“As-Built Documentation”:

Birth Certificate Document and 4 years follow up for SCM and Reference walls at Aalborg Portland

Date: 6-2-19

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Contents

General information

Name of construction	SCM and Reference walls
Client/owner	Aalborg Portland
Contractor	M. Thomsen Støtt A/S
Year of construction	2014
Geographical location	Aalborg Portland cement plant, Rørdalsvej 44
Exposure / Environmental class	A35/ XA3*
Specified service life	No one of cements used for concrete are allowed for this exposure/environmental class.
Brief description of the construction	Two walls of 7m length x 1,5m height x 0,3m width each. Concrete composition of foundation of walls was similar to reference A35 recipe based on Rapid and fly ash.

**It has been assumed that concentration of SO_4^{2-} of soil should be within the limiting values of highest exposure class according to EN 206-1*

Mix design, fresh concrete properties and casting

Construction part	Reference wall			
Date of casting	06-11-14			
Concrete recipe			**Weight [kg/m³]**	**Volume [m³/m³]**
Cement RAPID CEM I 52,5 N (MS/LA<2)			339	0.107
Fly ash B5			67.8	0.029
Water			154.4	0.154
Air entrainment agent			0.9	0.001
Plasticizer			3.3	0.003
Superplasticizer			0.8	0.001
Sand E0001 Bradsted Krogh			658.3	0.249
Aggregates E0508 Ansit – Rekefjord			161.2	0.059
Aggregates E0816 Thyborøn Kroghs			889.7	0.336
Equivalent water/cement ratio*	**Air content [%] (target)**	**Density [kg/m³] (target)**	**Slump [mm] (target)**	**Slump flow [mm]**
0.424	6.0	2275	120	-
Other details	Clinker from Rapid cement contains around 8.5% of C3A and hence, it cannot be considered as sulphate resisting cement type CEM I.			

Construction part	SCM wall			
Date of casting	06-11-14			
Concrete recipe			**Weight [kg/m³]**	**Volume [m³/m³]**
SCM Cement: CEM II/B-M(Q-LL) 52,5 N (HA)			360	0.122
Fly ash B5			32	0.014
Water			155	0.155
Air entrainment agent			0.88	0.001
Plasticizer			1.96	0.003
Superplasticizer			0.78	0.001
Sand E0001 Bradsted Krogh			663	0.250
Aggregates E0508 Ansit – Rekefjord			161	0.059
Aggregates E0816 Thyborøn Kroghs			890	0.336
Equivalent water/cement ratio*	**Air content [%] (target)**	**Density [kg/m³] (target)**	**Slump [mm] (target)**	**Slump flow [mm]**
0.420	6.0	2265	120	-
Other details	The SCM cement is CEM II/B-M(Q-LL) type, which is not considered as sulphate resisting cement type in accordance with the current EN 197-1.			

Cement compositions (% wt)	**RAPID**	**SCM cement**
Clinker (FKH)	91.2	63.2
Gypsum	4	2.8
Limestone filler (RAPID) or limestone filler + calcined clay (SCM cement)	4.8	34.0
Chemical composition of cements (% wt)	**RAPID**	**SCM cement**
SiO_2	19,38	25,80
Al_2O_3	5,41	7,07
Fe_2O_3	3,78	4,47
CaO	63,20	49,91
MgO	0,94	1,23
K_2O_{Total}	0,34	0,79
Na_2O_{Total}	0,26	0,54
SO_3 fused bed	3,41	2,48
TiO_2	0,26	0,37
Cl	0,03	0,06
P_2O_5	0,27	0,24
Cr_2O_3	0,01	0,01
LOI	2,60	7,06
Cr_{TOTAL} (mg/Kg)	59,06	78,35

Materials and construction details

Reinforcement type	Y12 pr 150 m.m
Spacer type	Plastic hjul
Cover thickness [mm]	30 m.m. dæklag

Execution errors and critical construction details

This section includes information regarding deviations and various execution errors that were encountered during the construction phase, which may be critical for the performance of the specified service life of the construction. Also, any repairs carried out during the construction phase are mentioned here. The documentation is based on observations made during the construction phase, as well as observations from an inspection.

[Insert name of execution error X]

Description + picture documentation of execution error X.

