An experimental study of the influence of dynamic pressure on improving grout penetrability

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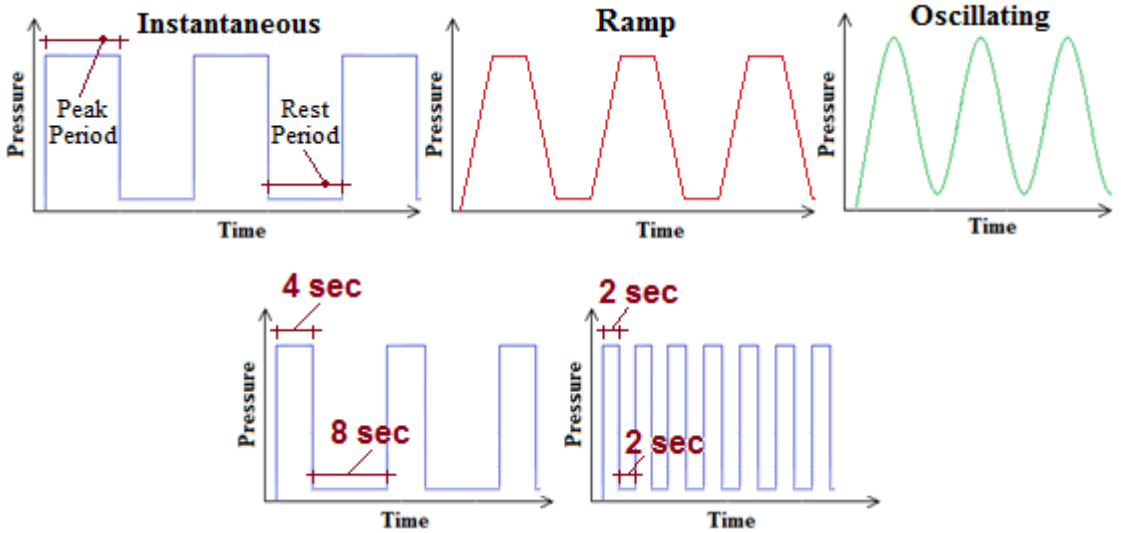
Introduction

To achieve a sealed area in rock, the grout should sufficiently penetrate through the fractures, while the filtration is an obstacle. Dynamic grouting, a method developed to improve grout penetrability, has been investigated both in the lab and the field since 1985. The focus of all the previous investigations was mainly on application of high frequency oscillating pressure using artificial parallel plates without constrictions with opening sizes larger than 100 µm. Whereas, the mechanism of improvement of grout penetrability was interpreted as reduction in viscosity due to the oscillation.

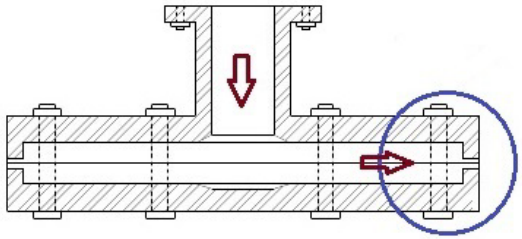
Other shapes of the dynamic pressure especially with low frequencies might however have a better influence on controlling the filtration and improving the grout penetrability and probably with more efficient mechanisms of action. Based on a preliminary study, the instantaneous variable pressure was found more effective than the other alternatives, e.g., the ramp variable pressure. Therefore, the main focus of this study was on investigating the influence of the instantaneous variable pressure with different peak and rest periods (4s/8s and 2s/2s) on controlling the filtration. A pneumatic pressure control system was therefore employed using parallel plates with constrictions of 43 and 30 µm. Comparison of results of the variable and the constant pressures revealed the great impact of the examined variable pressure on improving the grout penetrability.

