DOPAS: Full-scale demonstration of the feasibility and performance of plugs and seals

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Representing the DOPAS Consortium

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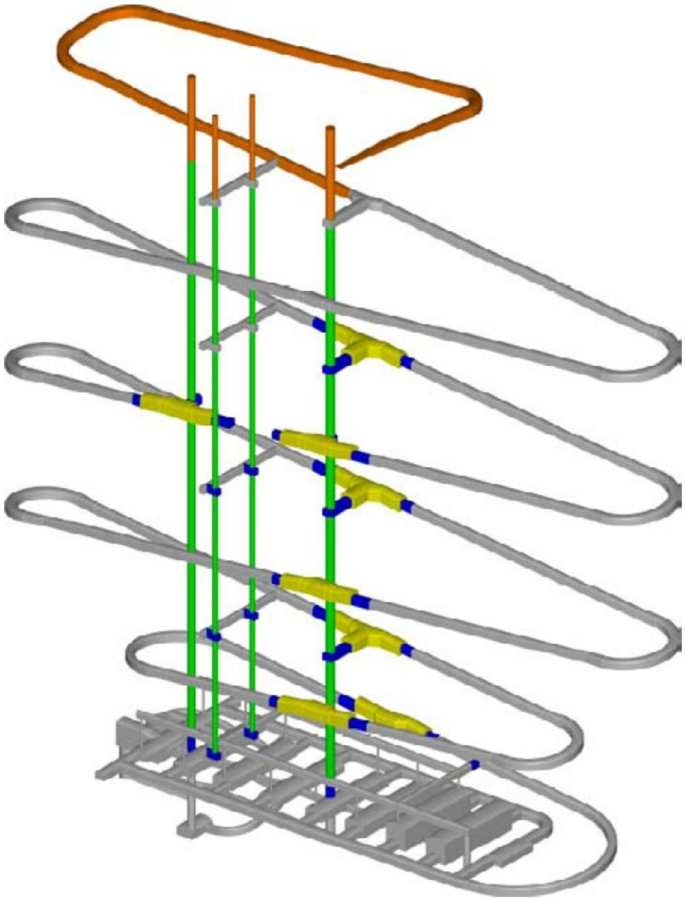
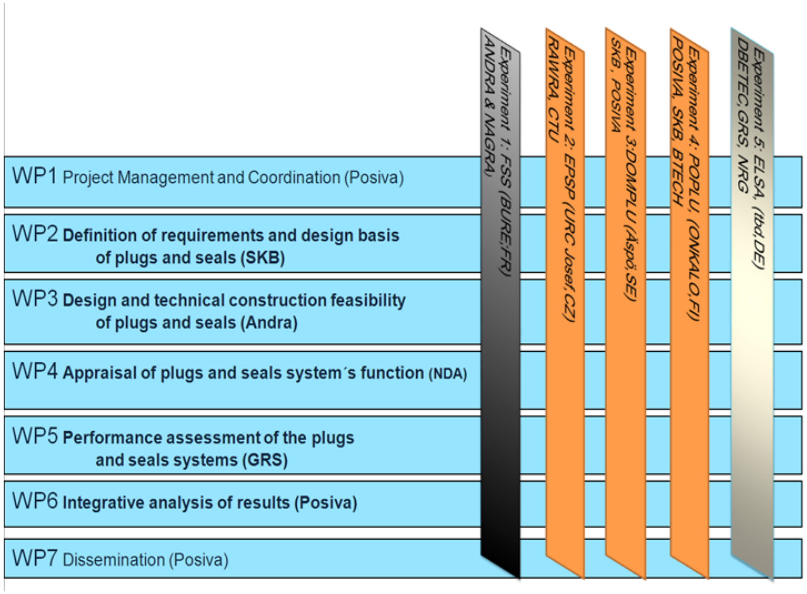
Repository Plugs and Seals

- Plugs and seals are components used to isolate and contain specific repository features
- Examples include:
  - Mechanical plugs, which may be used to provide an obstacle to human intrusion or to hold materials in place
  - Hydraulic plugs, which may be used to limit groundwater flow in specific locations
- Different plugs and seals will be emplaced in different locations in the repository



