Microstructural Appearance of Cement Paste as a Function of Curing Temperature and Maturity Age

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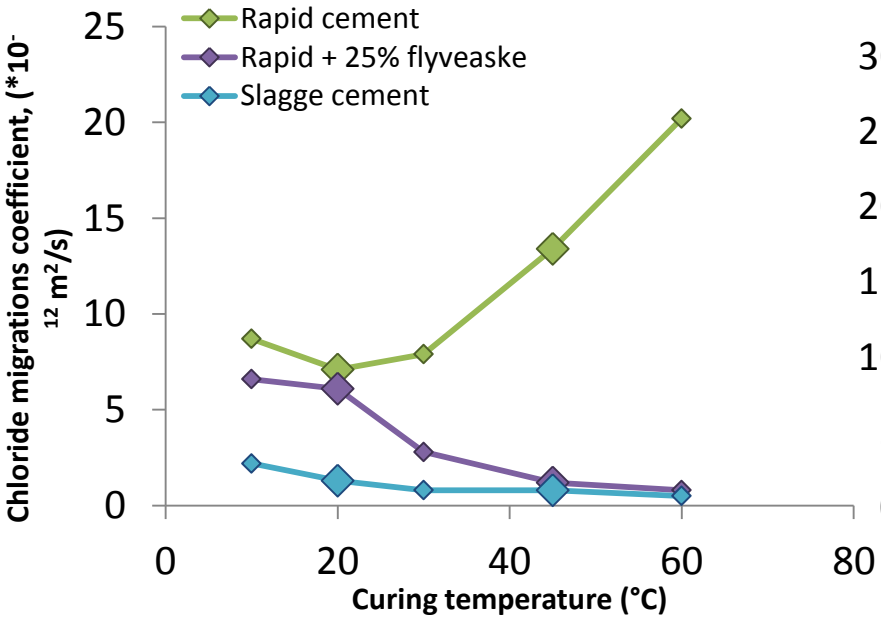
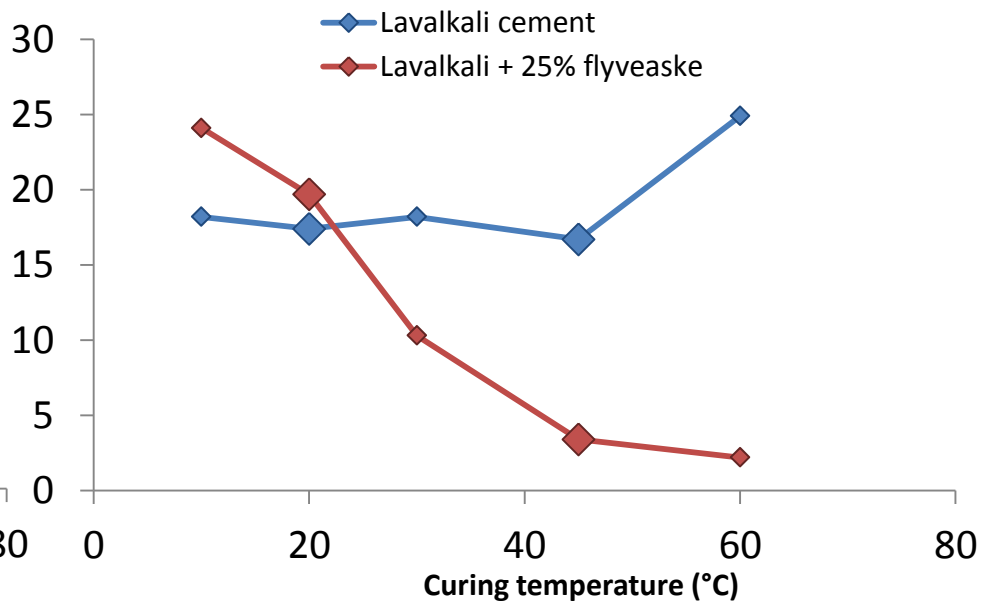
Background & Aim

Laboratory testing related to project “Egenskabsudvikling” showed the following results:

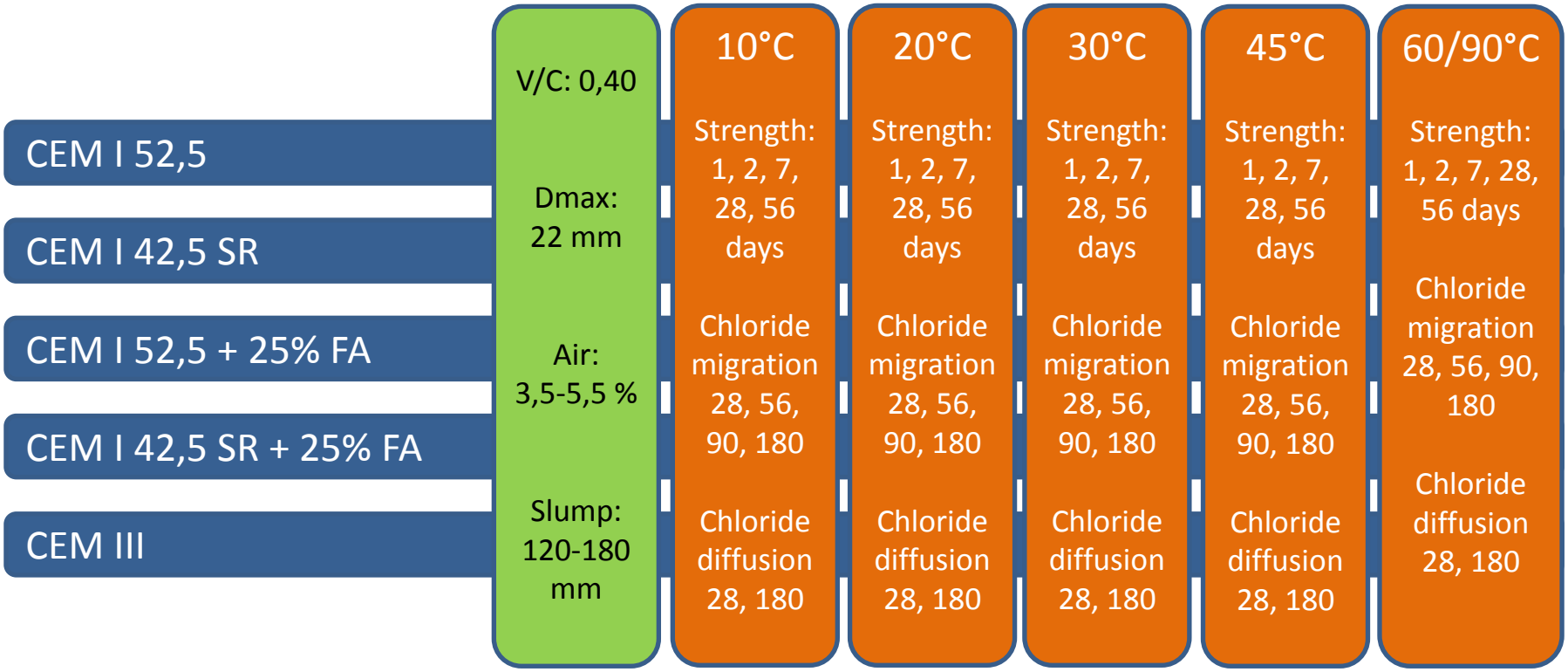
At the same maturity the chloride migration coefficient is lower the higher the temperature, for fly ash concrete; for non-fly ash concrete the chloride migration coefficient is higher.





Aim: Can the microstructure explain the test results?
Is there any difference in connectivity of the pores?

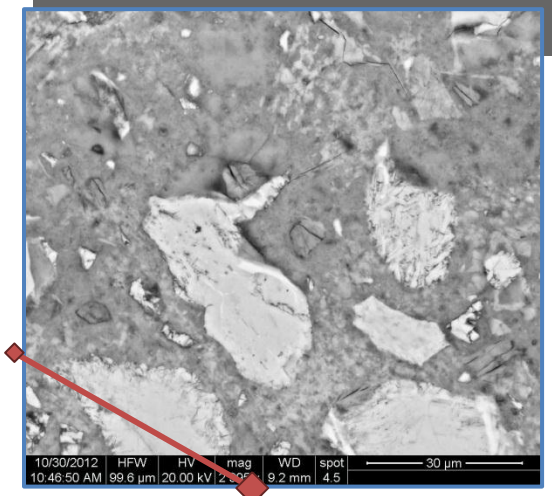
Eksperimental program

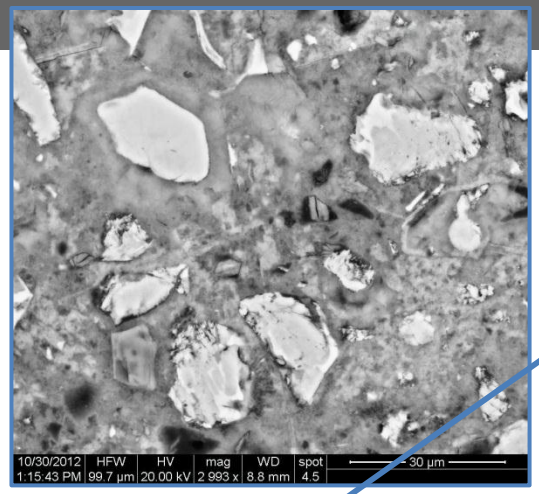


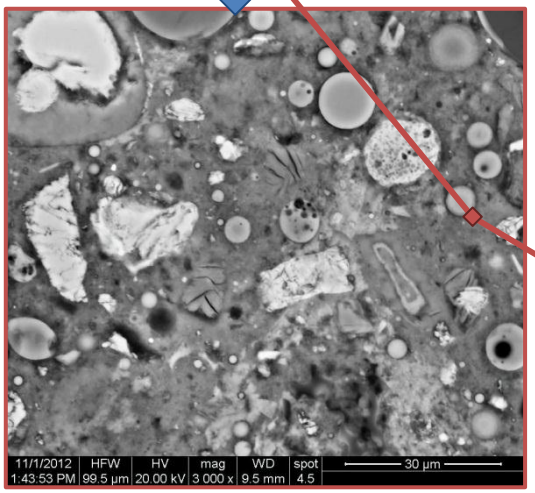
Petrographic analysis (each):