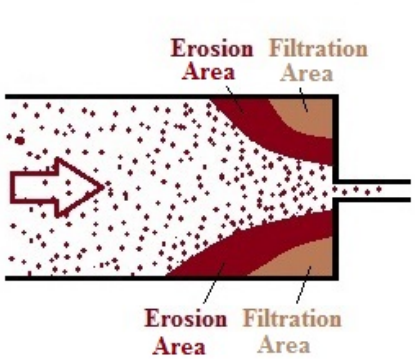


Objectives - Hypothesis

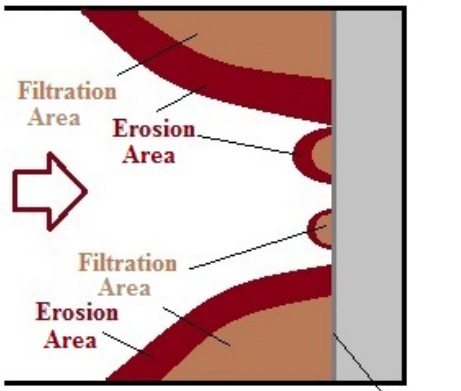
The main objective of this study is to investigate the influence of low frequency instantaneous variable pressure with different peak and rest periods on regulating the filtration and improving grout penetrability.

The hypothesis is that variation in pressure will change the flow velocity and consequently the flow pattern before the constrictions. This will increase the probability of eroding any partially built pluggs and re-open the plugged constrictions. The final result will be a better grout penetrability.

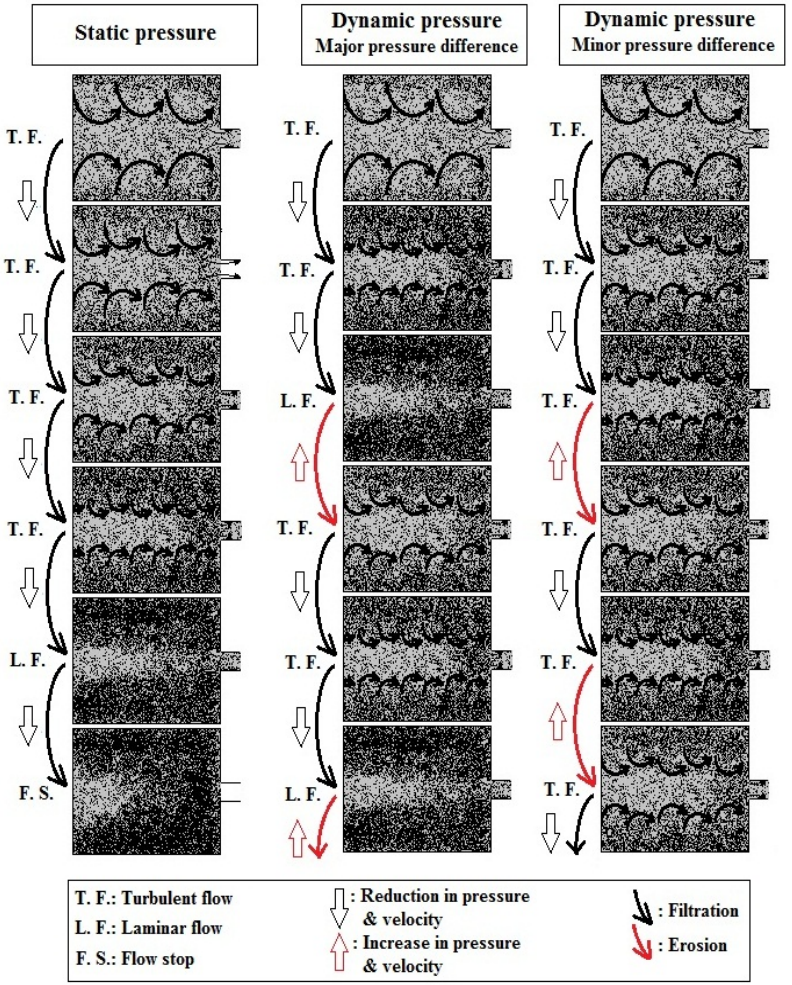




Filtration and erosion
Before a constriction
in cross section



Filtration and erosion
Before a constriction
in plan view



Materials and methods

Instruments:

- Short slot under application of static pressure
- Short slot under appllication of dynamic pressure using a pneumatic pressure control system and a ball sector valve

Evaluation methods:

