Posiva Plans And Experiences For Borehole Plugging

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Posiva has developed a theoretical borehole closure design for closure of deep investigation boreholes drilled in Olkiluoto island. These investigation holes have been made from 1989 to date to gather data from the underground disposal facility sites geological, hydrogeological and geochemical features. The data has been used to accept the site for repository location, assess the long-term safety of the site and to design the layout of the repository. These investigation holes will need to be closed at latest when the disposal facility is closed after operation to prevent the formation of preferential flow paths and contaminant transport routes between the ground surface and deposition tunnels/deposition holes. Some holes will however need to be closed sooner. As the need has risen to close certain holes sooner than after operation the borehole closure project has now been reviewed and further work is being designed to modify the theoretical design to implementable one. Now Posiva is planning the practical demonstration to be implemented and used as a borehole closure installation demonstration and test for further development work.

1 Introduction and background

In Eurajoki, southwestern Finland, excavation of an underground investigation facility, ONKALO, is already close to being completed and a spent nuclear fuel disposal facility is under construction after Posiva gained construction license for it in 2015. During site investigations and construction several deep investigation boreholes have been drilled in Olkiluoto island to get information about the bedrock properties. In 2016 the total quantity of these drillholes is 58 with the first made in 1989 and the latest in 2016. The holes vary in diameter, depth, inclination and distance to repository location.

As a part of closure of the underground disposal facility the boreholes, reaching from ground level to repository depth and below, will need to be closed and sealed. This topic has been investigated and tested for example by Posiva and SKB, and for the construction license application an example design was made to present an option for borehole closure (Karvonen 2014).

In 2013 Posiva overcored samples of borehole backfill from borehole OL-KR24 to gain data from material installed in 2005 (Rautio 2006). According to these results and international co-operation Posiva has now revised the design and is currently carrying out a project to change the previous theoretical design to implementable solution. In design of underground disposal facility and Olkiluoto site a need has arisen to close few specific boreholes already during coming years. For this work, the theoretical closure design done for the construction license is now transformed to implementable design for use within next years in tests and demonstrations.

2 Scope and objectives

Scope of borehole closure project is to ascertain that boreholes will not in long-term act as transport routes between repository depth and ground surface. In addition to them being potentially routes for radioactive nuclides, they might also act as routes for dilute waters to penetrate into Olkiluoto bedrock. Both of these two options will need to be hindered.

3 Methods and procedure

Theoretical design (Karvonen 2014) was done using structured selection method for each material placement. Material was defined to be borehole backfill for sparsely fractured, tight rock segments and borehole backfill material was selected to be dense bentonite installed with either basic method or container method. Basic method was designed to be used above depth level above -500 m and container method below that, as in container method the material was installed within a container, safe from erosion caused by water in the boreholes. In basic method the bentonite was installed within perforated copper tube, and thus water could affect it during installation, which could cause erosion. The hydraulic conductivity for the borehole backfill material was set to 10^{-9} m/s conservatively according to underground disposal facility closure design values at repository depth (Sievänen et al. 2012, Dixon et al., 2012).

Parts of the boreholes are not tight, but fractured and having fractures or fracture zones with high hydraulic conductivities. Limits were set that fractured rock was such that had more than 10 fractures per borehole meter, hydraulic conductivity > 10^{-8} m/s, or it was marked in original hole investigations as fractured zone (Ri>RiIII according to Finnish geological mapping system).

The uppermost part of the boreholes was found to be quite insignificant in considering the long-term safety, as the rock is already quite fractured and conductive. There the casings were considered to be left in the holes and a solid rock piece was designed to be installed below casings to slow potential erosion and hamper future drilling possibilities. Above the cylindrical rock piece either concrete or rock material can be installed.

After this theoretical closure design further work has been conducted in the field of borehole closure. In 2013 Posiva overcored borehole backfill and plug samples from OL-KR24 in Olkiluoto, which provided new important data concerning the materials and methods (Karvonen et al. 2015). In 2013 the underground disposal facility closure was modelled with sensitivity analyses also for the borehole closure material.

4 Results from latest investigations

In 2013 the overcoring of OL-KR24 revealed that installed quartz concrete had performed as expected and similar concrete mix can thus be used for fractured rock segments. The bentonite borehole backfill, the primary test material of the project, was also discovered to have sealed to borehole as expected, but the installation method with perforated copper tube delivered a surprise as the copper tube had cracked open vertically for the entire length of the sample. According to visual observations and supporting material tests the water flow had been adequately sealed vertically along the hole despite the breaking of the copper tube (Karvonen et al., 2015). This, however, resulted in recent design change to test a dump bailer in further borehole closure design.

Dump bailer technique uses drilling equipment and a container (dump bailer) to transport dense bentonite to required depth where it can be pushed out of the container. A plate, potentially of copper, acts as the bottom of the container and remains below the bentonite section in the borehole. This technique is already used for example in installing concrete in boreholes and occasionally in oil industry to install bentonite pellets. The swelling of bentonite could jam the material in the dump bailer, but this can be avoided either by coating the bentonite or by making the dump bailer watertight.

Hartley et al. (2014) confirmed by modelling the performance of underground disposal facility closure materials and during that work also made a sensitivity analysis with borehole backfill's hydraulic conductivity of 10^{-5} m/s. Even with this low value the transport routes were found to be limited and only with minor significance for some tens of meter in few specific boreholes. Previous work by Hartley et al. (2012) had modelled the significance of open boreholes (hydraulic conductivity of 10^{-1} m/s) and even that was discovered to be low. With this modelling data it was for implementation decided that the hydraulic conductivity of the borehole backfill could be changed from the theoretical design's 10^{-9} m/s and studies to reason this update are ongoing. Changing the value to slightly more conductive would still keep it within conservative level and provide better sealing function than what was modelled by Hartley et al. (2014).

Uppermost segment of the borehole is still considered by Posiva to be filled with either concrete or rock material. This segment does not have a significant sealing function, but it needs to be filled for it not to remain open. As for dividing the boreholes to sparsely fractured good rock and fractured rock, the theoretical design will be updated to be more robust with longer uniform segments and less material changes. The main hydraulic fractures and fracture zones are separated from each other by borehole backfill segments, but it is not necessary to isolate each small fracture from another. The potential vertical flow is thus prevented with bentonite in good rock segments in strategic, meaningful locations within the borehole.

5 Conclusions

Even though OL-KR24 borehole closure materials and methods were found to have provided a seal within the borehole, the investigation revealed that bentonite may function better without the copper tube. Thus the theoretical design (Karvonen 2014) has now been changed to install bentonite borehole backfill with dump bailer technique instead of basic method copper tubes. Recent modelling has also revealed that hydraulic conductivity of the borehole backfill can be less conservative than it was in the theoretical design. The short altering sections of borehole backfill and plugs will be designed longer and more uniform and critical locations selected for sealing the repository depth for ground surface and significant hydraulic fractures and zones.

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7 References

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