The DOPAS Project

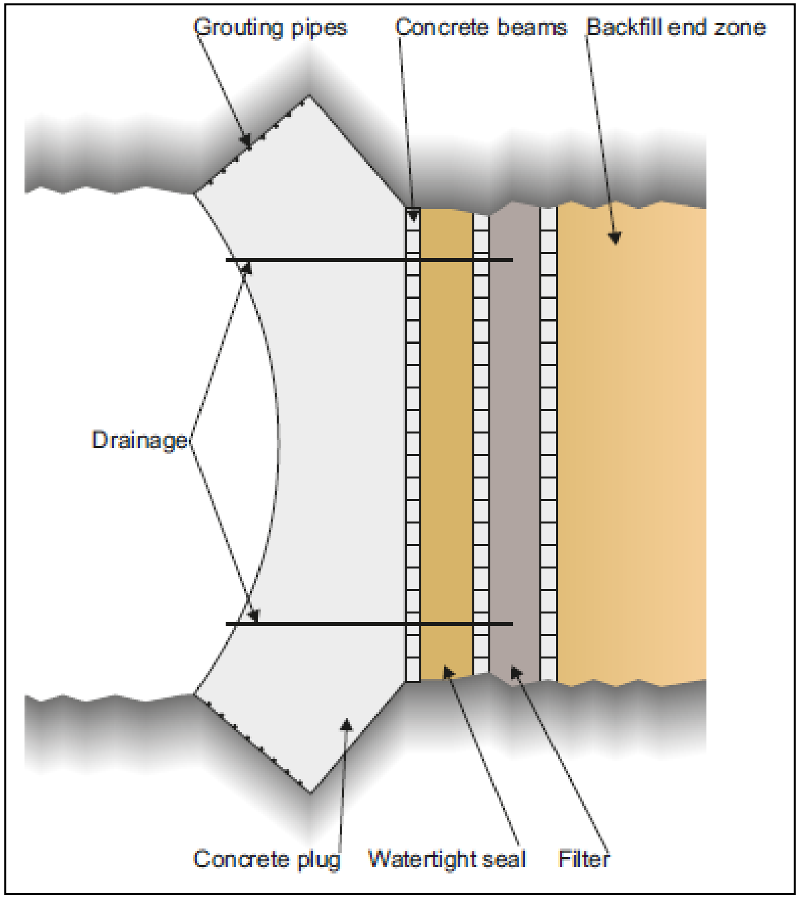
- **Five experiment being designed, implemented and assessed across seven work packages**
- **Supported by materials development**
- **Three experiments in crystalline rocks:**
  - **DOMPLU (Äspö)**
  - **POPLU (ONKALO)**
  - **EPSP (Josef)**
- **One experiment related to clay:**
  - **FSS (St Dizier)**
- **A set of experiments and performance assessment studies related to salt:**
  - **ELSA (generic German concept)**



Presentation Objective

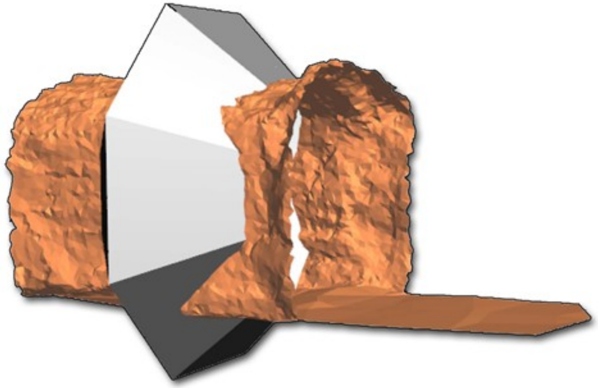
- Introduce conceptual designs of DOPAS plugs and seals, and describe their safety functions
  - Safety functions and conceptual design for each experiment
- To summarise how development of the design basis and assessment of compliance is supporting feasibility demonstration
- To present some initial results to illustrate how the technical feasibility of plugs and seals is being addressed in DOPAS