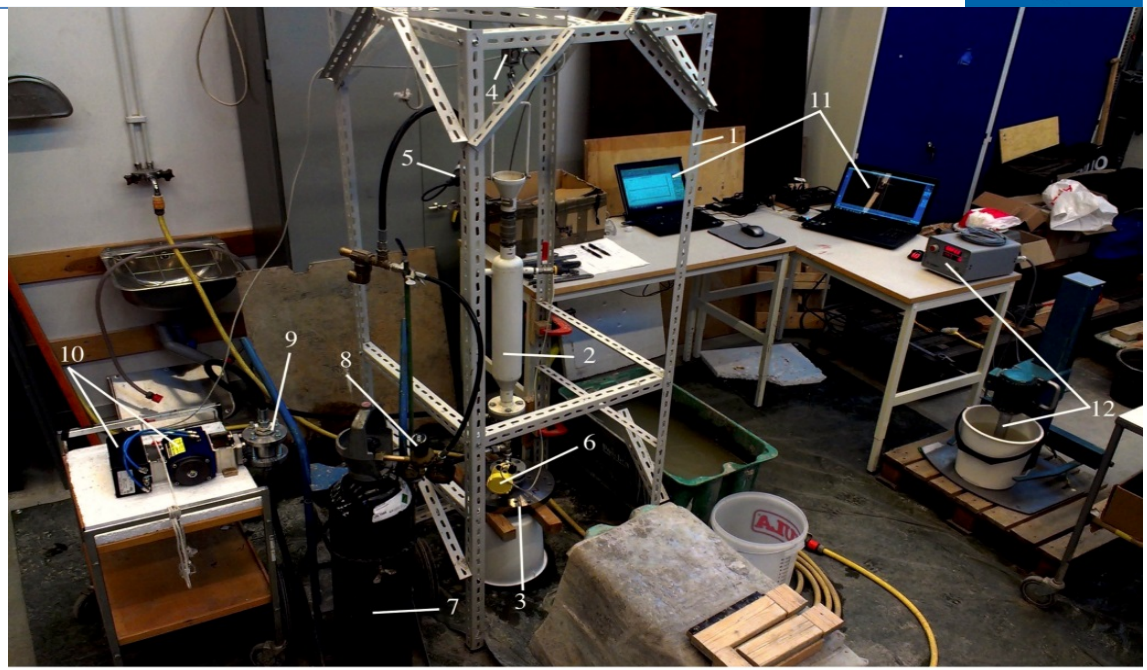
- The total weight of the passed grout
- The weight-time measurement
- The pressure-time measurement and the min-pressure envelope
- The cycle mean flow rate (CMFR)

$$CMFR = \frac{V}{T}$$

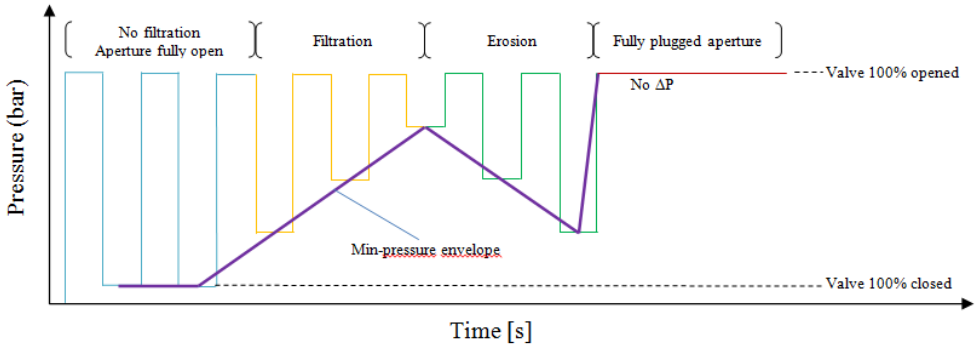
Where V is the volume of passed grout during each cycle and T is the duration of one cycle.