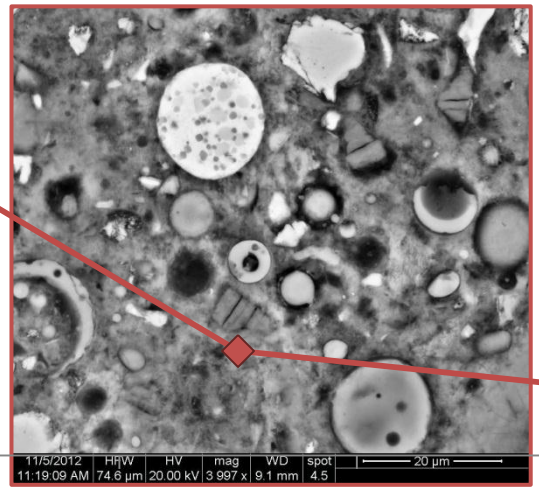
CEM I 42.5 SR +/- FA, CEM III:	6 polished samples (20°C & 45°C; maturity 7, 28 & 90 days)
CEM I 52.5 +/- FA:	15 thin sections & 15 polished samples (10, 20, 30, 45 & 60°C; maturity 7, 28, & 90 days

Chloride migration vs. curing temperature, 28 days









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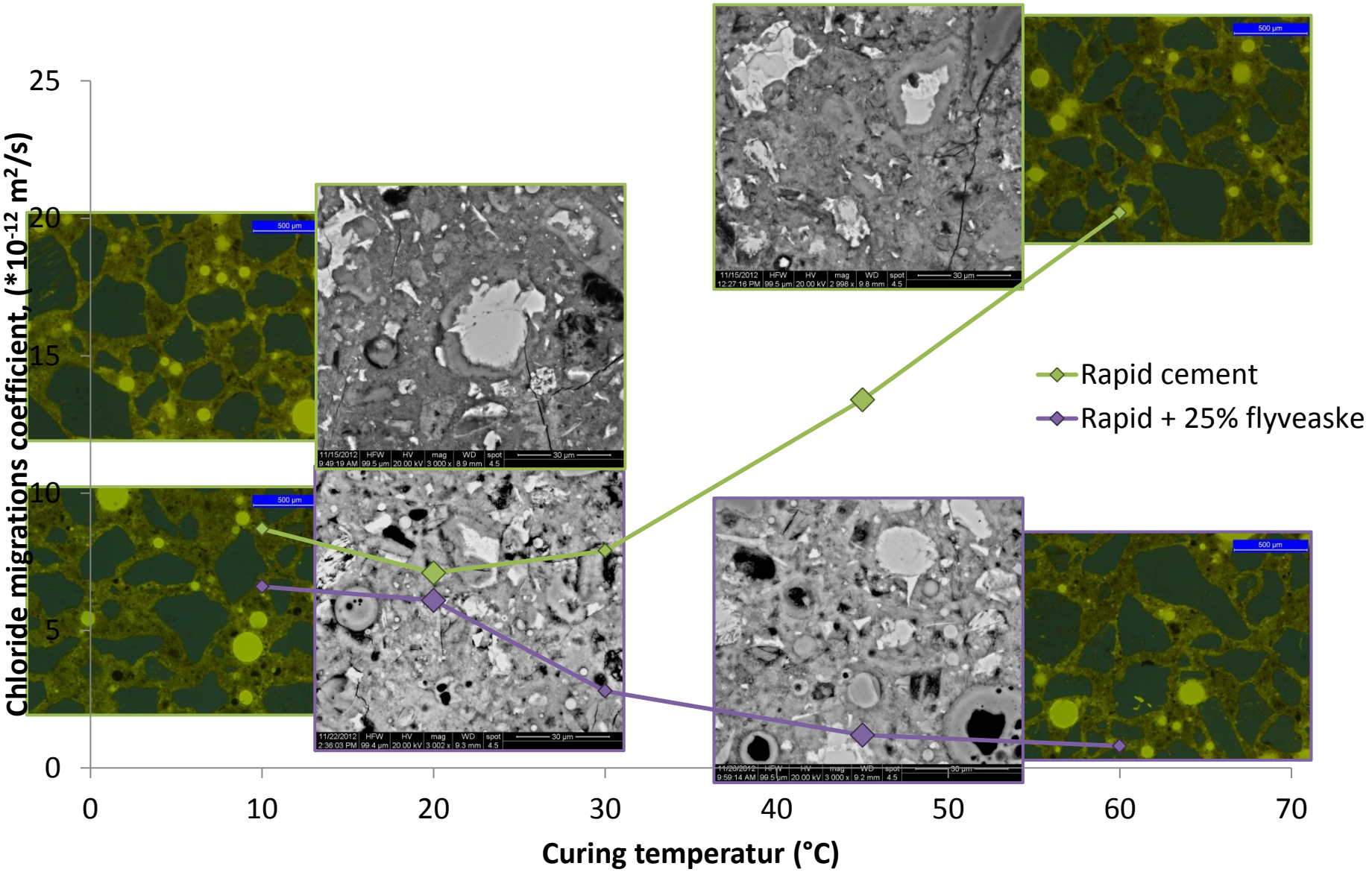
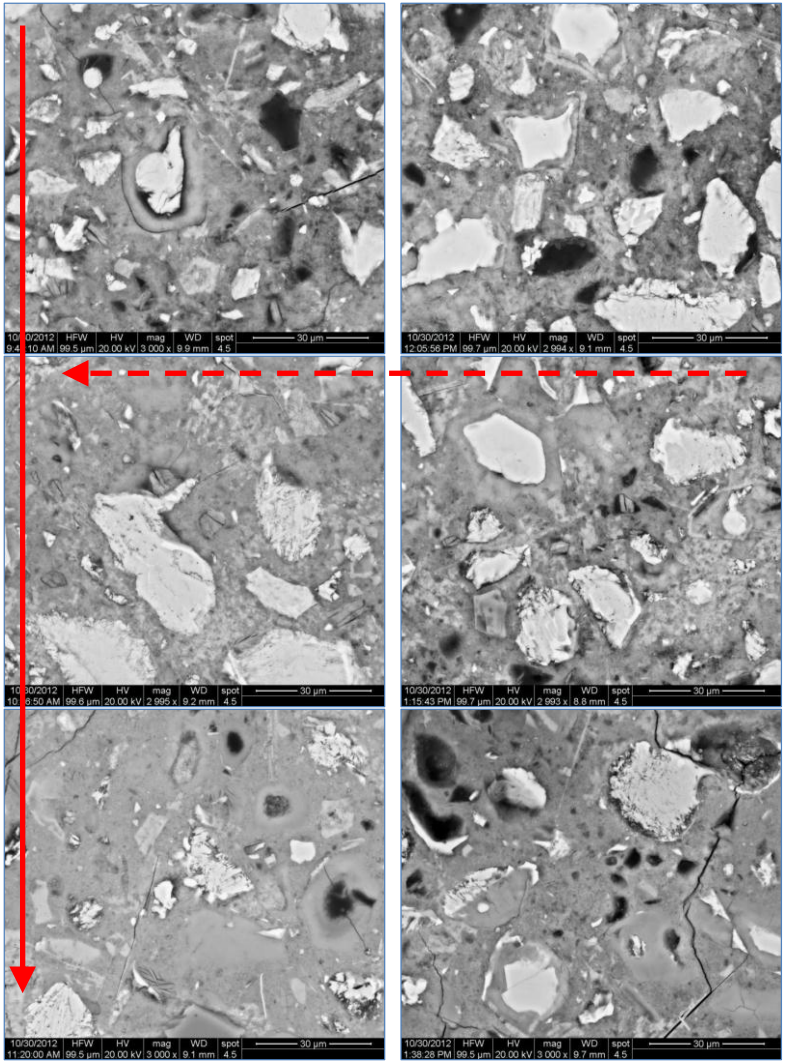


