BIND-AMOR: Flash-calcined dredging sediments of the AMORAS mechanical dewatering plant al cement substitute

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Situation – Port of Antwerp

- **Port of Antwerp**
  - 2nd largest port in Europe
  - 42 sea ship per day
  - 10 km²
  - 900 companies
  - 10 billion €/y added value creation
  - 60 000 FTE direct employment
- **Inland located (river) seaport**
  - Riverine transport of sediments
  - Constant sedimentation in docks
  - Dredging of 600 000 tonnes (dry matter/DM) per year
  - Estuarine disposal not allowed

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Introducing Amoras – A mechanical dewatering plant for dredging sludge

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From Filter cake to cement substitue

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FILTER CAKE - CHARACTEISATION

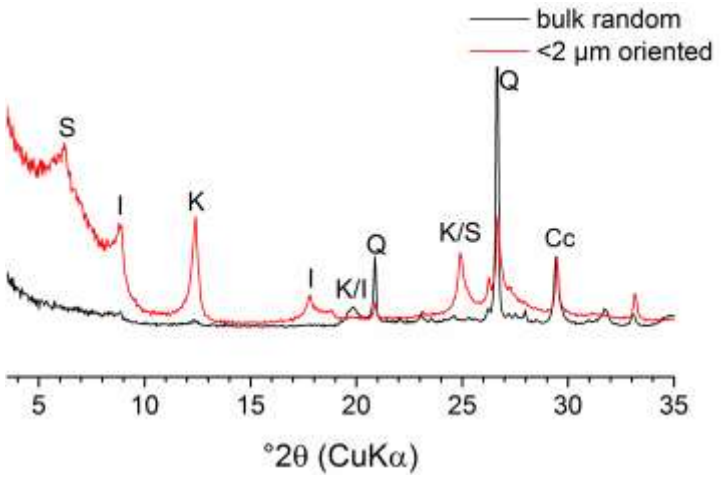
» **Filter cake** – dried at 40 °C till constant mass → **dry matter content 63 ± 3 wt.%**

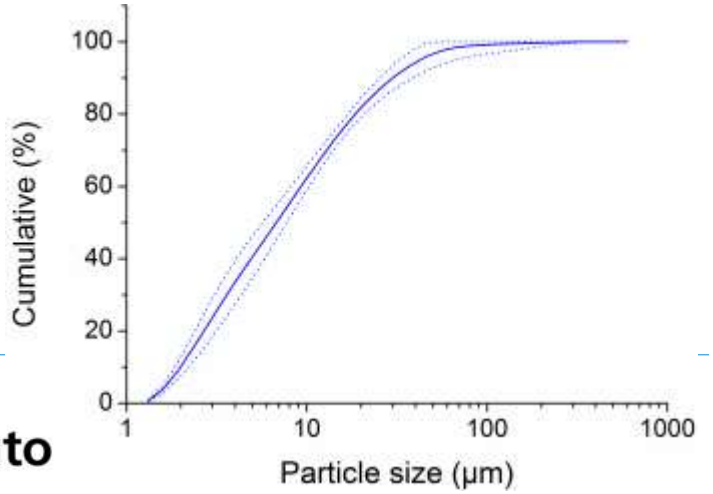
Chemical composition	
Oxide	**wt.%**
Al_2O_3	10
SiO_2	37
Fe_2O_3	9
CaO	12
MgO	1.6
Na_2O	0.5
K_2O	2
P_2O_5	1
TiO_2	1
S	1.1
TIC	1.9
TOC	3.6
Cl	0.1
LOI	22

Mineralogical composition	
Phase	**wt.%**
Quartz	20
Feldspars	4
Calcite	13
Other carbonates	8
Pyrite	1
2:1 Al clay (illite/smectite)	30
2:1 Fe clay (a.o. glauconite)	4
Kaolinite	3
Anatase	0.3
Unidentified/amorphous	17

