# Hydraulic Sealing Ability of Bentonite Pellet Filling at Small, Contact Apertures

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Saturation of the clay-based, barrier components in the repository for spent nuclear fuel at Olkiluoto will be governed by the hydrogeological conditions in the surrounding bedrock and the hydraulic properties of the components themselves, and may result in the formation of channels or pipes through the buffer or backfill material, and possibly erosion thereof, inside the deposition tunnels.

After the available void volume inside the deposition tunnel has been filled, but the central tunnels remain open, the water pressure gradient will be transferred from the initial inflow point to the tunnel plug (see Figure 1). Ideally the inflow will effectively cease and homogenization will take place. However, leakage may occur at a variety of downstream interfaces, e.g., other fractures, fissures, or joints, as well as the deposition tunnel plug itself leading to undesired water flow and the possible preservation of advective transport pathways.

Insofar as any deposition tunnel material may be able to seal leakages due to a “self-grouting” or ”self-filtration” effect, such outflow may be stopped altogether. Given the heterogeneous design of the tunnel backfill installations, it is reasonable to assume that the material in most direct contact with possible leakage interfaces will be the outermost foundation layer material, pellet-filling materials and plug components.

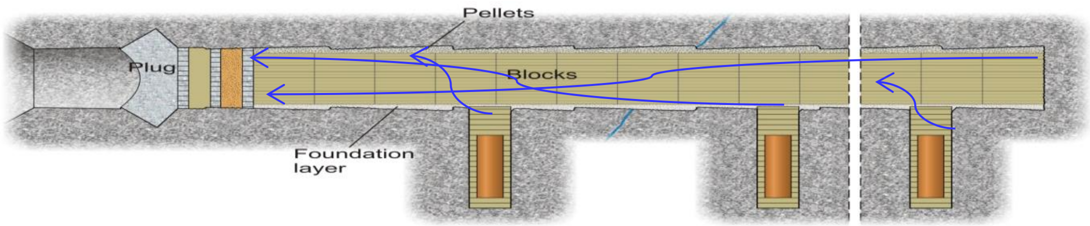


**Figure 1.** *Schematic figure showing a deposition tunnel and various saturation inflow scenarios (Keto et al. 2013).*

In order to evaluate the sealing potential of bentonite pellet material at small leakage apertures, a series of laboratory experiments were performed in which pellets of different materials and shapes (Wyoming bentonite, roller-compacted pillows and disks, Wyoming bentonite extruded rods and Milos bentonite extruded rods) were placed into contact with a small, contact leakage slit (Figure 2) and tested against solution salinity, inflow rate and aperture size. Additionally, threshold conditions for channel formation through the pellet volume were examined as well.

For MX-80, roller-compacted, pillow-shaped pellets at a dry density of ~920 kg/m$^3$, material extrusion into a 0.05 mm leakage slit routinely occurred after the saturation front reached the aperture. Complete sealing of leakage flow was never observed up to the maximum inflow pressure of 4000 kPa. However, periodic inflow, lower inflow rates, possible buildup of accessory minerals in the leakage slit, higher initial dry density of the pellets and smaller aperture size were observed to enhance the sealing ability, i.e., resulted in higher inflow pressures to maintain leakage outflow.

In sealing tests with MX-80 pillow-shaped pellets, immediately after the available void volumes were filled, distinct and sustained flow channels were formed at 0.01 L/min inflow rate and higher with 10 g/L TDS solution (Figure 3, column C). At flow rates of 0.1 ml/min and down to 0.0055 ml/min in tests against 10 g/L solution channel formation was not observed (Figure 3, column B). At similar inflow rates against tap water solution, water pocket formation was observed and the systems were "sealed" to the permeability of the pellet medium (Figure 3, column A).

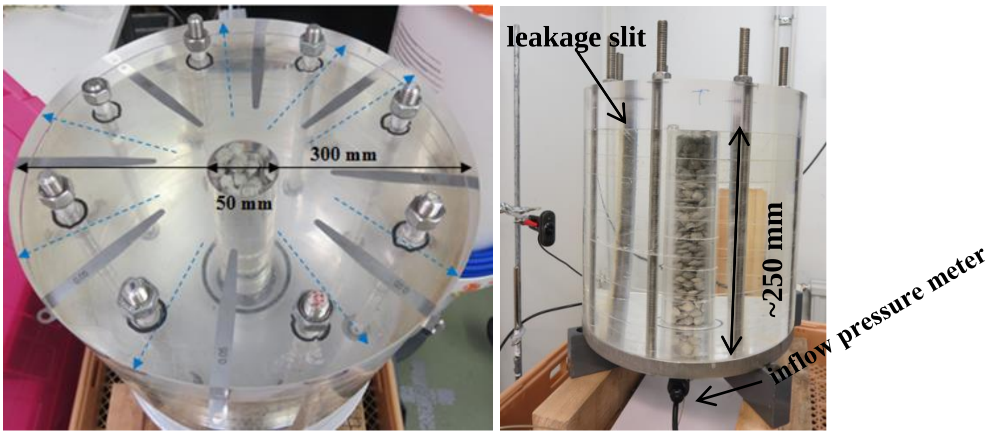


**Figure 2**. *Photographic images of the sealing test system. Overhead (left) and facing (right) images of the test setup after material installation. Blues dashed arrows show the direction of leakage outflow.*

