# Mini GAST: Experimental Upscaling of an Engineered Gas Permeable Seal

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This study mainly delves into process upscaling through different experimental techniques considering an engineered gas permeable seal concept designed for a future deep geological repository for radioactive waste. A demonstration test is implemented in the Grimsel Test Site (Gas-Permeable Seal Test GAST [1]). The GAST core is composed of a dynamically compacted 80/20% sand/bentonite (S/B) mixture, which underwent long-term saturation and subsequent gas transport experiments. The S/B mixture is characterised by a low gas breakthrough pressure and an increased gas transport capacity while maintaining a low water permeability, an essential feature for preserving the repository's integrity.

Innovative mock-ups and laboratory experiments allowed for assessing gas breakthrough pressures and advective flow properties after multiple breakthrough tests. The multi-scale program included gas permeability point tests ($\phi$ 38 mm and *h* 76 mm) and dm-scale mock-ups to assess gas permeability under different, controlled scenarios. S/B mixtures were dynamically compacted at a mean dry density of 1.66 Mg/m$^3$ and water content of 12%. Two mock-ups were developed: 1) a mid-scale mock-up MU-B (200 mm in length and 100 mm in diameter with five lateral filters to speed up saturation of three dynamically compacted layers) and 2) a larger-size mock-up MU-A (500 mm in length and 300 mm in diameter with ten lateral filters and three dynamically compacted S/B layers). The prototypes are highly instrumented with local total stress sensors, pore pressure transducers, pressure/volume controllers at the inlet/outlet and lateral filters, gas mass/volume flowmeters, thermocouples, LVDTs, and load cells or pressure transducers to monitor the normal stress applied to the compacted layers. The mock-ups' semi-cylindrical shape facilitated the emplacement of dynamically compacted S/B layers with layer-parallel flow conditions, thereby mimicking the in-situ demonstrators' geometry. A pressure/displacement-controlled mobile lid was designed to apply the necessary vertical stress to simulate constant volume conditions and mitigate any by-pass flow through interfaces. Fig. 1 on the left side shows longitudinal and cross-sections of MU-B with lateral filters, sections S01 to S07 of local instrumentation and the thickness of the three compaction layers C1 to C3 (a 7-mm bentonite layer GB was installed between S/B and the metallic surfaces to avoid any fluid by-pass). Fig. 1 on the right side presents a photograph of MU-A placed horizontally for compaction, loading and gas transport.

Fig. 2 presents the results for multiple gas injection stages performed in MU-B and MU-A during the 3-year testing campaign (two MU-B tests and one MU-A test). The initial breakthrough pressures under saturated conditions had typically the highest values (between 140 and 220 kPa, filled symbols in Fig. 2a). These initial breakthrough pressures decreased to 45 – 60 kPa for repeated breakthroughs (empty symbols in Fig. 2a). Breakthrough pressures largely recovered after the system was re-saturated (partially filled symbols in Fig. 2a). Fig. 2b demonstrates that the top mobile lid was efficiently controlling the effective normal stress so that gas breakthrough pressures were always kept below these stresses, avoiding any gas pathways through interfaces.

In summary, breakthrough pressure results at the dm-scale and with flow parallel to the S/B compaction layers showed maximum (initial) values suitable for a gas permeable seal, with magnitudes consistent with the gas-entry value during drying measured in small-scale tests.

The repeated breakthroughs led to a progressive reduction in the breakthrough pressure (except for cases with re-saturation), indicating that a stable gas path evolved. Resaturation with water essentially reverted the initial breakthrough pressure, suggesting the reversibility of local desaturation. The evaluation of gas flow tests finally yielded effective gas permeabilities about ten times larger than the intrinsic water permeability. The comparison of the laboratory experiments and the in-situ demonstrator is underway to further strengthen a common understanding and bridge between the multi-scale applications of gas-permeable materials.