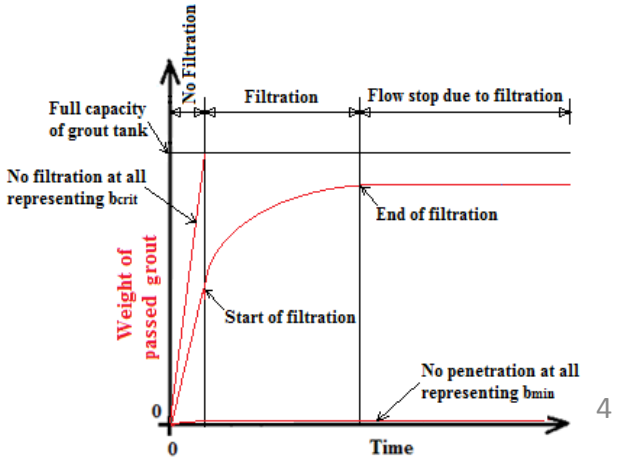
Materials:

- Cement: INJ30
- W/C : 0.8
- SP : iFlow-1; 0.5%



1. Steel frame
2. Grout tank
3. Short slot
4. Load cell
5. Pressure sensor-A
6. Pressure sensor-B
7. Gas tank
8. Pressure regulator
9. Ball sector valve
10. Actuator & I/P converter
11. Flow plot & Catman easy Softw.
12. Lab mixer





Results

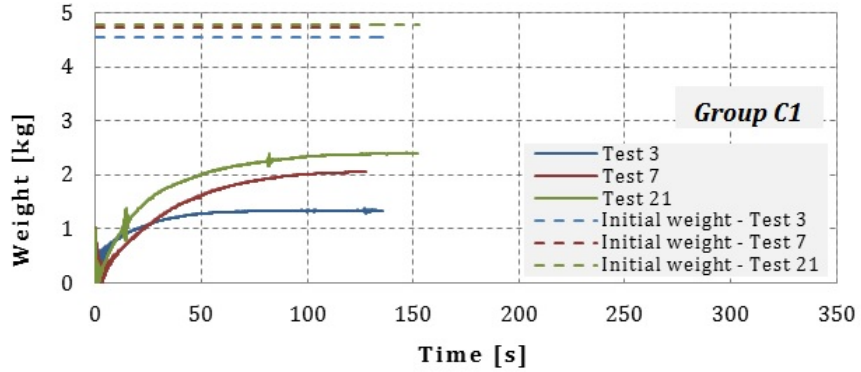
Comparison of total weight of passed grout for test groups C1, V1 and V3, using the 43 µm slot

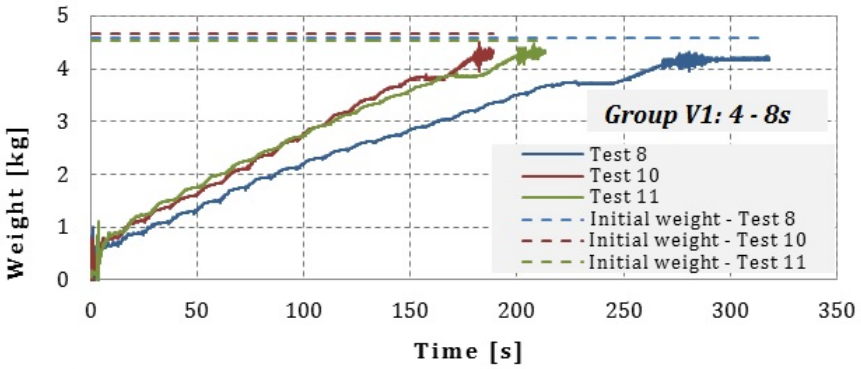
Test group	Test No.	Peak/Rest duration [sec]	Weight of passed grout [kg]	Final tank condition	Average weight of passed grout [kg]	Improvement compared to static pressure condition
C1 (static)	1	-	1.339	Not empty	1.932	-
	2	-	2.055	Not empty		
	3	-	2.402	Not empty		
V1 (dynamic)	1	4s/8s	4.189	Empty	4.271	2.2
	2	4s/8s	4.302	Empty		
	3	4s/8s	4.321	Empty		
V3 (dynamic)	1	2s/2s	4.093	Empty	4.072	2.1
	2	2s/2s	4.177	Empty		
	3	2s/2s	3.947	Empty		