SKB: DOMPLU

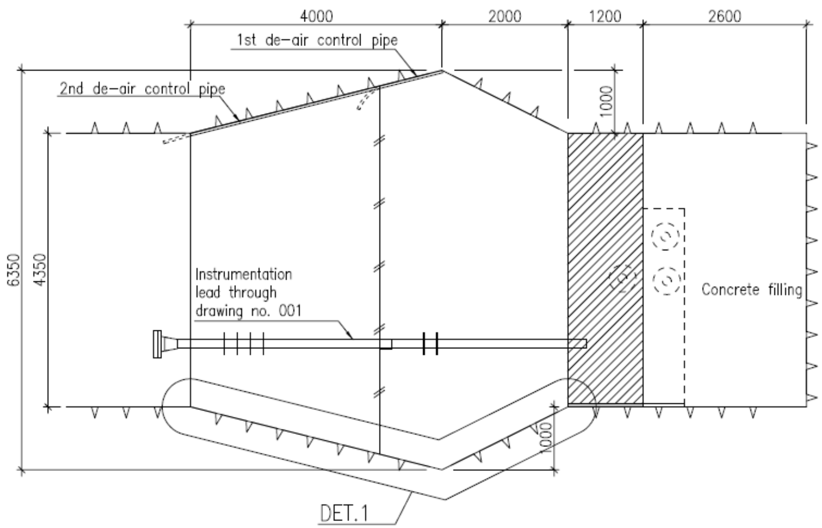


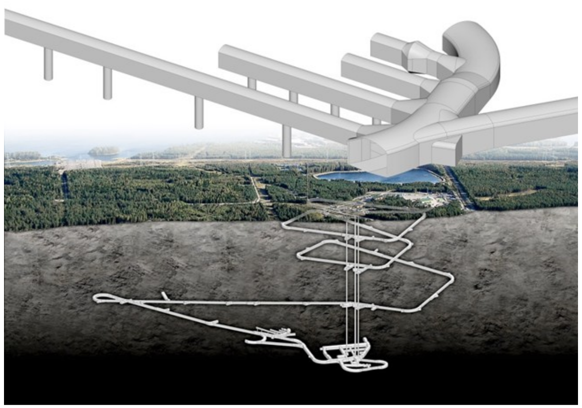
- Deposition tunnel plug test
- Function: confine the backfill in the tunnel, support backfill saturation and to provide a barrier against water flow / bentonite erosion (operations)
- Main components: concrete dome and watertight seal
- Other components support installation (e.g. manage pressure)

