Verification of Real Time Grouting Control (RTGC) theory using an artificial fracture with adjustable aperture order: A numerical and experimental investigation

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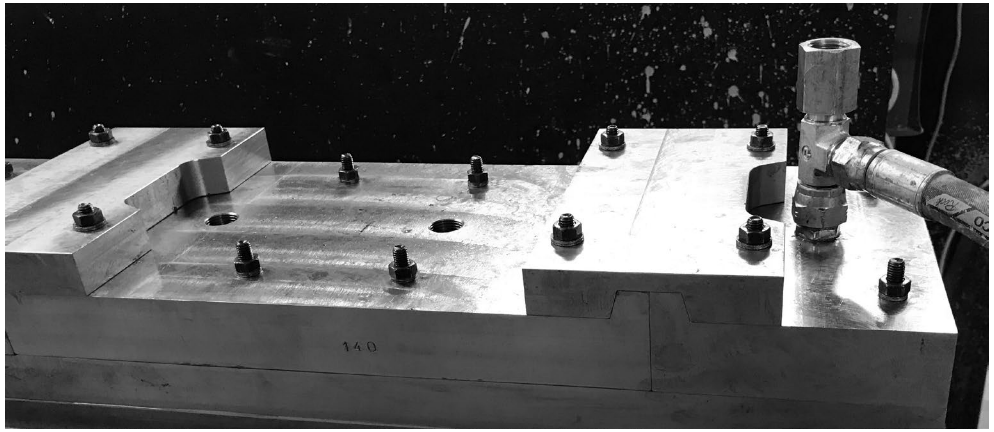

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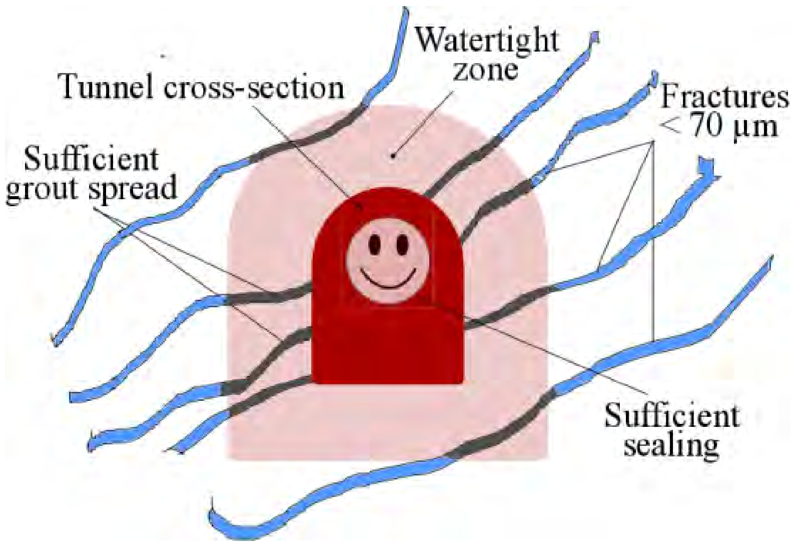
Backround

- Control and optimization of the grout spread in fractures is important to provide a reliable and an economical watertight-zone.
- One of the most advanced theoretical methods used for grouting analysis is the *Real Time Grouting Control* (RTGC).
- However, there is a lack of laboratory experiments for evaluation of RTGC performance under complex constrictions during grout flow

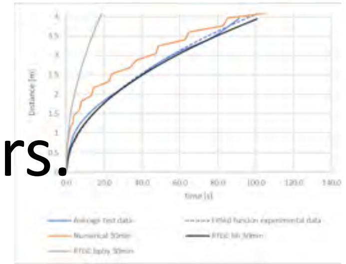


Effective grouting in tunnel

Goals

The objective of this project is to verify the reliability of RTGC theory experimentally and numerically in following steps:

1. Designing and building an apparatus with adjustable aperture distribution.



2. Experimentally evaluate the reliability of RTGC theory in prediction of the grout propagation at different aperture orders.
3. Verify the performance of RTGC theory with a numerical simulation of the grout flow.
4. Examine whatever hydraulic b_h or physical b_{phy} aperture provides more realistic RTGC predictions.