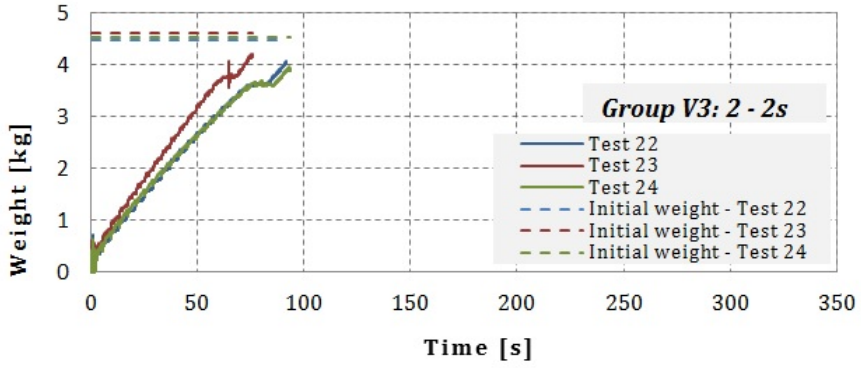
Comparison of total weight of passed grout for test groups C2, V2 and V4, using the 30 µm slot

Test group	Test No.	Peak - Rest duration [sec]	Weight of passed grout [kg]	Final tank condition	Average weight of passed grout [kg]	Improvement compared to static pressure conditions
C2	1	-	0.441	Not empty	0.299	**-**
	2	-	0.181	Not empty		
	3	-	0.275	Not empty		
V2	1	4 - 8	0.852	Not empty	0.786	**2.6**
	2	4 - 8	0.824	Not empty		
	3	4 - 8	0.684	Not empty		
V4	1	2 - 2	2.679	Not empty	3.190	**10.7**
	2	2 - 2	3.702	Not empty		

