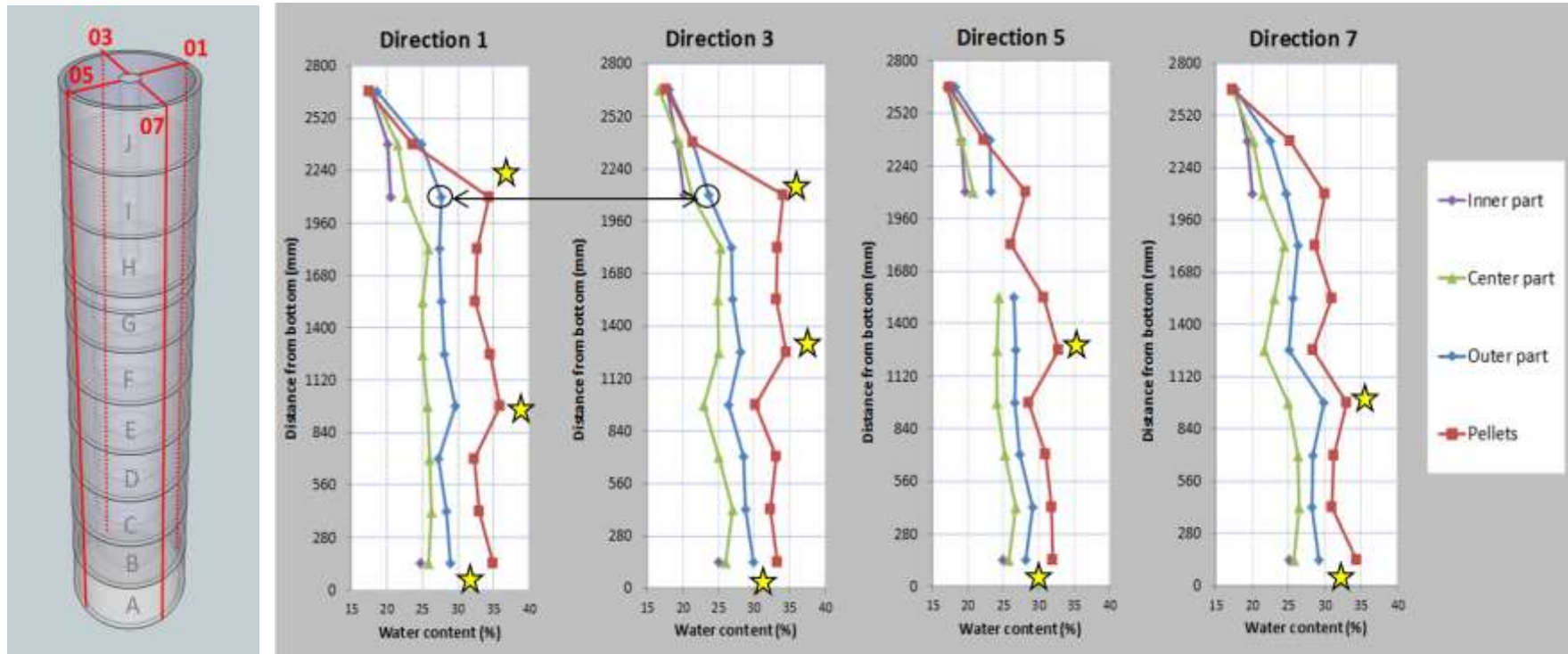


Heights: A: 140 mm, F: 1540 mm, H: 2100 mm, J: 2660 mm



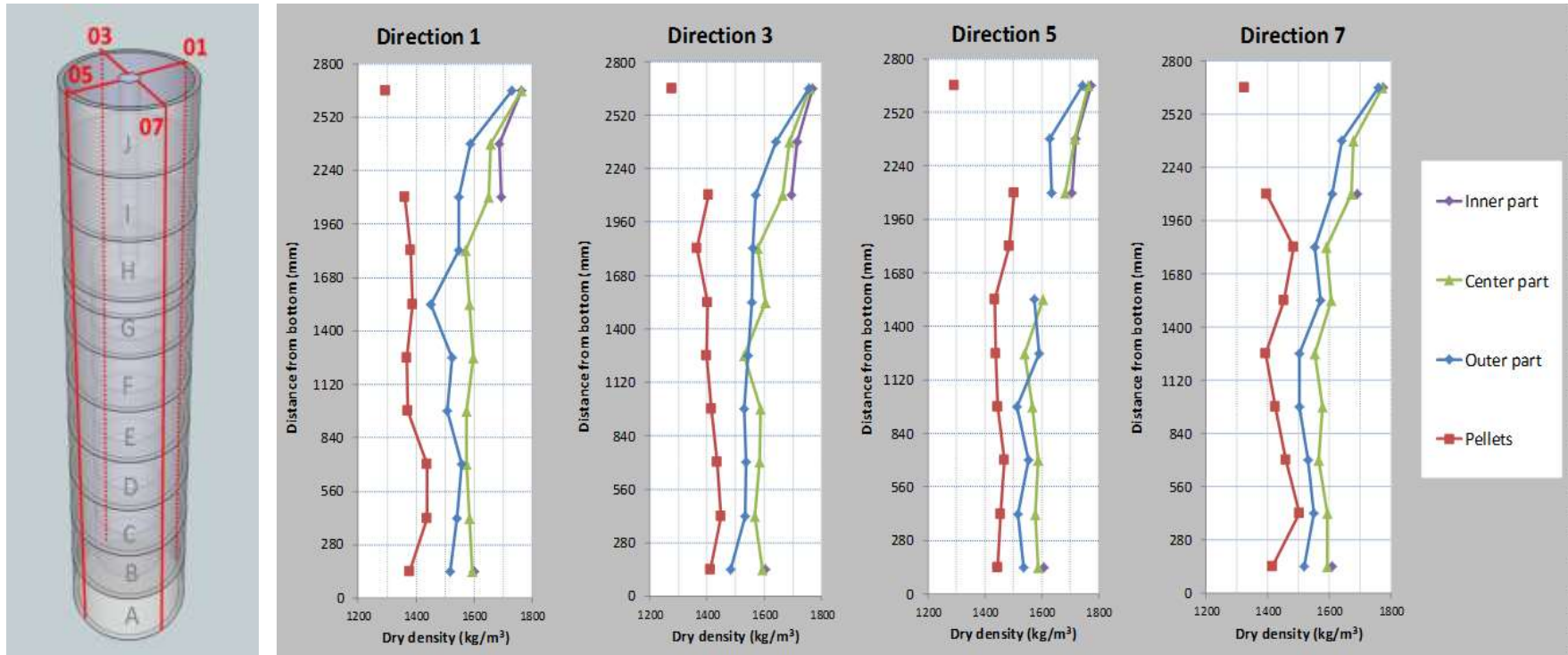
- a) J block was dry
- b) A, F & H blocks: 01 & 03 directions wetter
- c) Water was able to penetrate to block A inner zone

40 % scale Buffer tests – Example of vertical water content distribution analysis



- Block A was wettest
- Pellet layers were wetter in directions 01 and 03 compared to direction 05 and 07
- ★ indicates rock fracture/inflow location
- In block H outer zone (1960-2240 mm) direction 1 and 3 show differences in water inflow (migration of water)

40 % scale Buffer tests – Corresponding vertical dry density distribution





40 % scale buffer tests - summary/conclusions

- Good
 - Overall performance
 - Design and construction/installation solutions
 - Heating system
 - Sampling methods
- Issues
 - Monitoring 40 % failure rate of sensors after 3.5 years (including on-site power cut)
 - Dismantling of heating system
 - Disturbances caused by other constructions on-site



40 % scale buffer tests - summary/conclusions

- Well-defined geometry, reflected of Posiva's reference design then
- Large number of sensors, able to see evolution
 - Hydro-mechanical evolution of the bentonite blocks and the surrounding pellet fill
- Extensive post-mortem sampling data available
- Persisting heterogeneities in the system (insignificant regarding safe long-term performance of the buffer)
- Duration (2 years) of Test 1 not sufficient to wet the entire buffer, especially the upper buffer blocks
 - limitations to homogenization studies
- On-going Test 2 will provide valuable data on effect of artificial wetting + longer test duration

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