Calcination

Oxidation of S and TOC ↓ H_2O **Activation of clay minerals**





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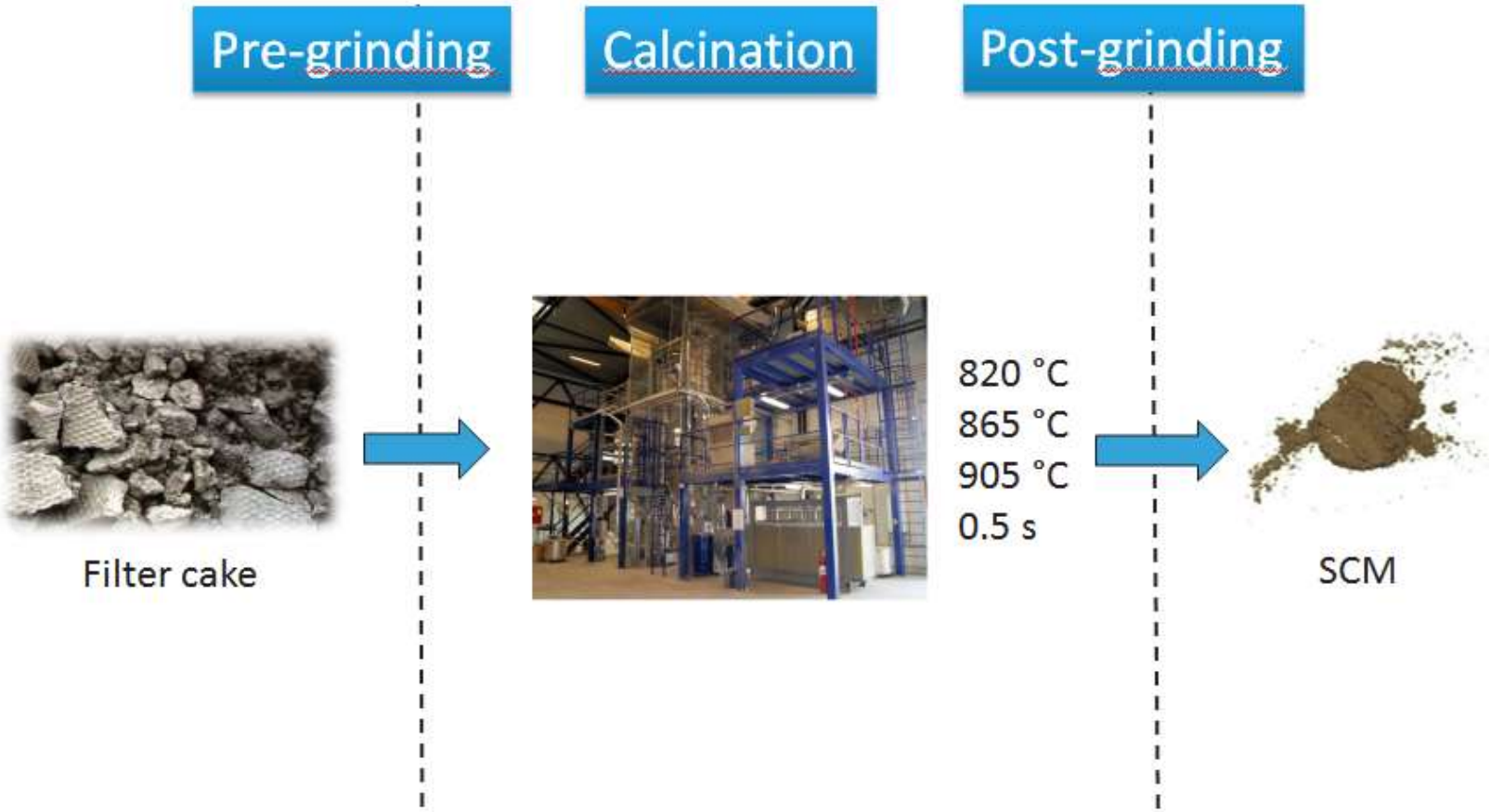
Filter cake to scm - calcination