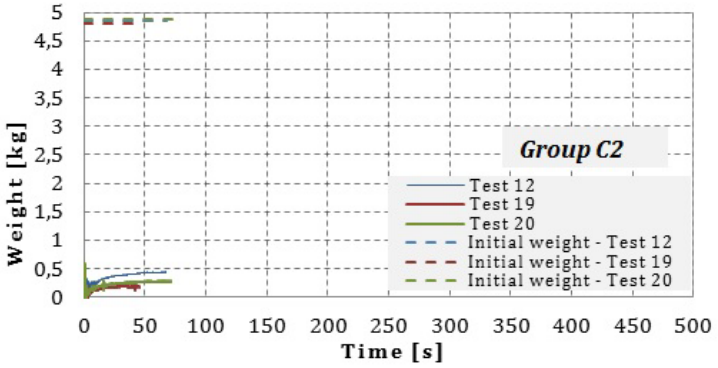
Results

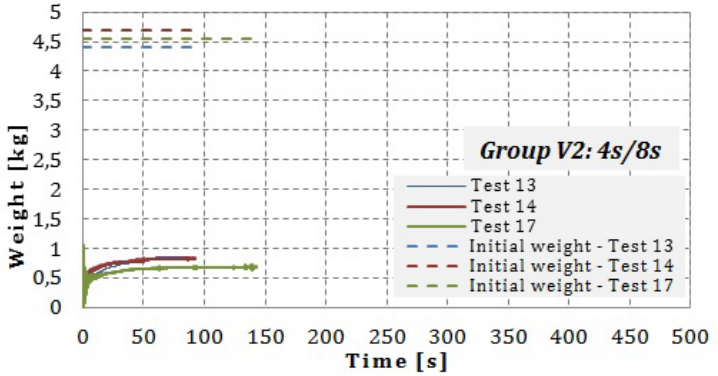


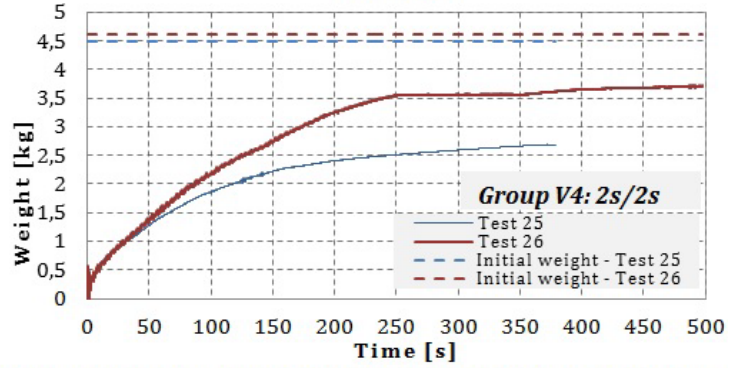




Weight - time measurement for test groups C1, V1 and V3 using the 43 µm slot and the peak - rest periods of 4 s/8 s and 2 s/2 s

