Investigation and development of material properties for shotcrete for hard rock tunnels

Undersökning och utveckling av materialegenskaper hos sprutbetong för bergtunnlar

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Background

- *In hard rock tunnelling shotcrete (sprayed concrete) is one of the most important materials used to stabilize and secure the rock.*

- *One important case is vibrations from blasting during tunnelling which lead to full or partial de-bonding between shotcrete and rock.*

- *Extreme environments, as for example transmizzive zones in the rock where a lot of water flows, drainage systems together with shotcrete linings make a more complex system. Cracking of shotcrete linings due to restrained shrinkage is in focus where crack limiting is an essential issue.*

- *Numerical analyses have also highlighted the need for accurate data on e.g. early bond strength as input for accurate analyses.*

Reseach project

Investigation of early age material properties of shotcrete for tunnels of hard rock.

Input for advanced modelling and analysis of shotcrete on hard rock.

Knowledge of time dependent material properties of shotcrete to attain:

- *more cost effective design of rock support*
- *reduced shrinkage cracking at early age*
- *more secure and efficient production process of hard rock tunnels.*

Principal idea

- *"The microstructure and material properties of shotcrete differs substantially from ordinary concrete."*
- *Today – mechanical properties for cast concrete are often used in the analysis of shotcrete.*

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Objectives

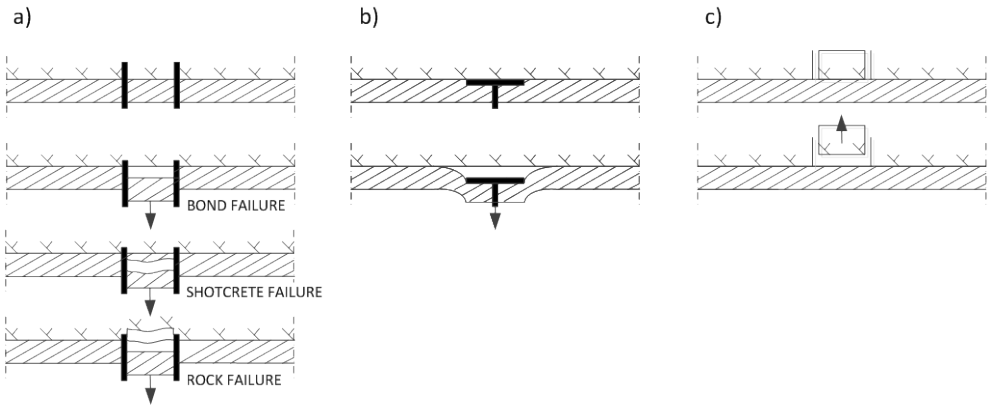
- *The main objective was to investigate different mechanical properties of shotcrete as a function of age.*

- *A second objective was to investigate and measure the bond strength between shotcrete and hard rock and to suggest and evaluate a suitable method for testing at early shotcrete ages.*
- *Studies of the microstructure at the interface between rock and shotcrete were also included.*

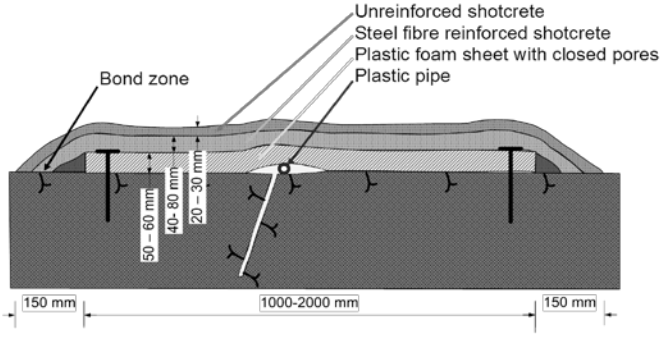
- *A third objective was to investigate free and restrained shrinkage of young and hardening shotcrete and the risk of cracking.*

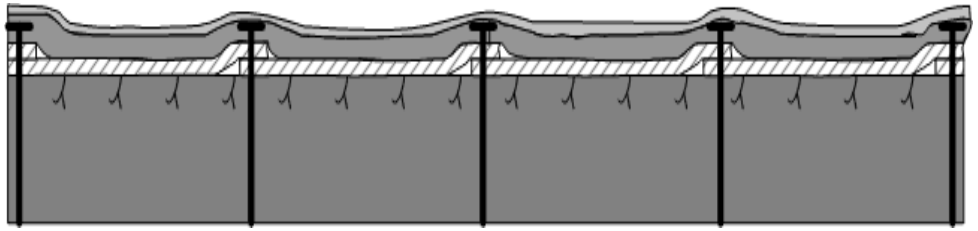
Shotcrete in tunnelling – two main issues