Microstructural Appearance

Sample A; CEM I 42,5 SR. Maturity increases from top 7days to 28 and 90 days

Curing temp: 20°C

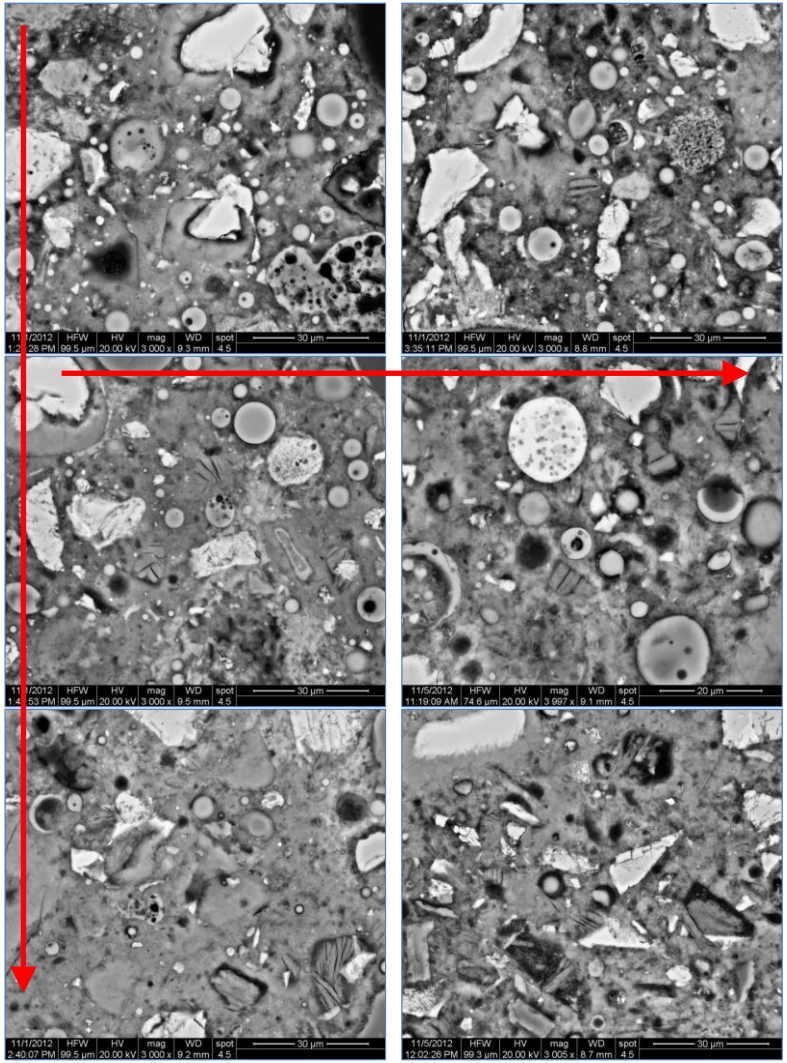
Curing temp: 45°C



Sample B; CEM I 42,5 SR + FA. Maturity increases from top 7days to 28 and 90 days