SKB: DOMPLU



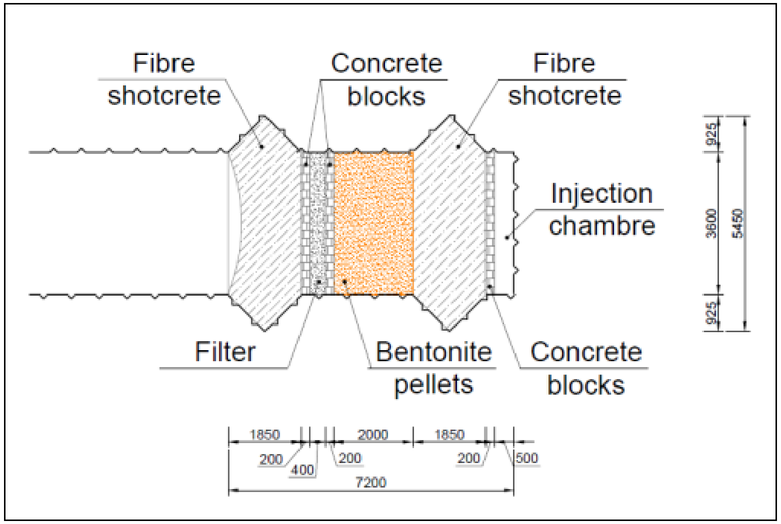
Posiva: POPLU





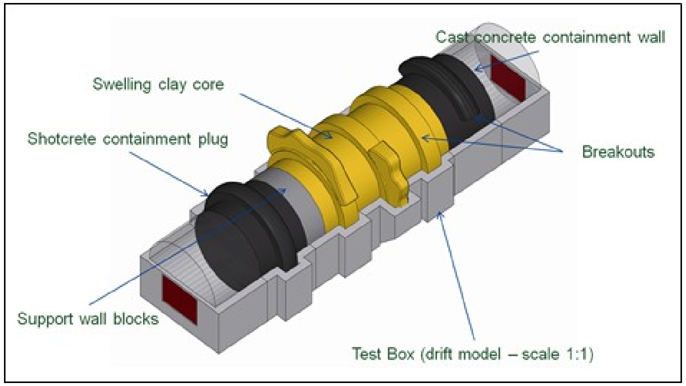
- **POPLU is testing an alternative plug to DOMPLU**
- **Massive wedge-shaped reinforced concrete plug**
- **End zone for pressurisation**
- **Potential advantages: construction simplicity and fewer types of materials**
- **To be constructed in 2014**

SURAO/CTU: EPSP



- Objective: materials and technology test
- Composite structure consisting of concrete domes and bentonite pellets
- Further development of Czech national expertise:
  - Use of steel fibre reinforced sprayed concrete
  - B75 bentonite
- Construction 2014

Andra: FSS



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- **Drift and ILW Vault seal test**
- **Function: limit water flow magnitude between underground and upper formations and reduce groundwater velocity**
- **Components: swelling clay core, K ≤ 1 x 10^{-9} m/s and low-pH concrete containment**
- **Issues: core emplacement in large volume with possible breakouts owing to lining removal**
- **Core emplacement June 2014**

Germany: ELSA

- Programme of laboratory and *in situ* experiments:
  - Further develop the reference shaft seal for salt
  - Develop reference shaft seals for clay host rocks
- Shaft seal safety function for salt:
  - Provide a sufficiently low hydraulic conductivity to avoid brine paths into the repository and movement of radionuclides out of it
  - Seals provide containment until salt creep reduces the hydraulic conductivity of the host rock – salt creep is expected to seal the repository in 1,000 years
  - Functionality of shaft seals is designed to last until next expected ice age: 50,000 years
- Work in DOPAS includes thermo-hydro-mechanical and chemical-hydraulic experiments, and process-level and performance assessment modelling