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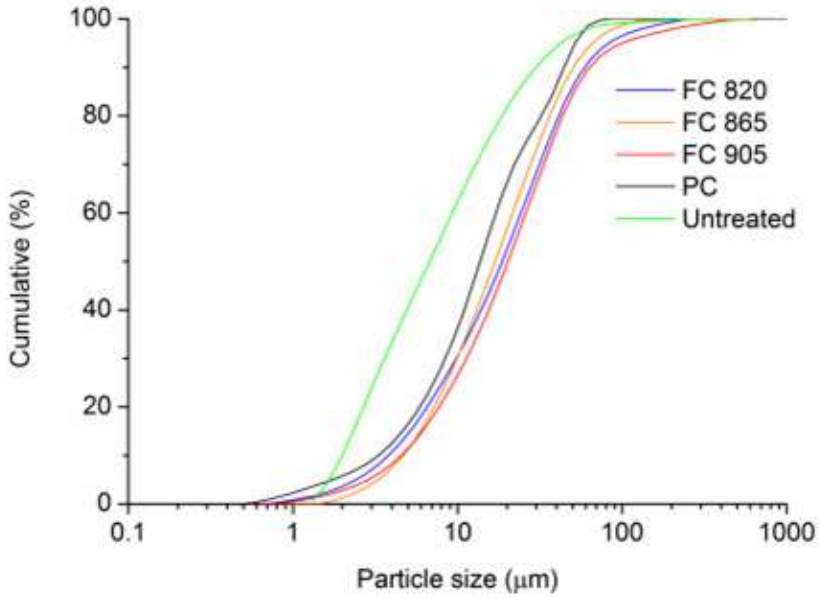