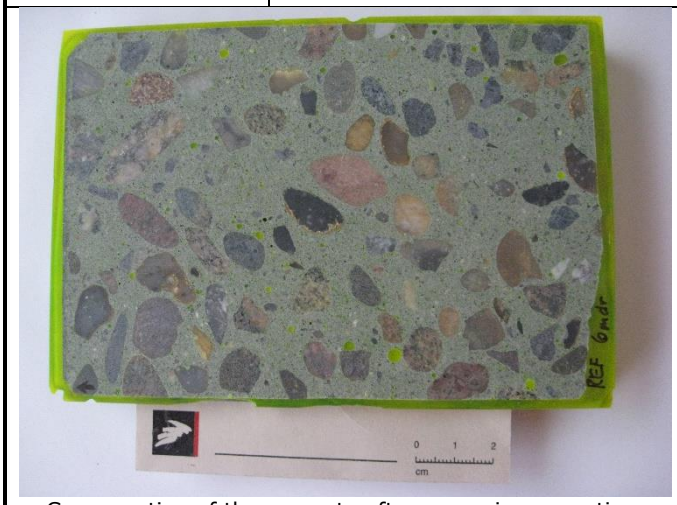
[Insert name of execution error Y]

Description + picture documentation of execution error Y.

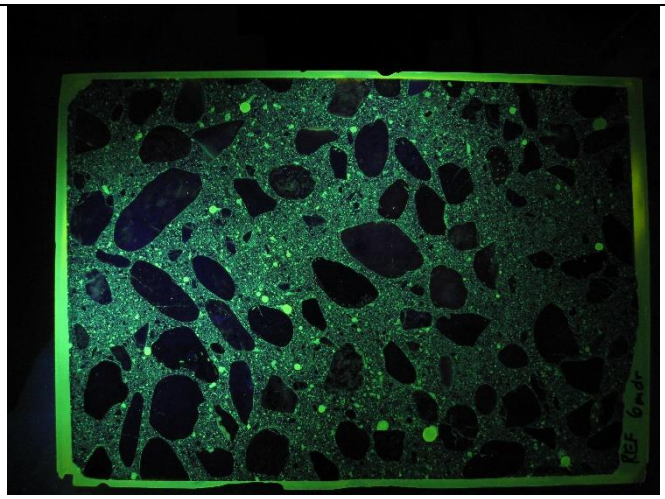
Results from microscopy

Sample ID	Reference, REF, plane section # REF, thin section # 7581-ref
Age	6 months
Observations	Macroscopically the concrete appears well consolidated with only few cracks visible (typically less than 10µm in width). The paste appears with a grey tint. The surface of the concrete is relative plane, finely rippled and covered with small calcite crystals (loosely packed). The outer 0.8mm contains many, short plastic paste defects. The defects have a preferred orientation vertical to the surface. At one occasion, a coarse surface parallel fine crack is seen just under the surface. The crack seems to be related to an alkali silica reacted flint particle (pop out). The paste in the outer 0.8 to 2.3 mm of the concrete surface is weakly and unevenly carbonated. The average carbonation depth is 1.2 mm (average of ten readings, std=0.5). Carbonated paste is further seen around a large air void in the surface to a depth of 4mm. The paste contains a relative fine-grained Portland cement with about 20vol% fly ash. Rather large crystals of calcium hydroxide appear in the paste as well as in many of the air voids. The air content is estimated to 4-5vol%. No sign of ettringite or gypsum are seen in air voids. Microscopically the paste appears somewhat inhomogeneous with some micro-cracks visible. The w/c ratio is estimated to 0.40 - 0.45, however, in some areas the w/c reached 0.60. The paste is slightly densified when carbonated.

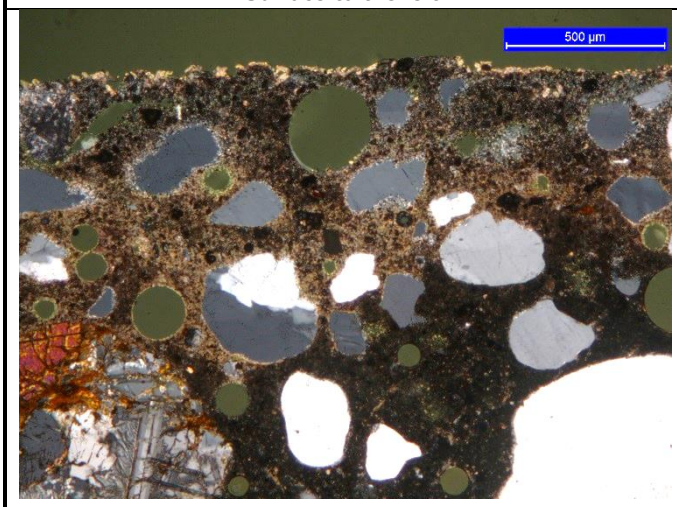
Sample ID	Reference, REF, plane section # REF, thin section # 7581-ref
Age	6 months