Curing temp: 20°C

Curing temp: 45°C



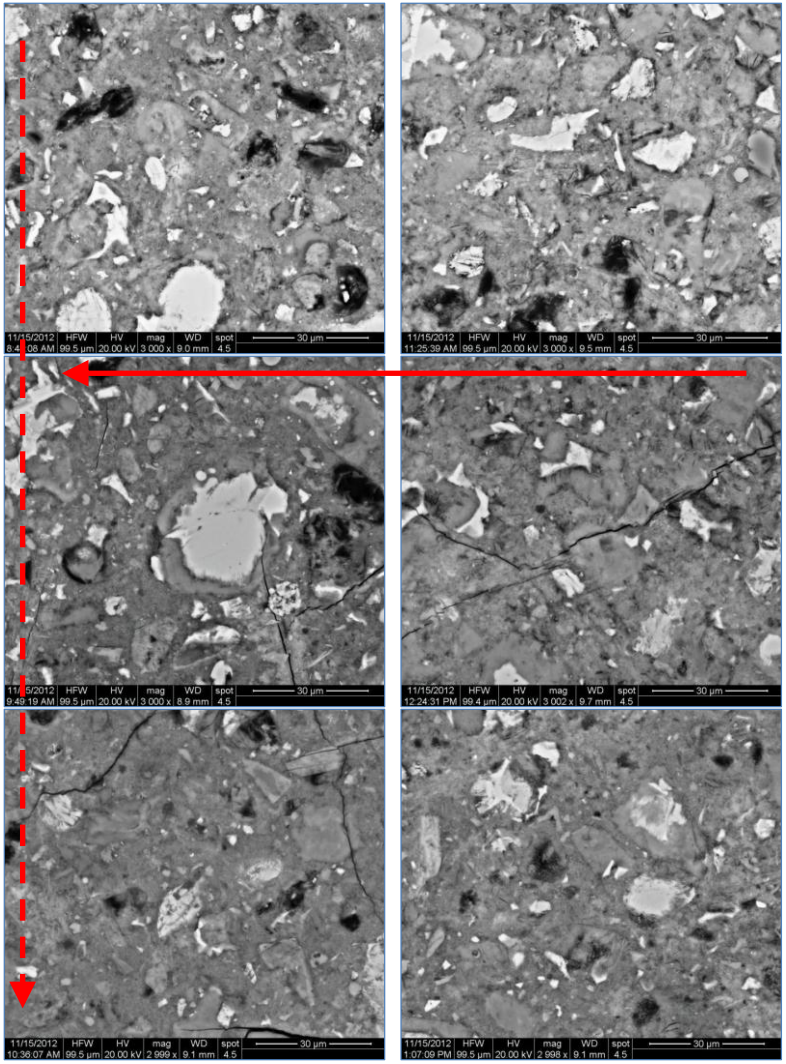
Red arrows indicate decrease in chloride migration coefficient

Microstructural Apperance

Sample C; CEM I 52,5. Maturity increases from top 7days to 28 and 90 days

Curing temp: 20°C

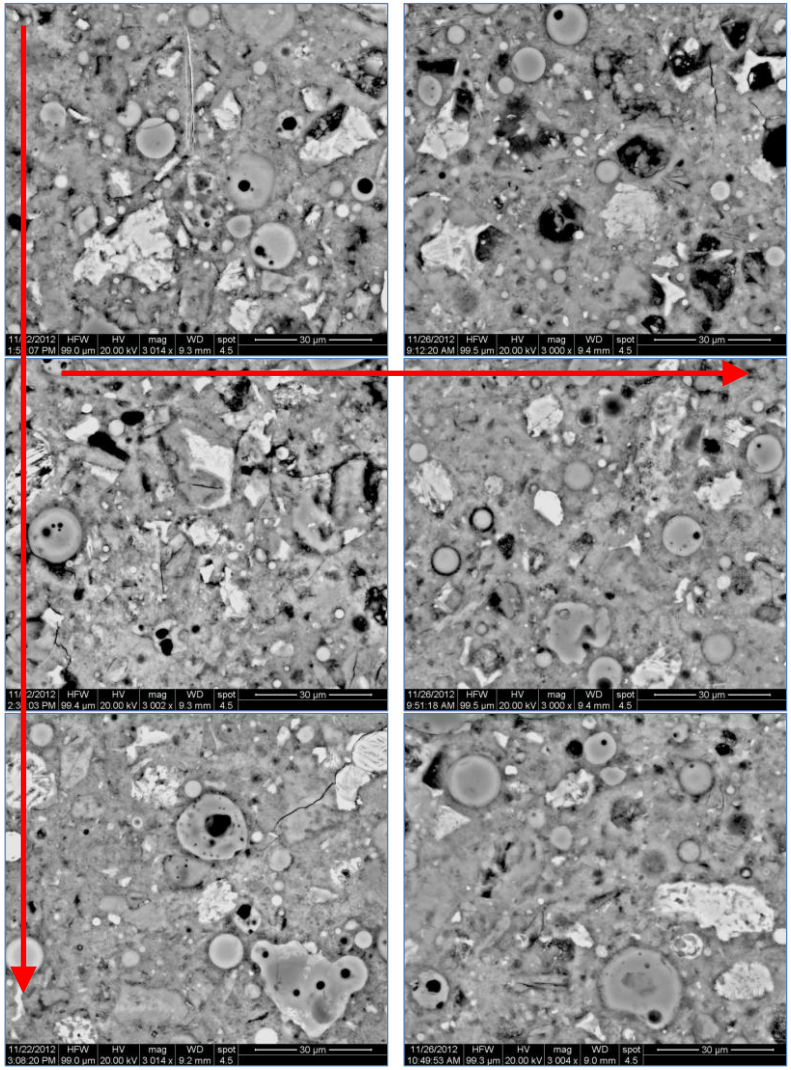
Curing temp: 45°C



Sample D; CEM I 52,5 SR + FA. Maturity increases from top 7days to 28 and 90 days