- Testing of early age bond strength



Shotcreted drains on rock – restrained shrinkage





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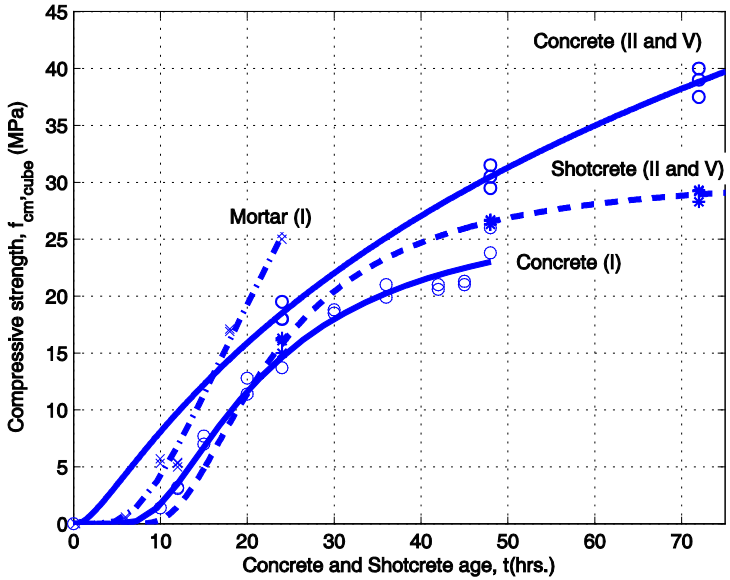
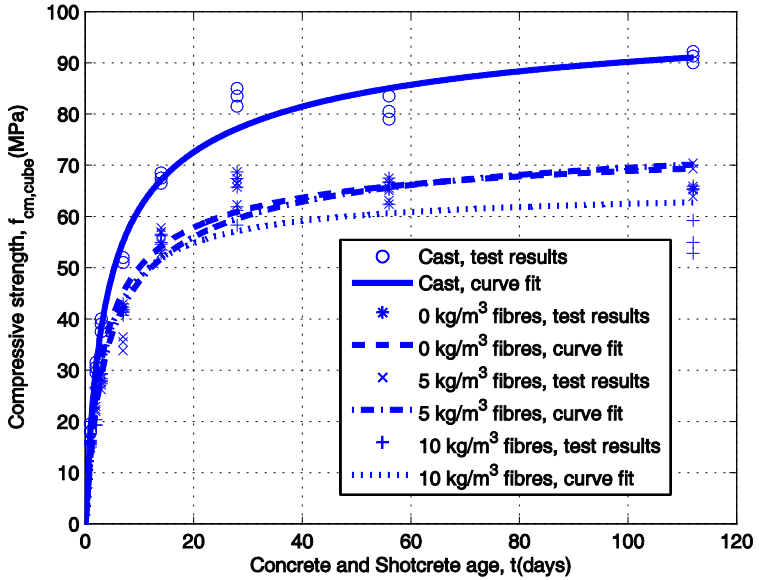
Results – Compressive strength, cast and sprayed concrete (shotcrete)

0-3 days



0-112 days



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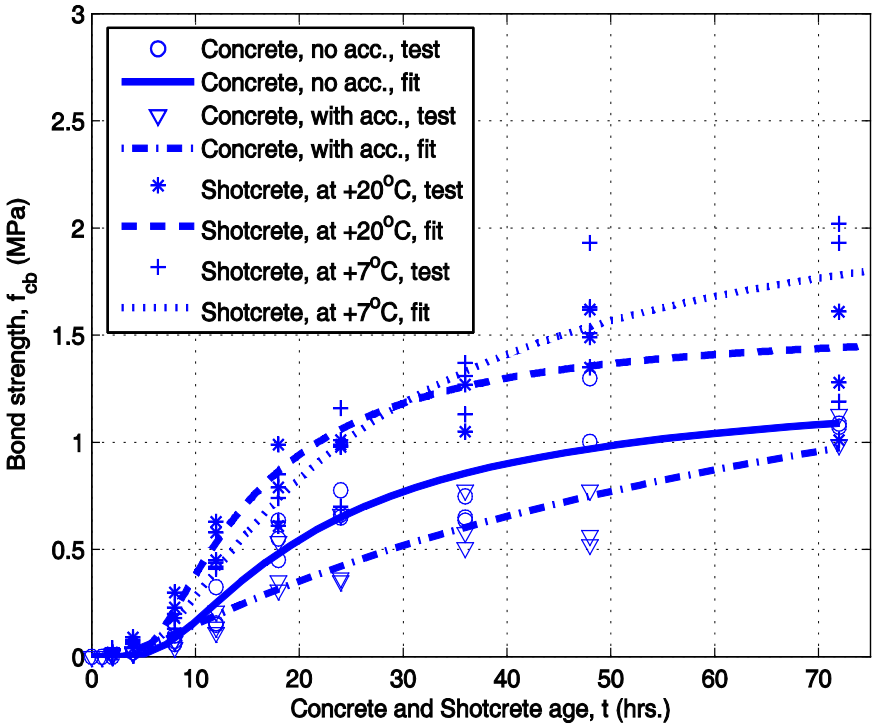
Results – Bond strength