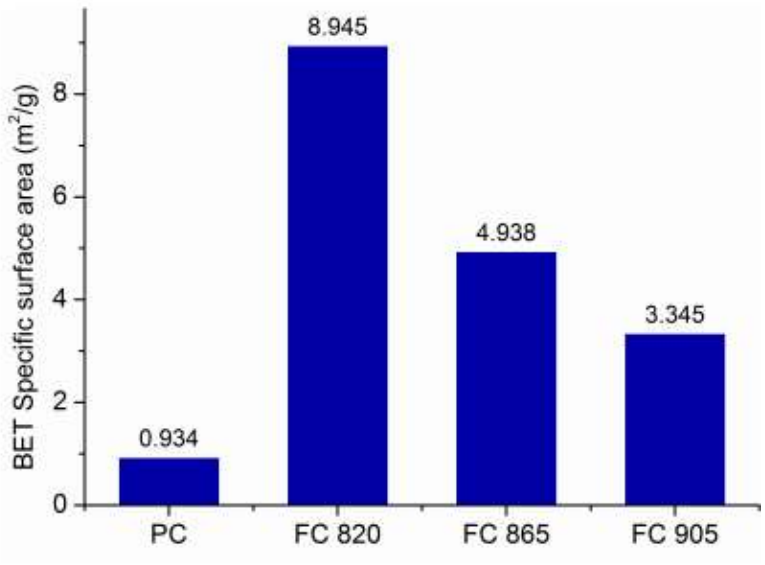
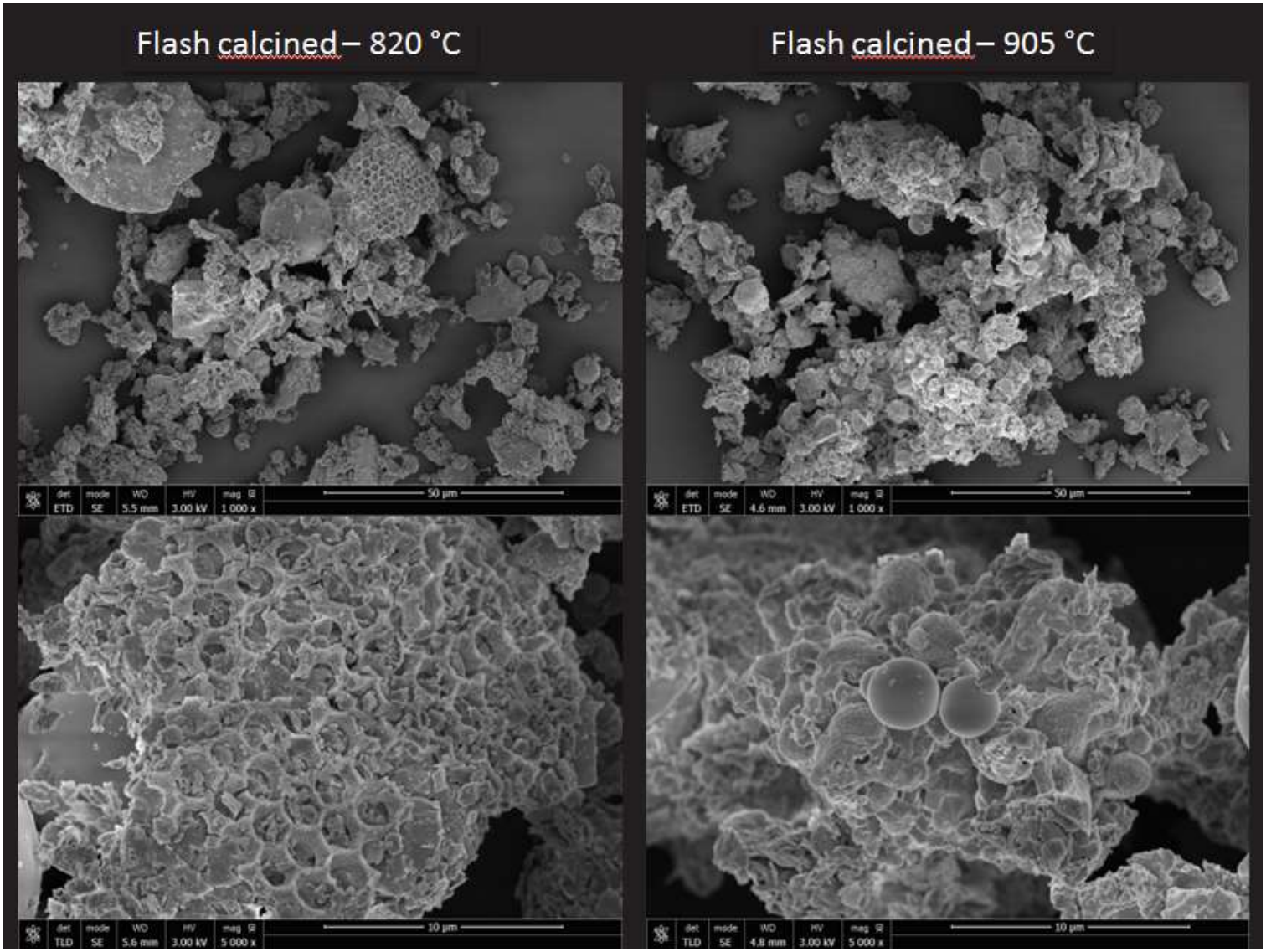
Filter cake to scm – calcined filter cake