Curing temp: 20°C

Curing temp: 45°C



Red arrows indicate decrease in chloride migration coefficient;

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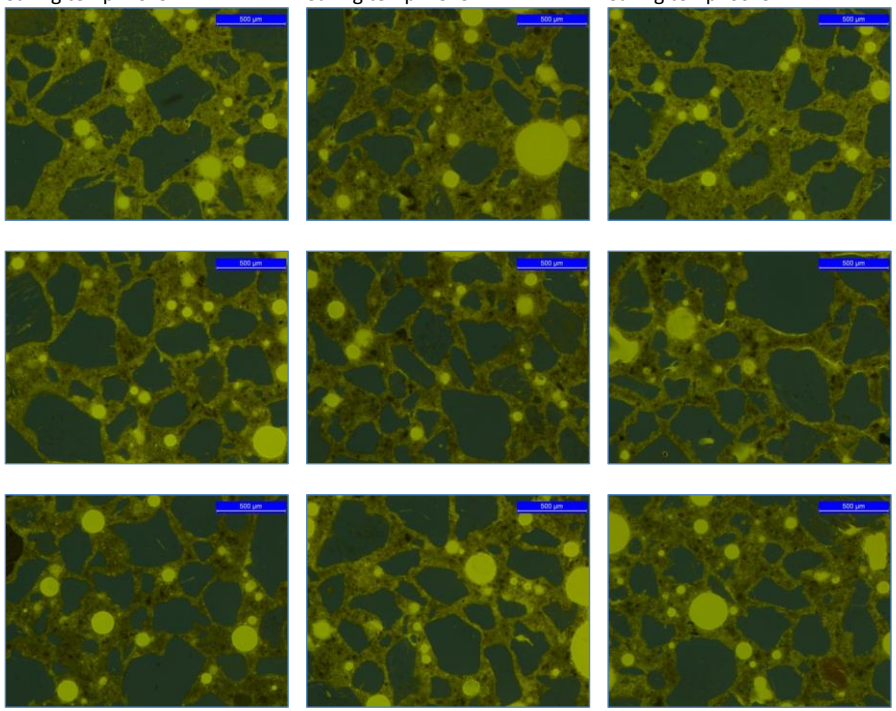
Microstructural Apperance

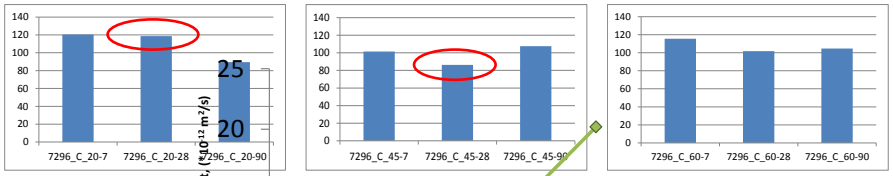
Cement Type	Temp	Age	Hadley holes Empty	Hydrates filling Hadley holes	Homogeneity of paste	FA hydration	Micro cracks in paste	Adhesion between IH & OH
A CEM I 42.5 SR	20	7	Many	Few	Inh.			
	20	28	Some	Few	Rel. Hom			
	20	90	Few	Few	Hom.			
A CEM I 42.5 SR	45	7	Many	Few	Inh.			
	45	28	Many	Some	Inh.			
	45	90	Many	Few	Hom.			
B CEM I 42.5 SR +FA	20	7	Some	Few	Inh.	No		
	20	28	Some	Some	Inh.	Yes		
	20	90	Few	Many	Hom.	Yes		
B CEM I 42.5 SR +FA	45	7	Many	Some	Inh.	No		
	45	28	Some	Many	Rel. Hom	Yes		
	45	90	Few	Many	Rel. Hom	Yes		
C CEM I 52.5	20	7	Some	Few	Inh.		Yes	
	20	28	Many	Few	Rel. Hom		Yes	
	20	90	Some	Some	Hom.		Yes	
C CEM I 52.5	45	7	Many	Few	Hom.		Yes	Poor
	45	28	Many	Some	Rel. Hom		Yes	Poor
	45	90	Many	Some	Hom.		Yes	Poor
D CEM I 52.5 +FA	20	7	Many	Few	Inh.	No		
	20	28	Many	Few	Hom.	No	Yes	
	20	90	Some	Some	Hom.	No	Yes	
D CEM I 52.5 +FA	45	7	Many	Some	Rel. Hom	Yes	Yes	
	45	28	Some	Some	Rel. Hom	Yes	Yes	
	45	90	Few	Some	Hom.	Yes	Yes	

Capillary Porosity

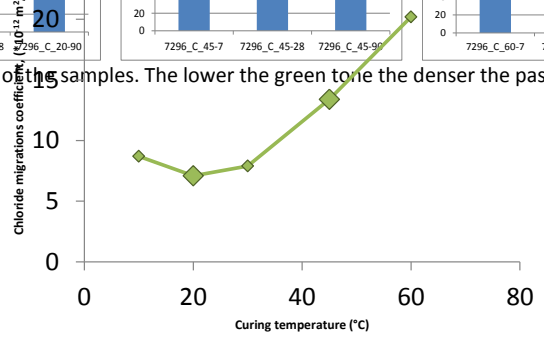
Sample C; CEM I 52,5. Maturity increases from top 7days to 28 and 90 days

Curing temp: 20°C | Curing temp: 45°C | Curing temp: 60°C





Average green tone of the samples. The lower the green tone the denser the paste. N=20.