$$\frac{\partial}{\partial x} T(C) \frac{\partial P}{\partial x} = 0$$

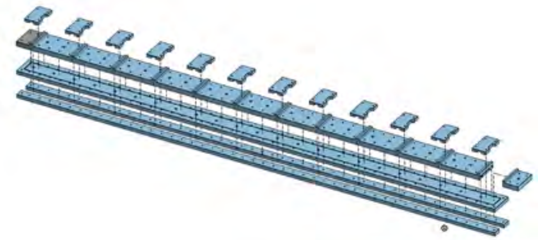
$$T(C=0) = -\frac{2WB^3}{3\mu_w}$$

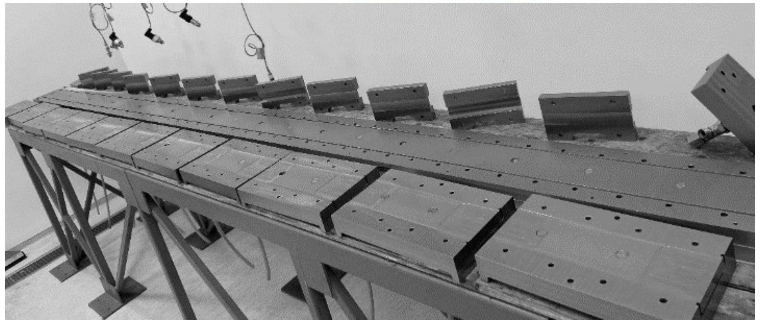
$$T(C=1) = -\frac{WB^3}{3\mu_g}\left(1-\frac{z_p'}{B}\right)^2\left(2+\frac{z_p'}{B}\right)$$

$$I_{max} = \frac{\Delta p \cdot b_{phy}}{2 \cdot \tau_0}$$

$$\frac{\Delta p \cdot b_h}{2 \cdot \tau_0}$$

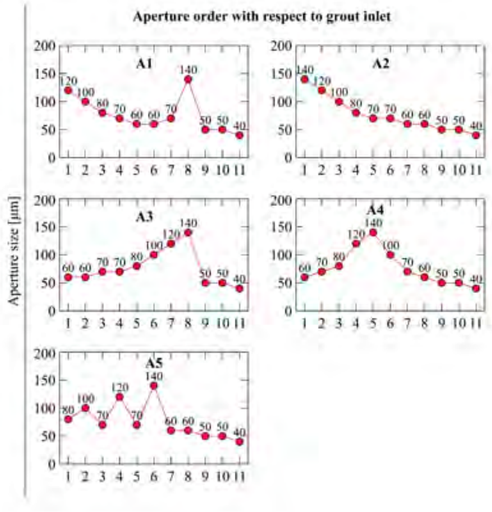
Production of adjustable artificial fracture and experimentally testiting RTGC theory

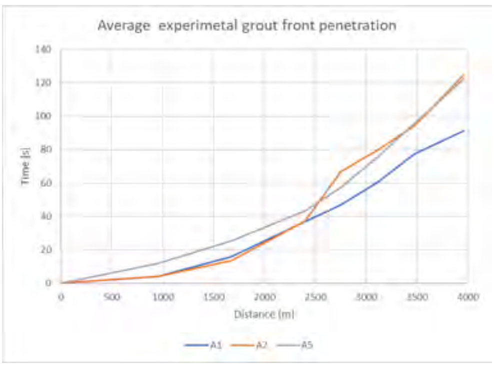




- A 4m long artificial fracture called Variable Aperture Long Slot II (VALS II) was designed and produced. It consists of 11 aperture plates with aperture sizes varying from 30µm to 120µm

- Water flow rate was measured and Grout propagation under 11 bar pressure for 3 aperture distributions was tested.