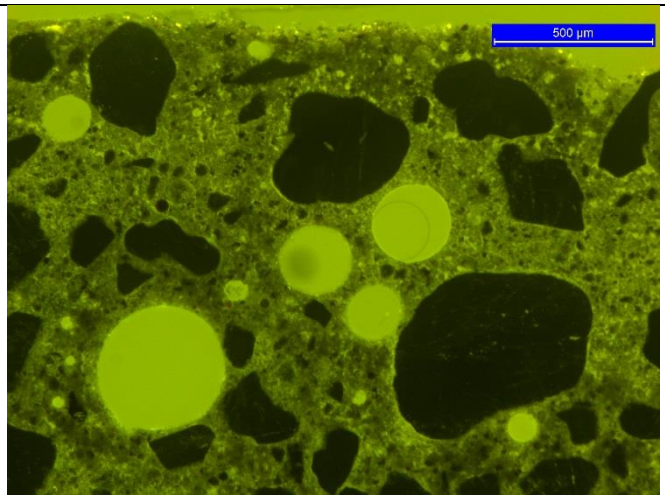
Cross section of the concrete after epoxy impregnation. Surface to the left.



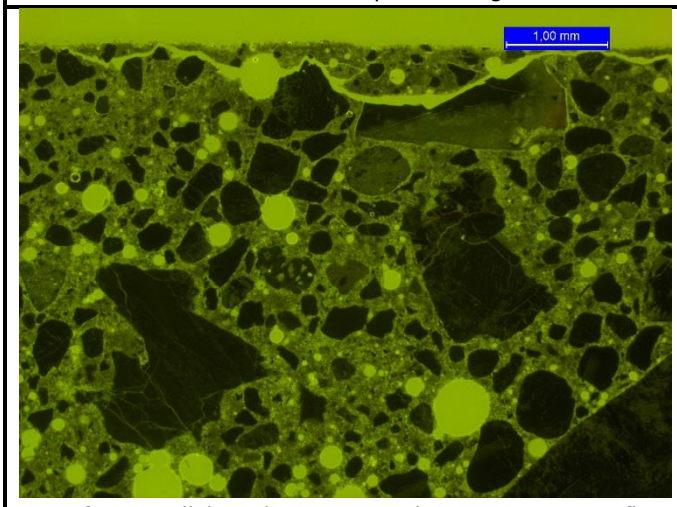
The same section as to the left, seen in UV-light. Only very few cracks are observed in the concrete.



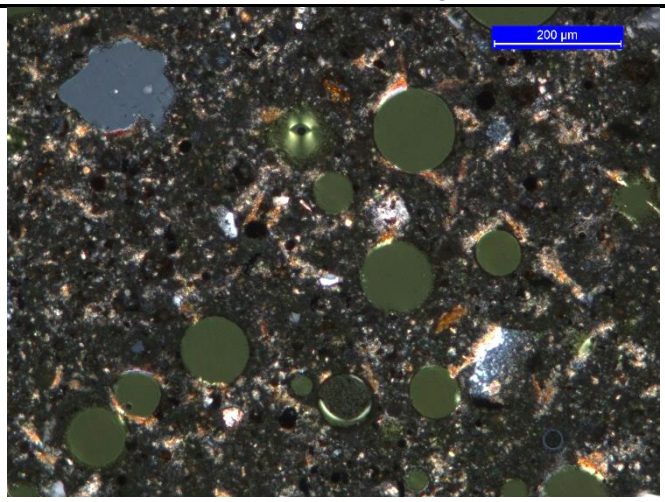
Small calcite crystals are present on the carbonated concrete surface. X-polarised light.



Small plastic defects are present in the outer 0.8mm of the concrete. Fluorescent light.