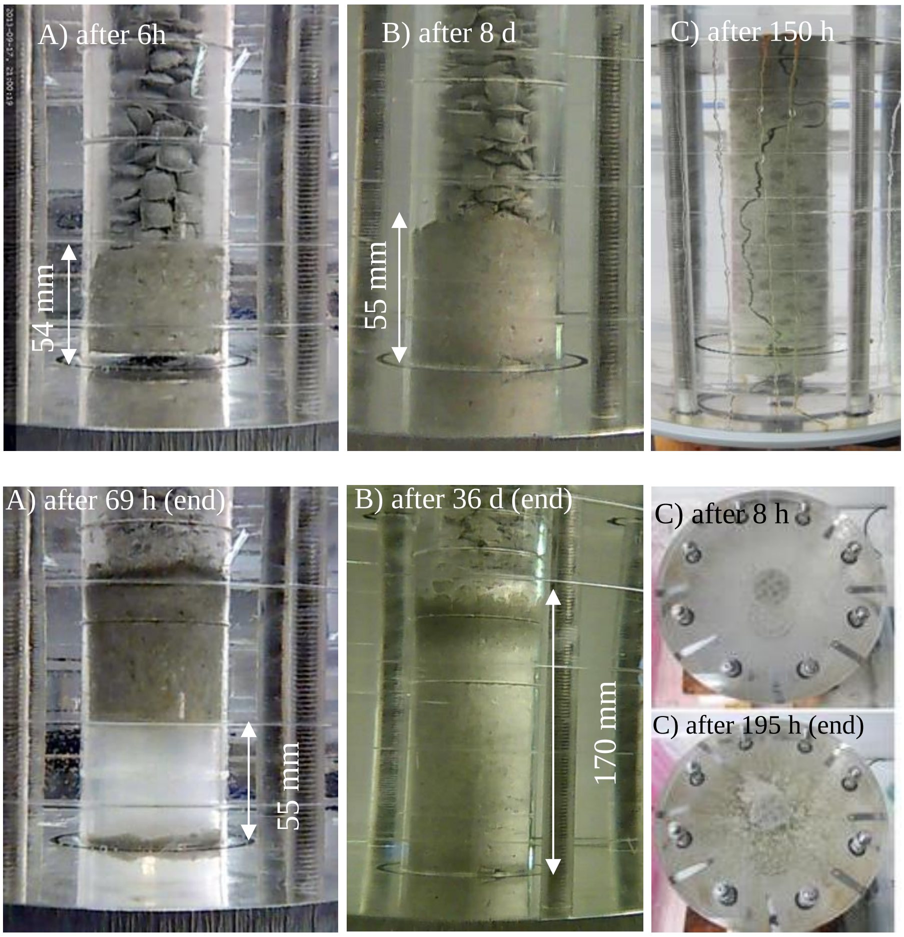


***Figure 3***. *Photographic images of three sealing tests with MX-80 pillow-shaped pellets: Column A - inflow rate = 0.1 ml/min with tap water, Column B - inflow rate = 0.0055 ml/min with 10 g/L TDS solution, Column C - inflow rate = 10 ml/min with 10 g/L TDS solution.*

Interestingly, completely different behaviour between extruded, rod-shaped (manufactured from Wyoming and Milos bentonites) pellets and roller-compacted, pillow-shaped and disk-shaped pellets (manufactured from Wyoming bentonite) at inflow rates of 0.01 L/min was observed. The latter materials, spanning densities from 919 to 1030 kg/m$^3$ and solution compositions from 10 - 70 g/L TDS, always gave rise to piping flow channels at the surface of the pellet volumes which were sustained over the course of the tests at inflow pressures below 2000 kPa. The extruded, rod-shaped pellets, on the other hand, show very rapid rises (2 - 4 hours) in inflow pressure to 4000 kPa (maximum for these tests) and sealing of the initial piping flow channels within the first 24 hours of the test.

Absolute sealing (i.e., zero outflow to a maximum pressure of 5 MPa) through wetted pellet volumes in contact with a small, planar leakage interface, potentially as a physical sealing of the leakage interface due to the intrusion of clay material, was not observed for any of the material, density, solution and inflow rate test combinations described in this report. However, it can be stated that sealing to the possible hydraulic conductivities of the pellet medium was observed for the extruded, rod-shaped pellet systems. Effectively, such sealing represents the highest level of potential sealing for any given, clay-based repository component to a non-clay based interface.

The leakage slit is likely an overly conservative interface. Insofar as failures through the tunnel plug may be more pointwise, future sealing tests will focus on smaller leakage features.

**References**

Keto, P., Hassan, M., Karttunen, P., Kiviranta,, L., Kumpulainen, S., Korkiala-Tanttu, L., Koskinen, V., Jalonen, T., Koho, P. & Sievänen, U. 2013. Design, production and initial state of the deposition tunnel backfill and plug. Posiva Report 2012-18. Posiva Oy, Olkiluoto.