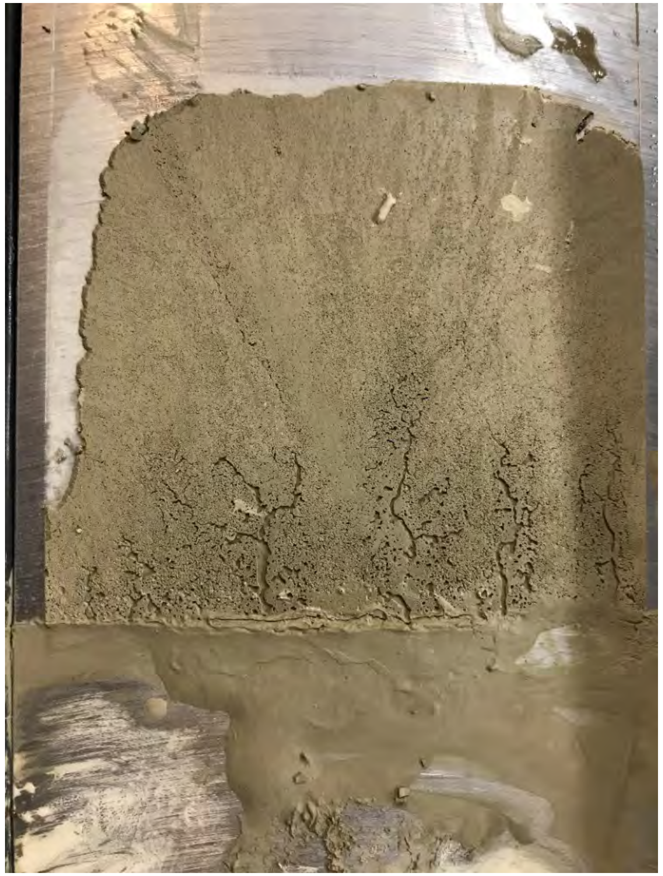




Grout filtration problem

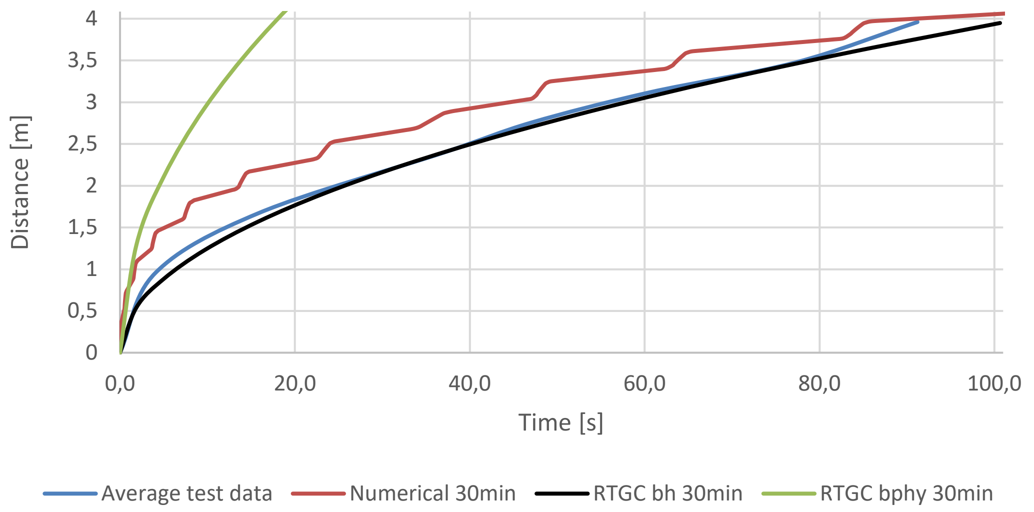
- For repeatability, grout propagation at each aperture distribution alternative was aimed to be tested 3 times.
- However, more test had to be performed due to often filtration of grout at VALS II inlet, which led to premature stop of the test.

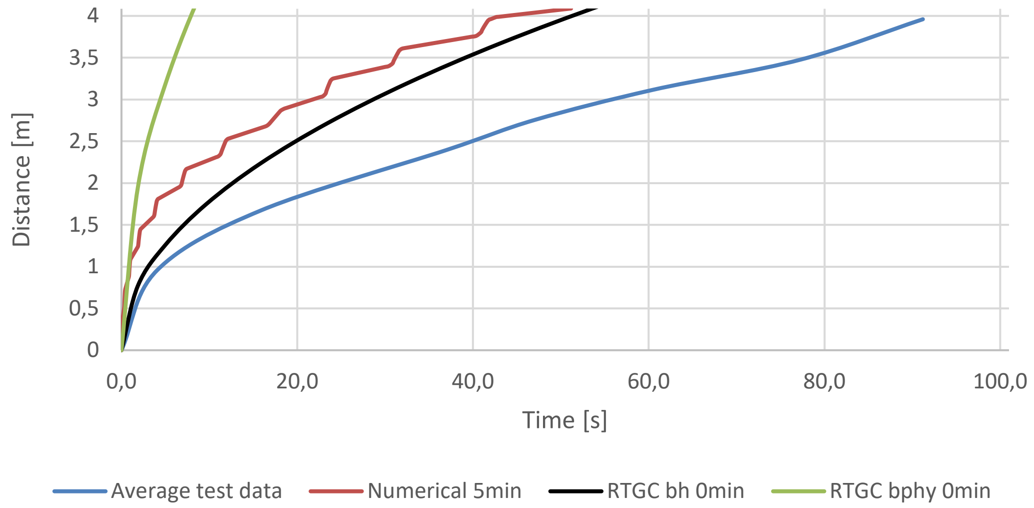
Alternative configurations	Test number of experiments to achieve successful 3 tests	Success rate
A2	10	30%
A5	5	60%
A1	5	80%



Comparison of measured grout propagation to RTGC predictions and numerical simulations

- RTGC predicted grout propagation best when hydraulic aperture b_h and grout rheology at 30 minutes was used in the calculations.
- When physical aperture b_{phy} was used in calculations RTGC overestimated the grout propagation.
- Numerical simulation results slightly overestimated grout propagation at beginning of the test.





Conclusion

- VALS II was designed, produced and was tight for both, water and grout testing under pressure. The results had good repeatability VALS II was tested .
- When grout rheological properties at 30 minutes after mixing is used the RTGC b_h predictions match tests results very well.
- The numerical simulations results overestimated penetration distance compared to experimental test results because they did not consider the time-dependent rheology properties and the additional friction loss caused by inertial effects.