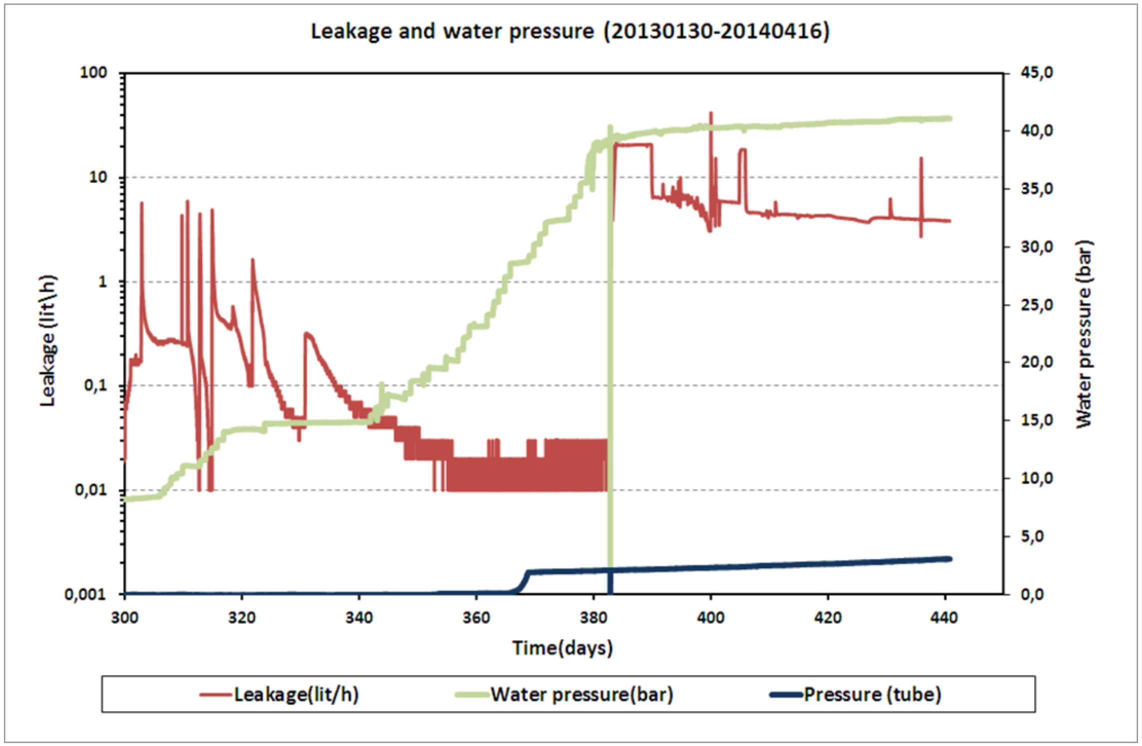
Development of the Design Basis

- Design basis consists of requirements on structures and conditions under which these requirements must be met
- Design basis is hierarchical
  - Safety functions represent the high-level requirements
  - For implementation, more detailed requirements are developed; in the DOPAS design basis these include requirements to use specific solutions
  - Low permeability > use swelling clay > swelling clay pressure > clay density
- For each experiment in DOPAS a comprehensive list of requirements and conditions has been developed
- Each list is grouped with respect to experiment-specific features: requirement timescales; components within each plug or seal structure; etc.
- Each requirement is analysed to check compliance of the experiment with the design basis
- The analysis allows iteration of the design basis, reasons for solutions to be presented and identification of construction procedures for implementation

Examples of Learning I: DOMPLU: Performance Monitoring

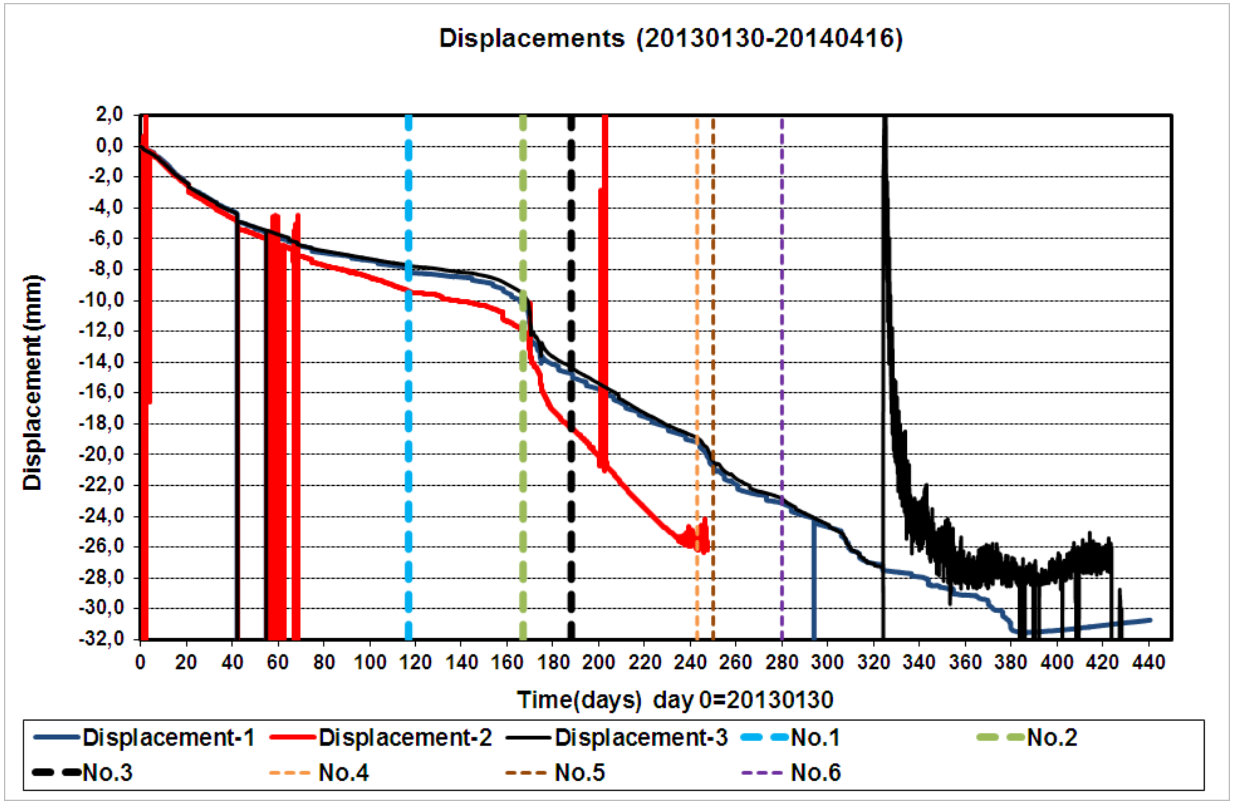
- **DOMPLU incorporates 100 sensors monitoring:**
  - **Water pressure [Bar]**
  - **Leakage rate [litre/min]**
  - **Temperature [ºC]**
  - **Concrete strain [extension per unit length]**
  - **Concrete displacement relative to the rock [mm]**
  - **Relative Humidity [%]**
  - **Total pressure including swelling clay [Bar]**
  - **Filter displacement relative to the end wall [mm]**