Particle size distribution



BET SSA





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FILTER CAKE TO SCM – CALCINED FILTER CAKE

- Phase transformations - XRD

Phase composition	Untreated	FC 820	FC 865	FC 905
Phase	wt.%	wt.%	wt.%	wt.%
Quartz	20	26	27	25
Feldspars	4	7	8	9
Calcite	13	4	4	3
Other carbonates	8			
Pyrite	1			
Anhydrite		2	2	2
Lime		2	1	1
Fe-oxides (hem/mag)		2	3	3
2:1 clay	**34**	**14**	**6**	**6**
Kaolinite	3			
Unidentified/ amorphous	**17**	**45**	**49**	**51**

Thermal decomposition

Clay minerals $\rightarrow$ $x(Al_2O_3) + y(SiO_2) + H_2O$

$2\ FeS_2 + 7.5\ O_2 \rightarrow Fe_2O_3 + 4\ SO_3$ (2)

$CaCO_3 \rightarrow CaO + CO_2$ (3)

High T reactions

$CaO + SO_3 \rightarrow CaSO_4$

$x(Al_2O_3) + y(SiO_2) + (CaO)$ $\rightarrow$ Active phases

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Summary

- **600.000 tonnes DM/y of sediments are being dredged and landfilled to secure maritime access to the Port of Antwerp**

  - Flash calcination reduces organic carbon, no changes in Cl and sulfate levels (low emissions)

  - Higher calcination temperature results in:
    - Lower specific surface areas (lower water demand)
    - Larger fraction of spherical particles – melt formation
    - Higher degree of clay decomposition – larger amorphous fraction

  - Reactive phase identified (>50% of material):
    - Spherical glassy phases (solidified melt droplets)
    - Porous aggregates
    - Ca-enriched

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BIND-AMOR phase 2

Concrete tests

Composition of concrete

	RC-I	RC-II	FCC-20	FCC-30	FCC-40
CEM I 52.5 N [kg/m³]	360	-	288	252	216
CEM II/B-V 42.5 N [kg/m³]	-	360	-	-	-
CFC 865 [kg/m³]	-	-	72	108	144
Riversand 0/4 [kg/m³]	640	640	640	640	640
Gravel 4/14 [kg/m³]	1225	1225	1225	1225	1225
Water [kg/m³]	180	180	180	180	180
PCE superplastifier [wt.%/B]	0.1	0.0	0.3	0.6	0.9

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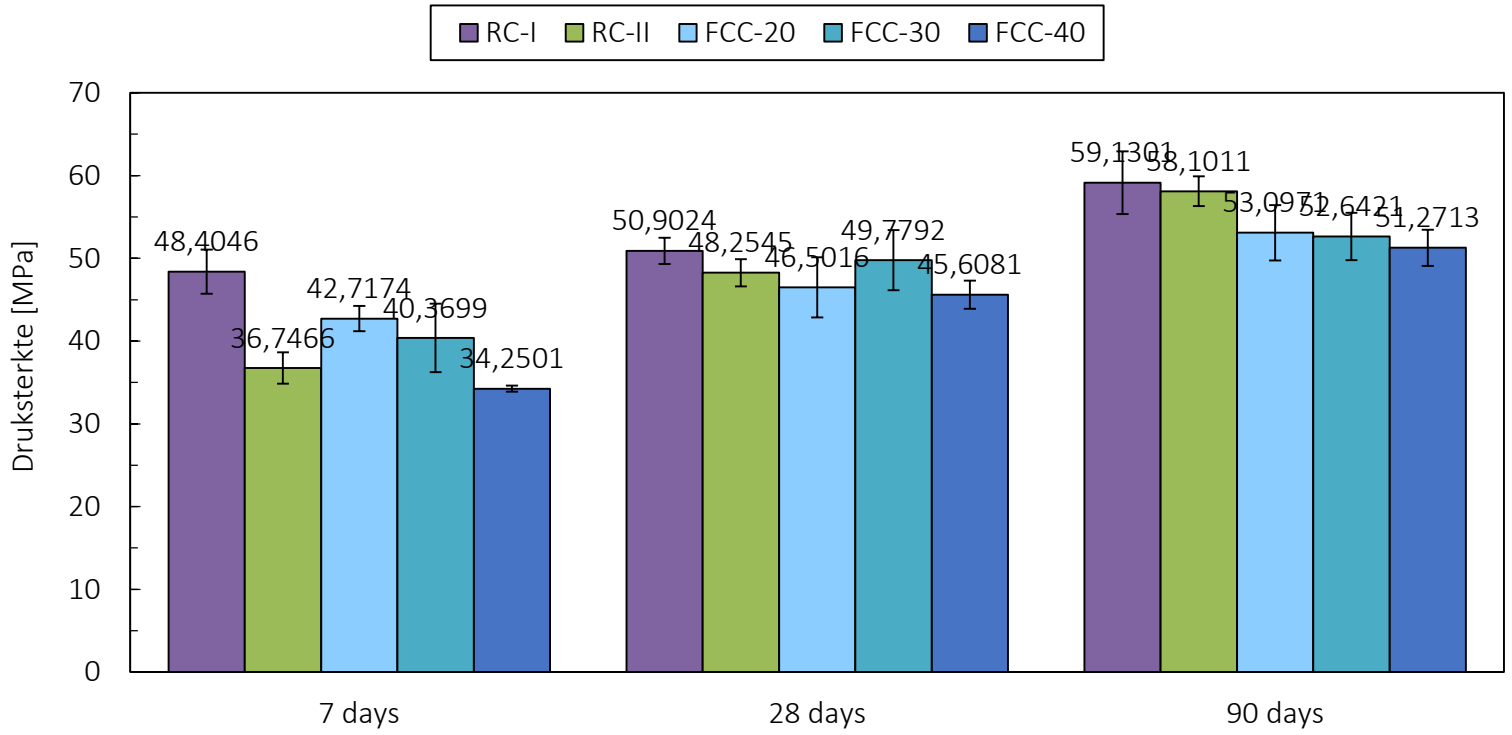
Strength