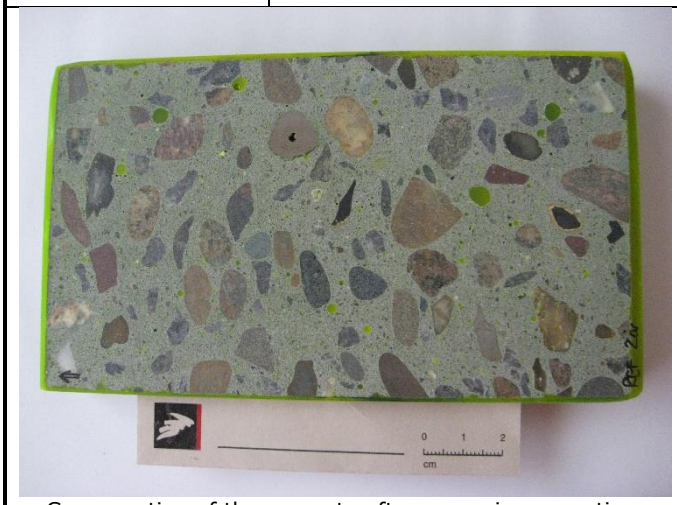
A surface parallel crack is seen in relation to a reactive flint particle. Fluorescent light.



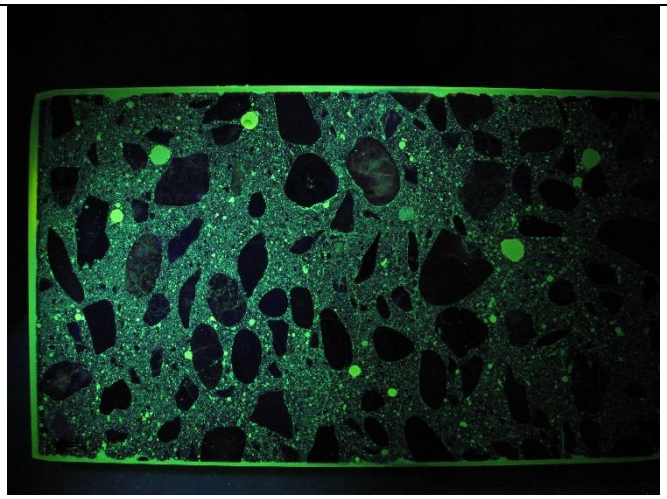
General texture of the paste containing large crystals of calcium hydroxide. X-polarised light.

Sample ID	Reference, REF, plane section # REF, thin section # 7988-ref
Age	2 years and 4 ½ months
Observations	Macroscopically the concrete appears well consolidated with only few cracks visible (typically less than 10µm in width). The paste appears with a grey tint. The surface of the concrete is relative plane, finely rippled and covered with small calcite crystals, forming a 0.04mm thick crust, which occasionally is scaled. The paste of the outer 1.2mm appears with an increased porosity and contains many, short plastic paste defects, in the form of small paste defects and adhesion cracks at the paste/aggregate interface. One fine plastic crack is observed vertical to the surface to a depth of 6mm. The paste in the outer 0.8 to 2.2 mm of the concrete surface is carbonated. The average carbonation depth is 1.2 mm (average of ten readings, std=0.4). Carbonated paste is further seen around larger air voids positioned near the surface, to max. depths of 6mm. A 0.02mm thick highly opaline zone appears in front of the carbonated paste. Between the calcite crust and the carbonated paste the outer 0.04mm of the paste appears black (de-calcified), when viewed in X-polarised light. The paste contains a relative fine-grained Portland cement with about 20vol% fly ash. Rather large crystals of calcium hydroxide appear in the paste as well as in many of the air voids. The air content is estimated to 4-5vol%. Small needle shaped ettringite crystals are present in many air voids. Gypsum is not observed. Microscopically the paste appears somewhat inhomogeneous with some micro-cracks. The w/c ratio is estimated to 0.40 - 0.45, however, in some areas as in the surface region the apparent w/c reached 0.60.