Examples of Learning I: DOMPLU: Pressurisation and Leakage



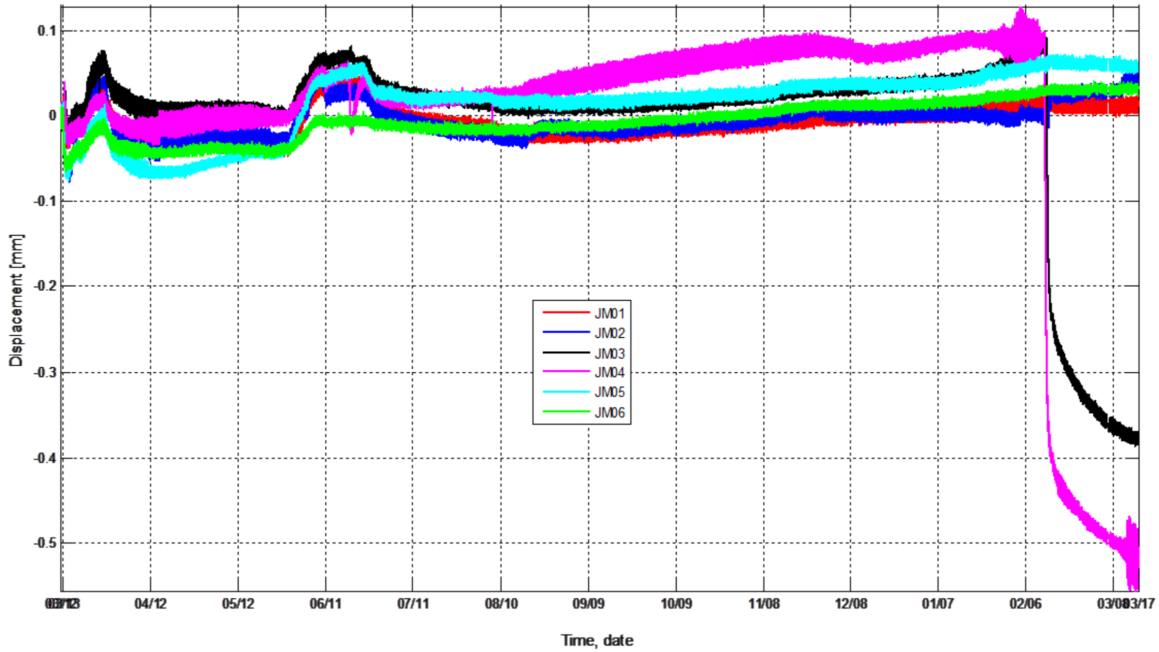
- **The plug system has been watertight up to a water pressure of ~40 bar**
- **At pressures ≥~40 bar, leakage has occurred via the rock, sensor cables and the concrete/rock interface**
- **With water pressure of ~40 bar, the leakage rate is ~4 liters/hour (65 ml/min)**
- **No bentonite found in water**

Examples of Learning I: DOMPLU: Filter Displacement



- **All three sensors are showing inwards displacement**
- **The filter is being compressed by the bentonite seal**
- **In total there has been a movement of about 3 cm since the installation**