EN 12390-3



- Early strengths lower than CEM I, higher than CEM II at 30 wt.% substitution.
- Higher strengths after 28 and 90 days due to pozzolanic reactions.
- Strengthclass C30/37 for FCC mixtures .

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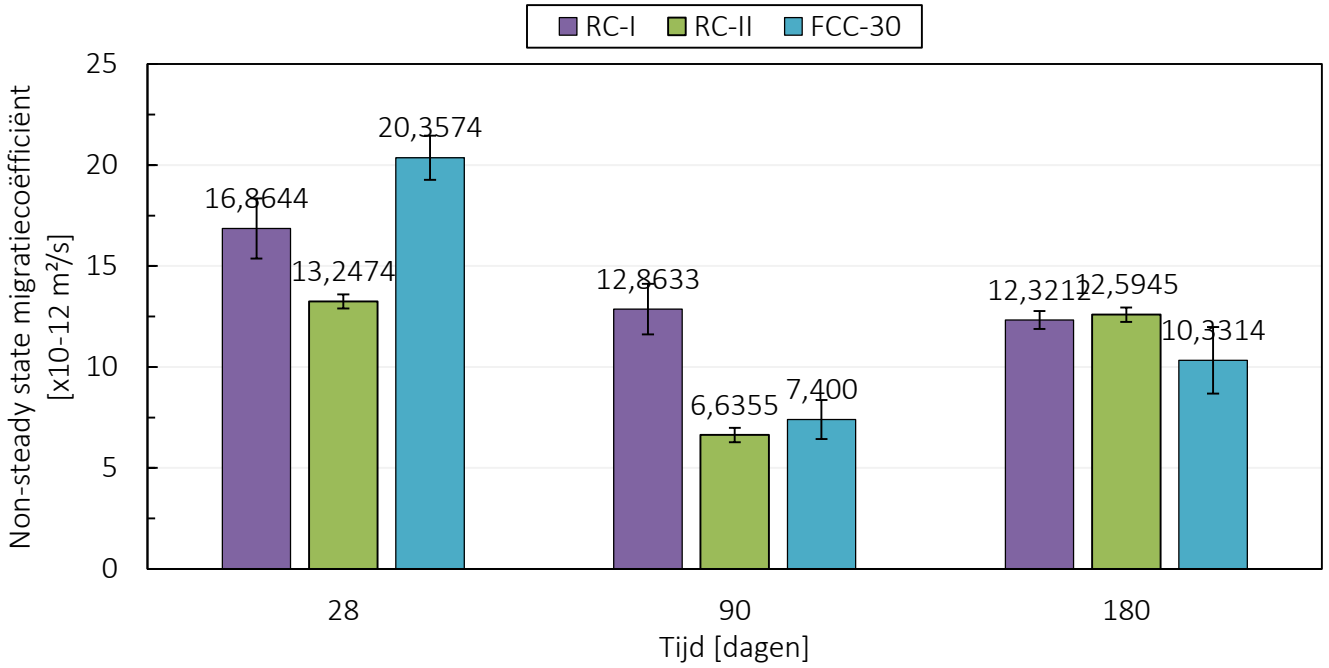
Penetration of chlorides