0-3 days, cast and sprayed concrete



Sprayed

Cast

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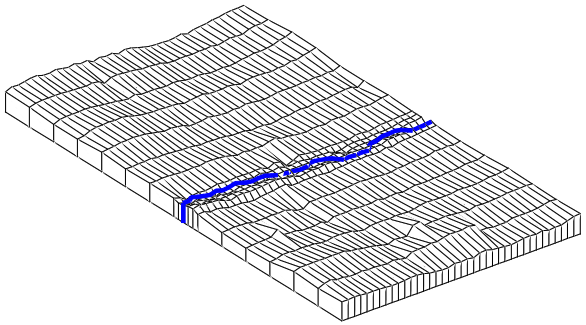
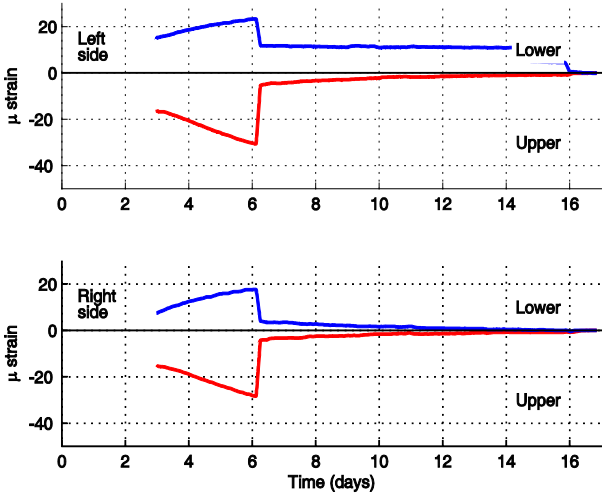
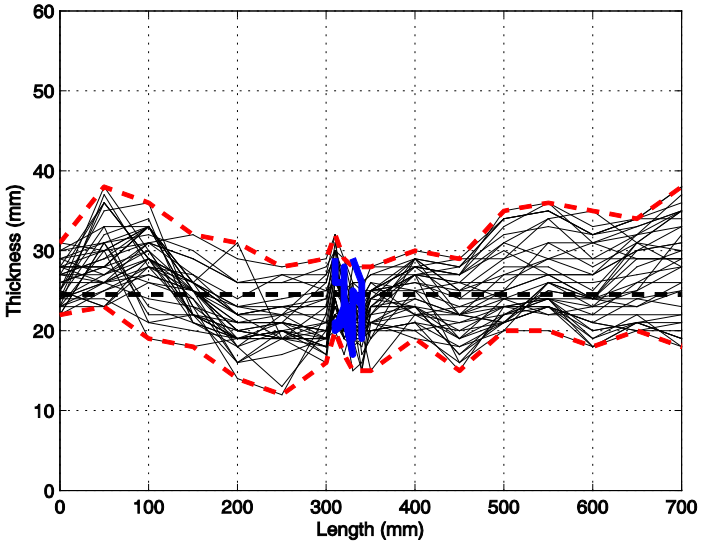
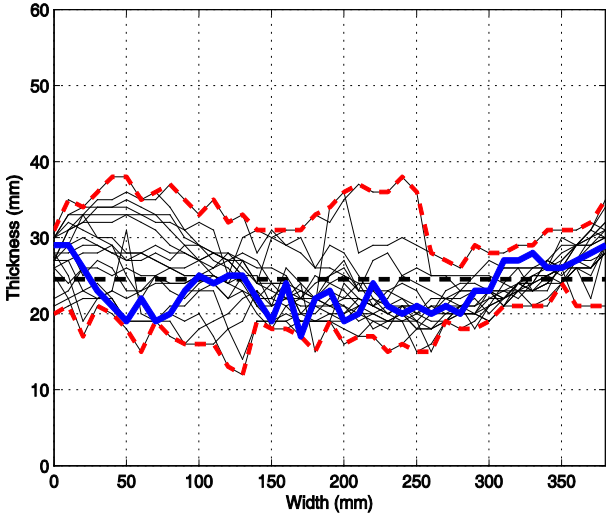
Results – partly restrained shrinkage, slab test









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Results – Partly restrained shrinkage, slab test summary

Test slab no.	1	2	3	4	5	6
Fibre content (kg/m^3)	0	0	5	5	10	10
Mean layer thickness (mm)	25	33	32	37	37	41
Minimum thickness (mm)	17	26	22	34	20	17
Time to failure (days)	6	7	8	16	7	8
Failure type	crack	crack	crack	crack	crack	bond
ε_U (µstrain)	-25	-43	-40	-66	-25	-44
ε_L (µstrain)	13	25	23	33	21	29

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Conclusions and future work

Basic material properties

- *Cast concrete – higher compressive strength than shotcrete*
- *Tendency that glass fibres reduces the compressive strength*

Bond strength testing

- *New method proved useful for testing from a couple of hours after shotcreting*
- *Difference in strength growth ratio*

Shrinkage testing

- *New method realistically captures the behaviour of end-restrained shrinkage shotcrete slabs on soft drains for hard rock in situ*
- *Glass fibres delays time of cracking*

Future work

- *Different climate conditions, i.e. temperature and humidity conditions relevant for tunnel environments*
- *Optimal mix of glass and steel fibres*

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