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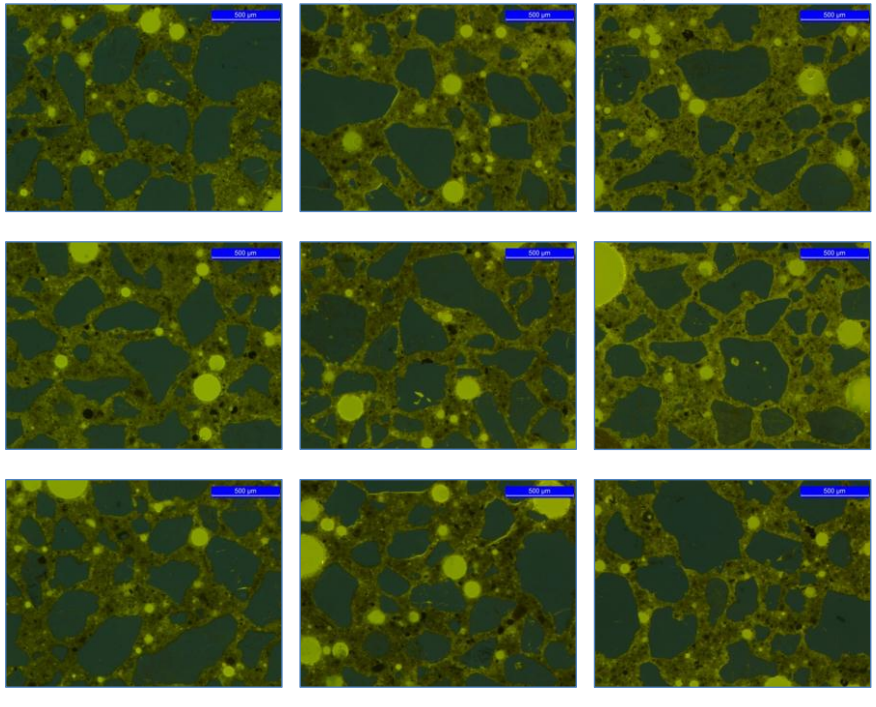

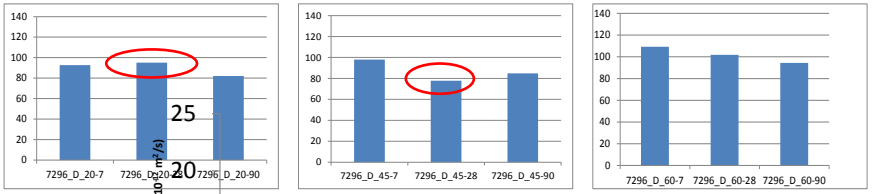

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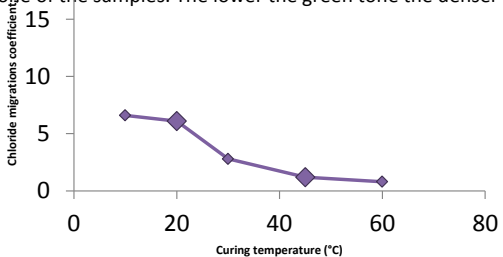