NT BUILD 492

- **Chlorides migrationcoefficient**



- 28 days: lower resistance to penetration of chlorides for FCC-30 mixture.
- 90 and 180 days: higher resistance due to lower porosity and permeability.

Conclusions

- **FCC as an SCM**
  - Early strengths were lower than the CEM I, but higher than the CEM II. At 3 months simular strengths as the CEM I are reached.
  - The higher the replacement of cement by calcined dredging sediments, the lower the early strenght development.
  - Strenghtclass C30/37
  - narrow poriënstrucutre + lower porosity & permeability → increased durability.

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ENVIRONMENTAL QUALITY

- Concrete with 40% calcined filter cakes - 28 days of hydration – crushed to < 4 mm
- Column leaching test according to EN12457-4
- Comparison to Flemish limit leaching values for reuse as building material (unbound)

					Limit values	
[mg/kg dm]	SCM1	SCM2	SCM3	Ref	*Current*	*Proposed*
As	< 0.02	< 0.02	< 0.02	< 0.02	*0.8*	*0.8*
Ba	12.6	14.2	13.1	**36.1**		*20*
Br	0.83	0.97	3.28	0.4		*20*
Cd	< 0.002	< 0.002	< 0.002	< 0.002	*0.03*	*0.03*
Cl	127	113	122	60		*1000*
Co	0.014	0.013	0.017	0.015		*0.5*
Cr	0.074	0.069	0.086	0.21	*0.5*	*0.8*
Cu	0.075	0.063	0.058	0.05	*0.5*	*0.8*
F	0.46 - 2.07	0.036 - 2.02	0.066 - 2.02	1.39		*55*
Hg	< 0.002	< 0.002	< 0.002	< 0.002		*0.02*
Mo	0.15	0.12	0.13	0.04		*55*
Ni	0.017	0.005 - 0.013	0.003 - 0.014	0.012	*0.75*	*0.75*
Pb	0.136	0.12	0.08	0.17	*1.3*	*1.3*
SO_4	34	34	34	33		*2200*
Sb	< 0.02	< 0.02	< 0.02	< 0.02		*1*
Se	0.054	< 0.01	< 0.01	< 0.01		*2*
Sn	< 0.04	< 0.04	< 0.04	< 0.04		*1*
V	< 0.005	< 0.005	< 0.005	< 0.005		*2.5*
Zn	0.048	< 0.06	0.03 - 0.07	0.05	*2.8*	*2.8*

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Conclusion

- **FCC as an SCM -> durability**
  - Increased resistance to penetration of chlorides.
  - Increased resistance to carbonation after sufficient curing.
  - Decreased resistance to freeze – thaw cycles.
  - Simular resistance to penetration of acids
  - Increased resistance to alkali-silica reaction.
  - Reduction of autogenous shrinkage.

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