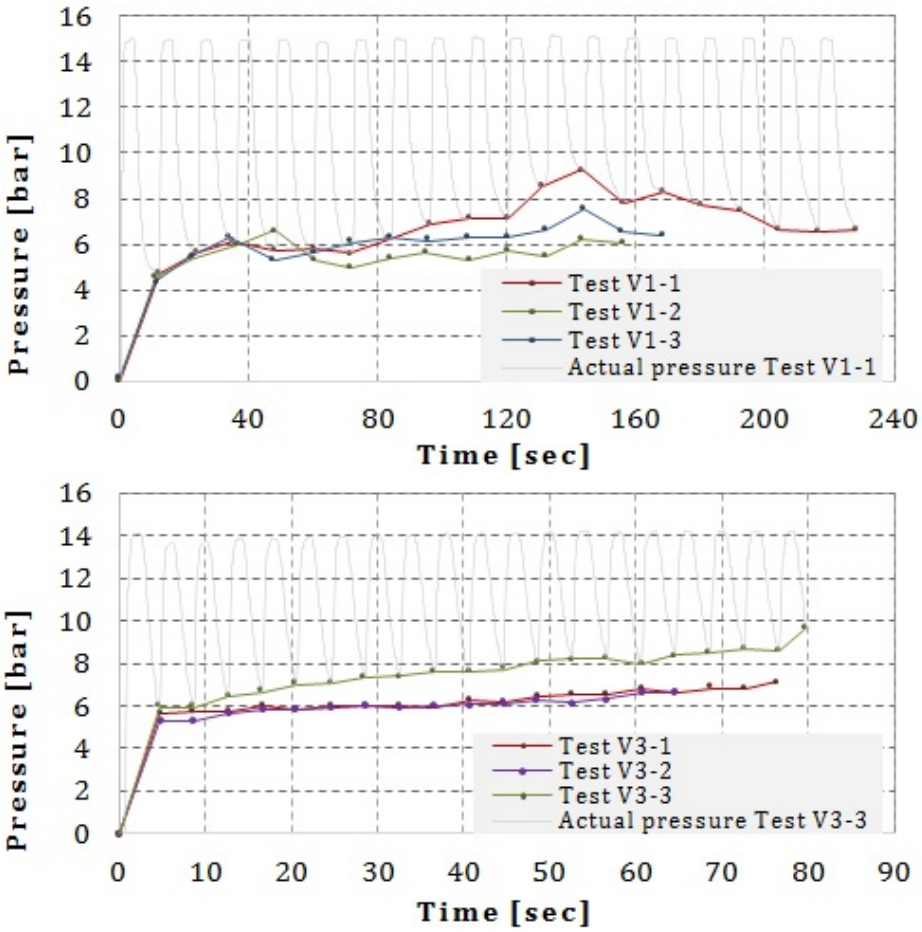




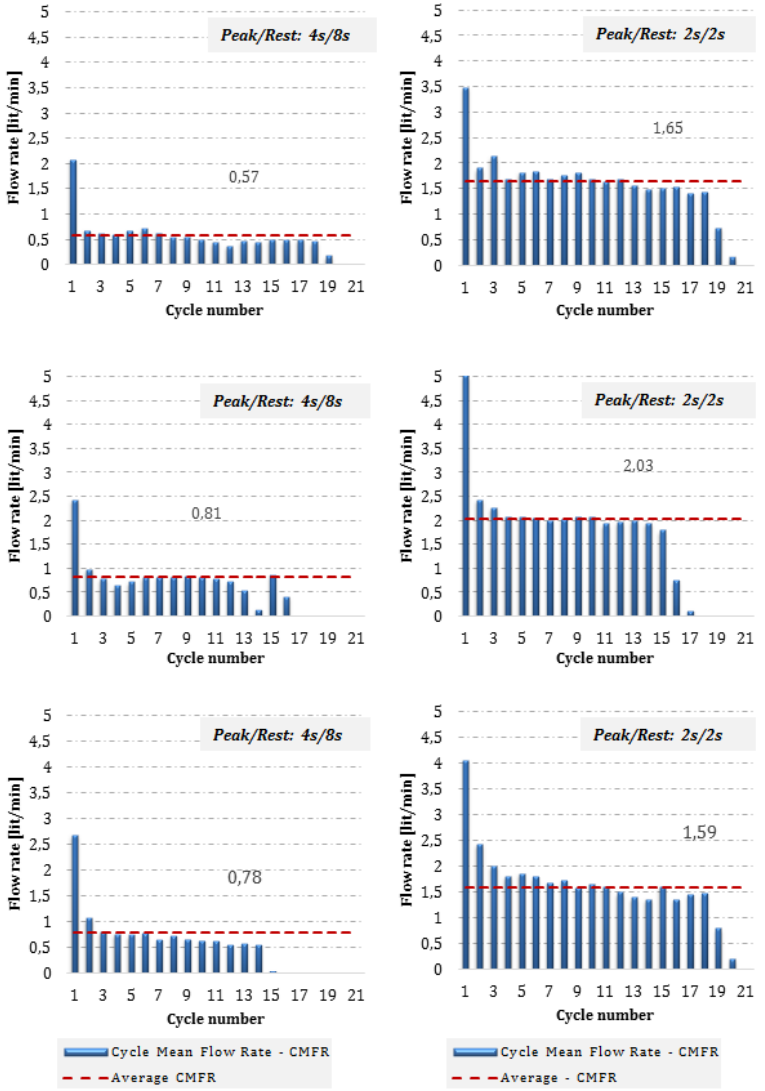


Weight - time measurement for test groups C2, V2 and V4 using the 30 µm slot and the peak/rest periods of 4 s/8 s and 2 s/2 s

Results



Filtration envelopes for test groups V1 and V3 with peak/rest periods of 4 s/8 s and 2 s/2 s respectively using the 43µm slot



Cycle mean flow rates (CMFRs) and average CMFRs for the test results of 43 µm with 4 s/8 s and 2 s/2 s peak/rest periods

Conclusion

- Application of instantaneous variable pressure had a great impact on improving grout penetrability compared to the application of constant pressure at constrictions through the artificial fractures.
- The results of both selections of the peak and rest periods, i.e. the 4s/8s and 2s/2s, revealed that cycle periods higher than 1 sec regulated the filtration and improved the grout penetrability effectively.
- The results also showed that application of the 2s/2s peak/rest period is much more efficient than the 4s/8s period. In the 30 µm slot, the 4s/8s and 2s/2s peak/rest periods showed about 2.6 and 11 times improvement respectively compared to the static pressure.
- In the 43 µm slot, the average *CMFR* was higher (about 2.5 times) for the 2s/2s peak/rest period, which emptied the grout tank in just half of the time required for the 4s/8s period. This means that choosing the correct peak/rest period depending on the grout recipe and the conductivity of the area, i.e. the fracture sizes, will significantly reduce construction time in the field.
- Accumulation of cement particles, i.e. filtration, mostly occurs during the first cycle. The key to a successful dynamic grouting is thus to prevent or reduce the filtration in the first cycle.
- The mechanism of improvement of grout penetrability under application of instantaneous variable pressure is hypothetically variation in flow pattern before the constriction due to the change in pressure and flow velocity. This is under further investigation within experimental and numerical approaches and the results will be revealed in later stages of the project.