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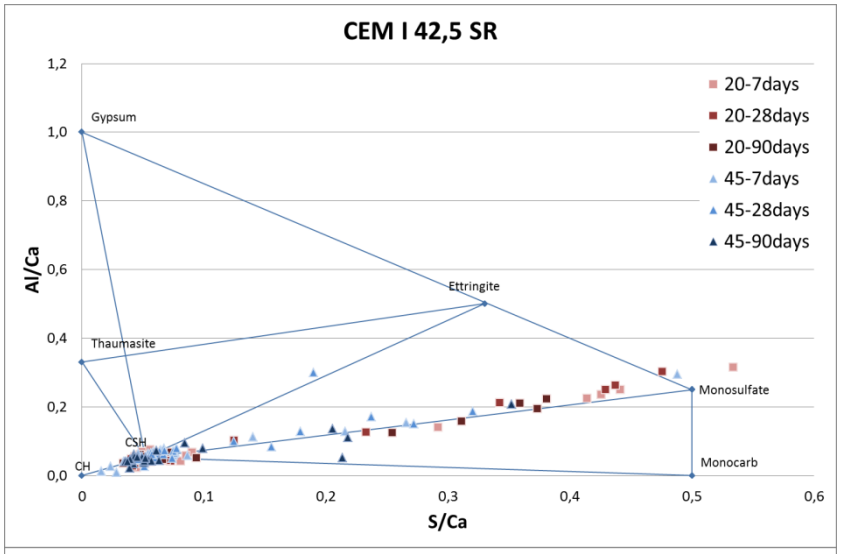
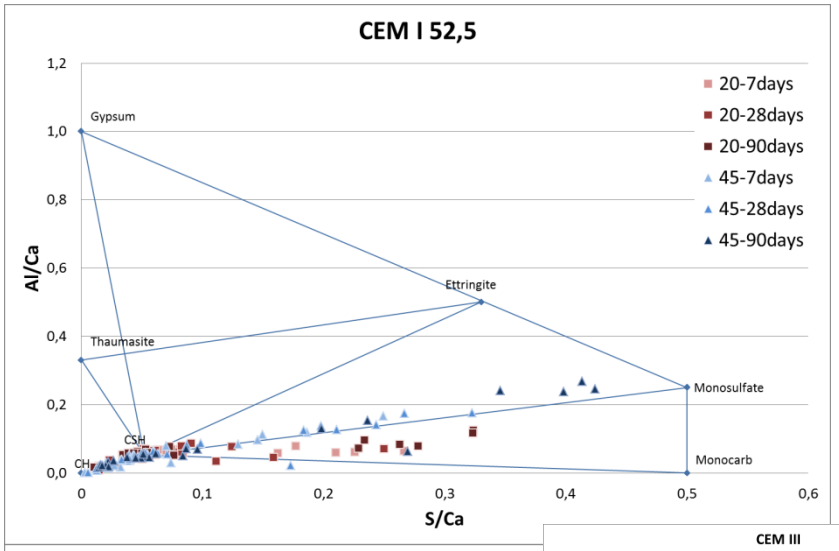
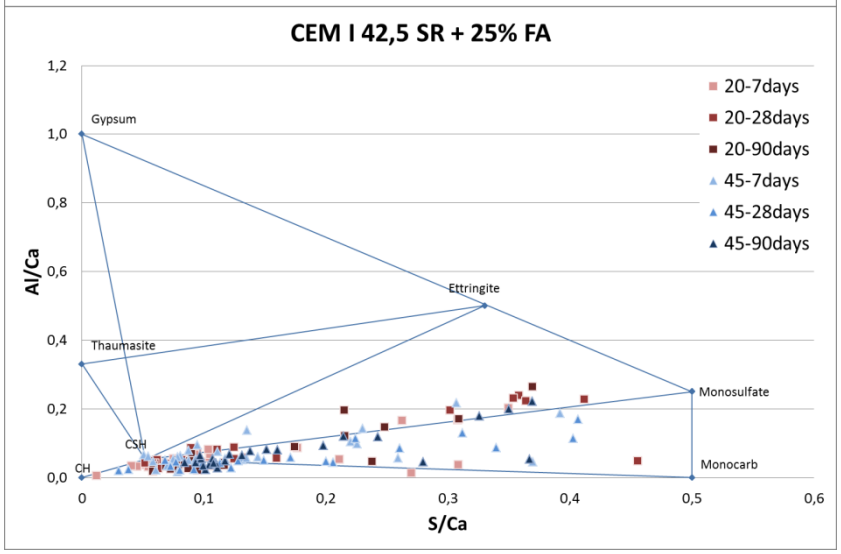
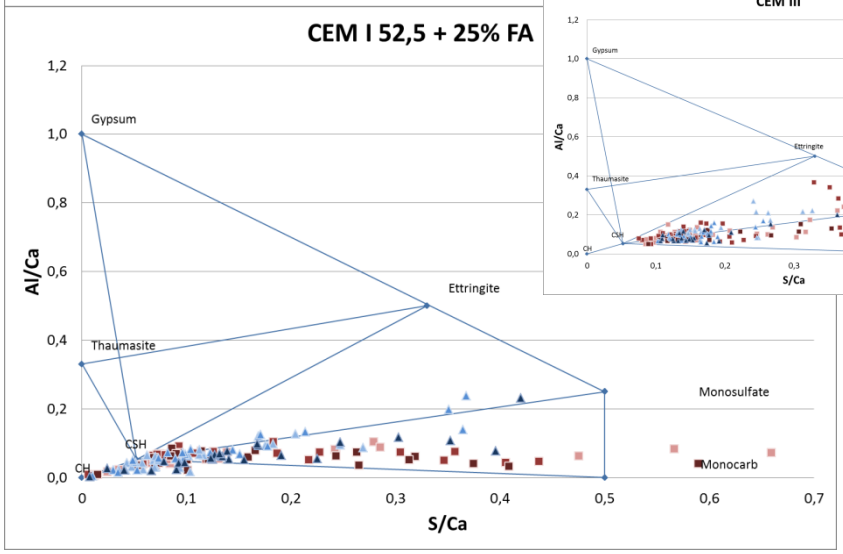
Phase Compositon









Ettringite: $Ca_3Al(OH)_6.12H_2O.(SO_4)_3.2H_2O$, monosulfate: $Ca_2Al(OH)_6.SO_3$; monocarboaluminate: $3CaO.(Al,Fe)_2O_3.CaCO_3.11\text{-}12H_20$

CONCRETE EXPERTCENTRE

Conclusion

- The petrographic analysis using fluorescence impregnated thin sections and polished section did not explain the test results regarding chloride migration

- Generally the fluorescence analysis showed that the paste porosity of the samples are very similar

- The SEM-EDX analysis showed some difference in the amount of:
  - Hadley holes
  - Infilling of Hadley holes
  - Homogeneity of the paste
  - Degree of fly ash hydration
  - Micro-cracks in paste
  - Adhesion between IH & OH

- The phase assemblage differs between cement type and curing temperature