Examples of Learning I: DOMPLU: Closure of Crest



- **Joint meters in the top of the concrete dome(JM03 and JM04) show significant displacement in response to the increase in water pressure; these sensors show a negative displacement, i.e. closing of a gap**

Examples of Learning I: DOMPLU: Design, Construction and Operation

- **Monitoring data corresponds well to the expected performance**
- **The sealing function improves with time**
- **Flooding of the filter has been successful owing to active management of the pressure**
- **Despite the water leakages, no eroded bentonite has been found**
- **Rock requirements are shown to be important for plugs**
- **Sensor cables through plugs cannot be recommended for a future repository**
- **Installation procedures can be developed based on the experience of DOMPLU: emplacement of beams, filter and seal-pellets, and routines and design for dome formwork**

Examples of Learning II: FSS Pellet Bentonite Mixture

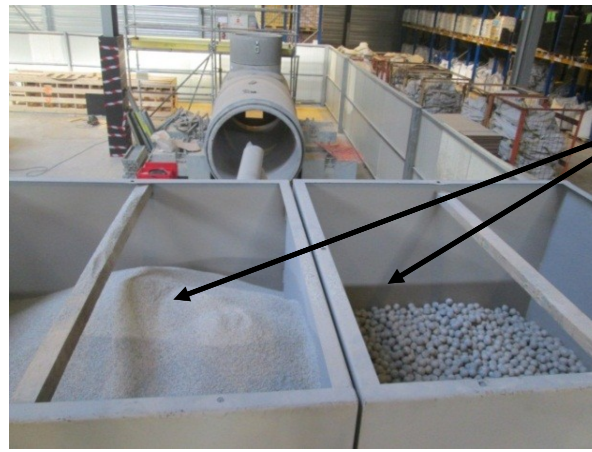
- **Function of seals is dependent on the hydraulic conductivity of the swelling clay core and its contact with the host rock**
  - **Target ≤1 x 10^{-9} m/s**
- **The geometry of the system, including possible breakouts leads to a conclusion that a pellet/powder mixture is the most suitable approach for swelling clay core emplacement**
- **32-mm diameter pellets selected based on suitability of production method**
- **Laboratory testing used to identify best mixture:**
  - **68% Pellets – 32% Powder**
  - **ρ_d = 1.60 g/cm^3**

Examples of Learning II: FSS Clay Core Emplacement

- Emplacement based on dual auger system: augers can be controlled separately to adjust flow and material ratio
- Metric scale emplacement results
  - ✓ New conveying device to provide an adequate flux of pellets to be conveyed by the auger screw
  - ✓ Filling the bigger part (about 2/3) of the core with the 2 filling augers one above the other
  - ✓ Filling the top of the core (about 1/3) with the 2 filling augers side by side, thus creating a pressure build up likely to fill the recesses
- Density with new method: around 1.5 g/cm^3
- New density sufficient for hydraulic conductivity of 1×10^{-9} m/s

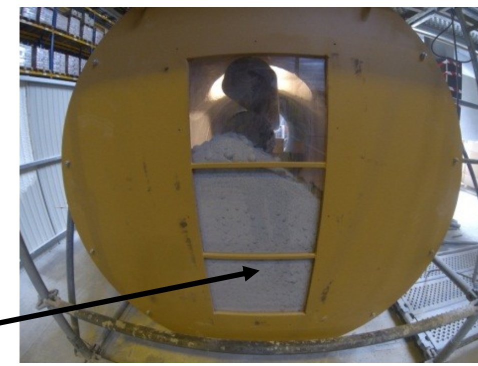
FSS Swelling Clay Core Emplacement Augers Metric Testing

Two augers – one above the other



2 independent hoppers

A window is placed at the bottom of the pipe



Conclusions

- **Demonstrations of full-scale plugs and seals are supporting the implementation of geological disposal**
- **Examination of the design basis is providing a platform for developing detailed designs and procedures for implementation**
- **Iterative cycle of design, testing and assessment is allowing engineering solutions to be identified for significant challenges and for realistic design basis requirements and conditions to be defined**

Acknowledgements

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- More information can be found on the DOPAS website: www.posiva.fi/dopas
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DOPAS

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