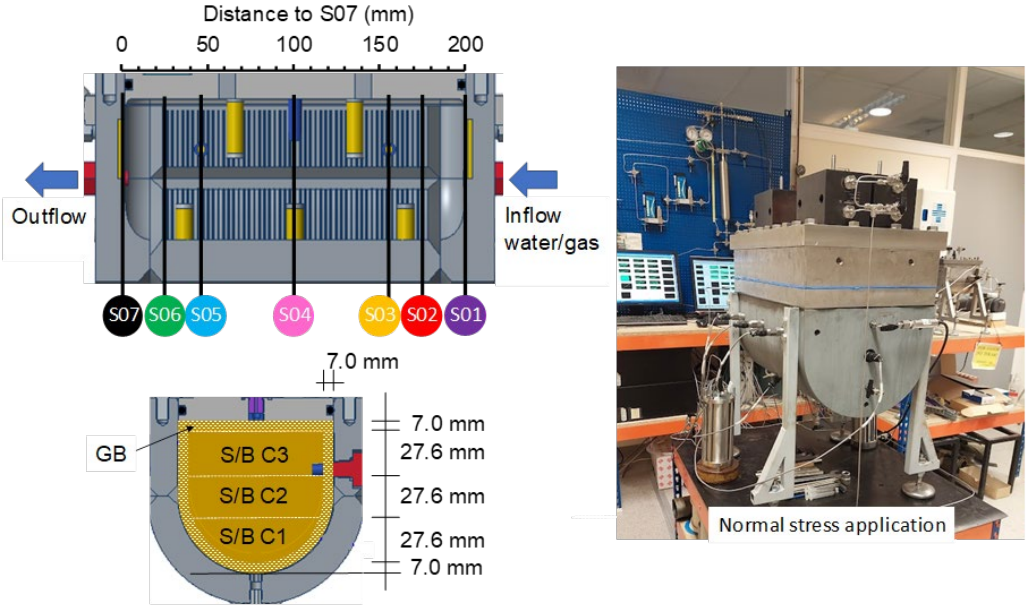


*Figure 1: Left: Longitudinal (top) and cross- (bottom) sections of MU-B with instrumentation sections S01-S07 and compaction layers C1-C3. Right: Photograph of MU-A in a horizontal position during normal stress application.*

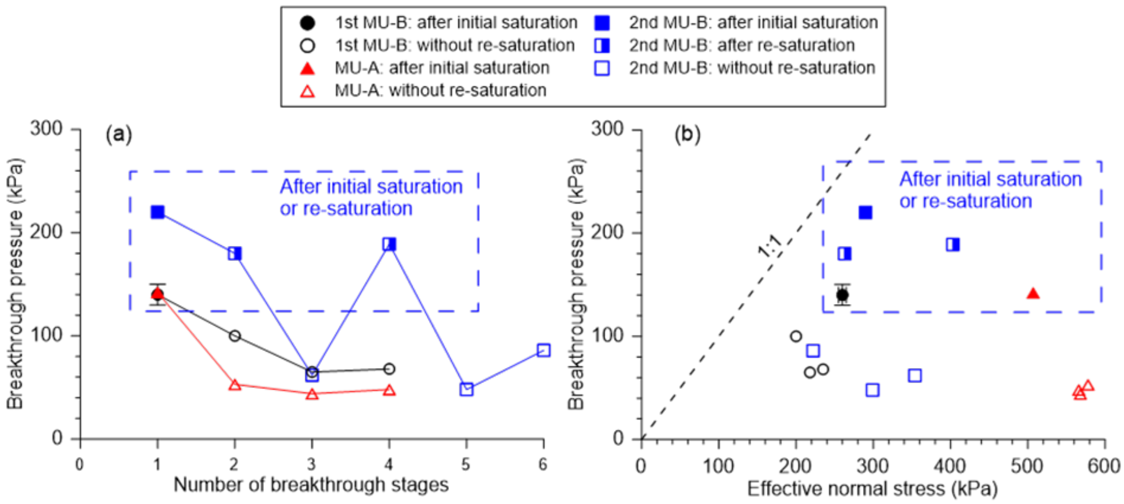


*Figure 2: MU-B and MU-A test results. Evolution of gas breakthrough pressures after multiple breakthrough tests.*

## References

[1] T. Spillmann. “GAST-Introduction”. https://www.grimsel.com/gts-projects/gast/gast-introduction (accessed: April 5, 2024).

[2] E. Romero, C. Alvarado, and A. Lloret, “New challenges in experimental unsaturated soil mechanics. Experimental upscaling of an engineered gas-permeable seal”, in 8th Int. Conf. on Unsaturated Soils, 2023, E3S Web of Conf. Volume 382, 05001, doi: 10.1051/e3sconf/202338205001.