Development of UK approach to sealing deep site investigation boreholes: knowledge transfer from other industries

Presentation to DOPAS 2016 Seminar
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26th May 2016
Project objectives and structure

– Develop approaches for sealing deep boreholes against groundwater flow and gas migration in generic geological settings potentially relevant for a UK GDF

– Phase 1 (November 2013 - April 2014): identified key issues and developed a programme of generic R&D

– Phase 2 project (July 2014 - March 2017): implement programme
Key issues for ‘generic’ R&D in borehole sealing

– Determine standard of sealing likely to be required
– Identify appropriate materials for seals and support elements
– Identify appropriate placement methods
– Determine approach to assuring quality of emplaced seals and supports

– Recognise that different geological environments may require different sealing solutions
Task 11/19. Determine appropriate materials for support elements in lower and higher permeability sections of borehole

Task 5. Identify placement methodologies for borehole sealing materials

Task 1. Confirm functional requirements for various seal and support elements

Task 2. Build understanding of post-closure requirements for borehole seals

Task 3. Selection of sealing materials to be considered by the project

Gate 2

Task 4. Define a phased lab programme to (i) test the different concepts and (ii) enable concepts that will be evaluated further (in Task 7) to be selected

Gate 3

Task 6. Phase 1 laboratory programme

Gate 4

Task 7. Phase 2 laboratory programme

Task 9. Develop QA/QC methodology for borehole sealing

Task 12. Final deliverable from Project. -options assessment to identify and justify preferred sealing concepts for generic geological environments
Illustrative borehole stability analysis: High Strength Rock (HSR) and Lower Strength Sedimentary Rock (LSSR)
RWM project. Forms of bentonite considered

- Potential sealing materials in HSR and LSSR:
  - high density bentonite blocks
  - bentonite pellets
  - bentonite slurries

- Experimental programme undertaken by Clay Technology to determine:
  - early swelling, settlement and erosion behaviour
  - impact of water composition on a range of bentonite properties
Use of the existing knowledge base

- Oil and gas industry experience of borehole sealing
- Water resources industry
- CO₂ storage projects and R&D. Experience of borehole sealing
- Nuclear industry R&D on bentonite properties
- International experience with field-scale demonstration experiments in URLs
- Natural analogues
- Input from other projects for RWM
- Understanding developed from the Phase 1 Borehole Sealing Project
- Design and placement of borehole seals at potential radwaste disposal sites
- International experience with repository sealing programmes

Phase 2. Sealing deep site investigation boreholes
Knowledge transfer. Sealing and backfilling of radioactive waste repositories

Many areas applicable, but recognise the differences

– Geometry in a borehole is more difficult to fill
– Borehole is generally full of water
– Borehole likely to encounter wider range of groundwater chemistry
– More significant interactions between borehole seal and groundwater
– Less opportunity to determine performance of borehole seal
– Required standard of sealing may be lower for a borehole than for e.g. vault or deposition hole
Knowledge transfer. Overall approach to sealing boreholes

– Broadly consistent across industries: oil and gas; CO₂ storage; water resources

– Common themes:
  • Seals placed across low permeability sections of rock in uncased sections of hole
  • Intervals between seals are filled with materials that provide mechanical stability (‘support elements’)
  • Lengths of cemented casing often remain in-situ. Casing locally milled out to allow placement of seal
  • Seals are not placed directly across high permeability horizons
Knowledge transfer. Use of bentonite for sealing boreholes

Oil & gas industry
– Pellets used in onshore USA, generally in vertical cased wells up to 1,000m deep
– >9,000 wells sealed with Zonite™ pellets
– Patent application for a bullet-shaped block

Water resources industry
– pellets used to seal uncased boreholes
– Pellet generally coated to delay onset of swelling
Knowledge Transfer. Techniques for placing sealing materials

– Considerable potential for technology transfer from oil and gas industry
– Placement techniques used in oil and gas industry
  • Conventional pumping
  • Coiled tubing pumping
  • Gravity placement
  • Dump bailing
  • High velocity and high pressure pumping of particulates
Conventional and coiled tubing pumping

- *Conventional pumping*: default technique for plugging and abandoning wells using cement-based slurries
- *Coiled tube pumping*: more precise in depth and rate control. Typically used for placing cement slurries and sand plugs
- Either could be adapted to pump bentonite-based slurries
- Use of inhibiting fluid when pumping bentonite drilling muds
- Laboratory programme demonstrated that pumpable bentonite slurry (maximum yield stress of 45 Pa) in 2M KCl has dry density of ~730 kg/m³
Gravity placement

- Placement into wellbore or tremmie pipe
- Potential for bridging
- Conventional approach to delaying hydration is through coating
- Effect of salinity on pellet stability: rapid spalling of pellets in 1M NaCl
- Potential limitations on approach
Dump bailers (1)

- Metallic cylindrical vessel typically run on wireline. Outer Diameter > 3 mm smaller than borehole Inner Diameter
- Contains a small volume of material (typically from 0.005m³ to 0.1m³)
- Can be released by gravity alone or by positive displacement
- Routinely used to place cement slurries and sand to > 2,000m
- Speed varies between 600 – 2,000 m per hour
Dump bailers (2)

Advantages

– Accurate placement. No ‘bridging’ is possible
– Simplicity of approach. Tried and tested technology
– Flexibility: can place all of slurries, pellets and (potentially) blocks
– Control of fluid environment during placement

Disadvantages

– Multiple trips required (small volume of existing bailers)
– some RDD needed to demonstrate positive displacement system
Knowledge transfer summary. Potential for techniques to place bentonite in site investigation boreholes

– potential for existing oil and gas industry techniques to place bentonite in boreholes at a site being investigated for a GDF

– Simple Red-Amber-Green ‘traffic light’ system
  - **GREEN.** Routine practice for placement of bentonite
  - **AMBER.** Routinely used for placement of other materials. Could be adapted to place bentonite in boreholes at a site being investigated for a GDF
  - **RED.** In our judgment, technique is not applicable, or not recommended, for the placement of bentonite
Potential of oil and gas industry techniques for placing bentonite in boreholes up to 1,000m deep

- **GREEN.** Routine practice for placement of bentonite
- **AMBER.** Routinely used for placement of other materials. In our judgment, could be adapted to place bentonite
- **RED.** In our judgment, technique is not applicable, or not recommended, for the placement of bentonite

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