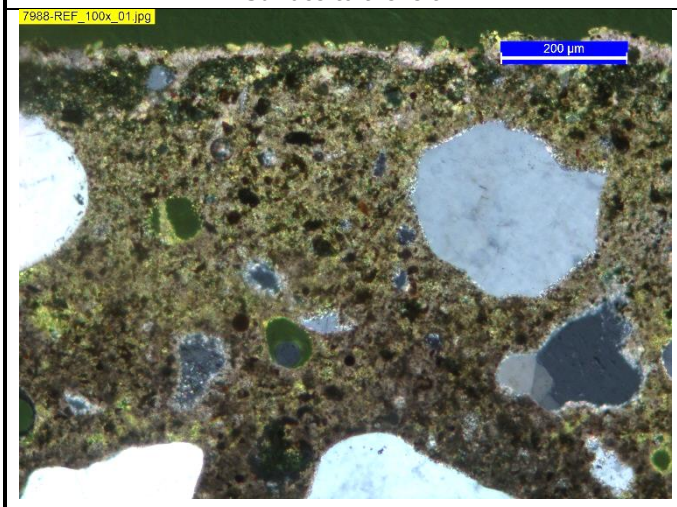
Sample ID	Reference, REF, plane section # REF, thin section # 7988-ref
Age	2 years and 4 ½ months



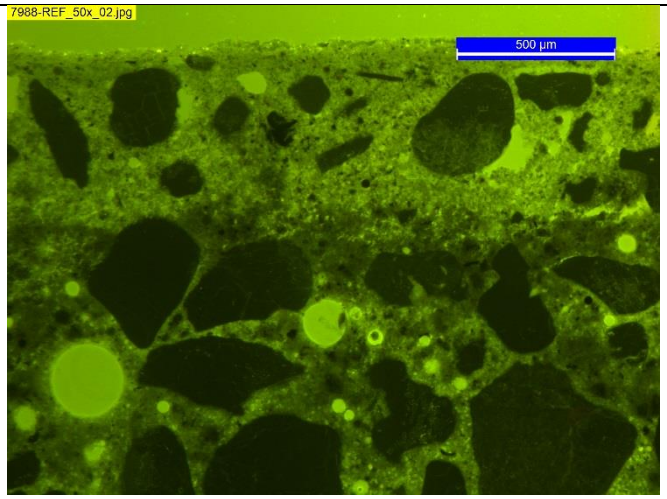
Cross section of the concrete after epoxy impregnation. Surface to the left.



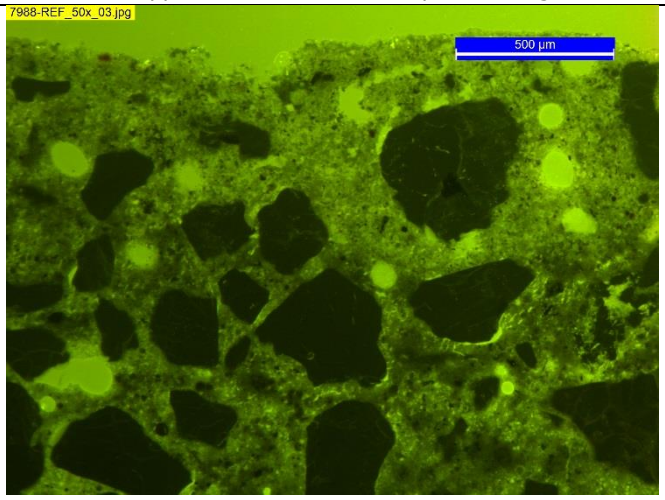
The same section as to the left, seen in UV-light. Only very few cracks are observed in the concrete.



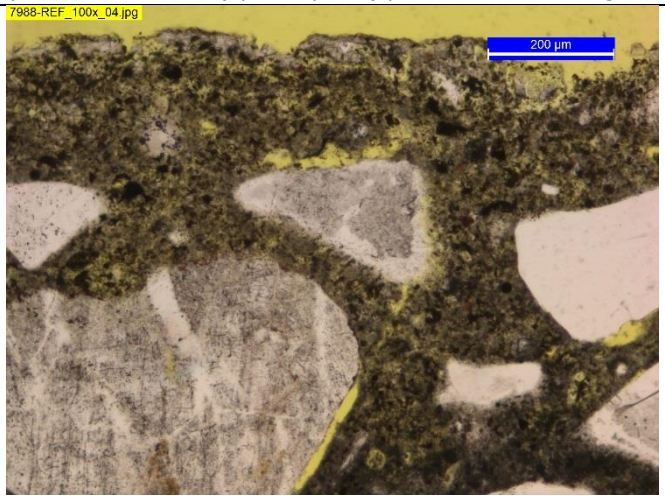
Small calcite crystals are forming a more or less, intact crust on the carbonated concrete surface. Paste just under crust appears black, leached. X-polarised light.



The carbonated zone appears with an increased porosity. Small plastic defects are present at the interface between porous and denser (opaline paste) paste. Fluorescent light.



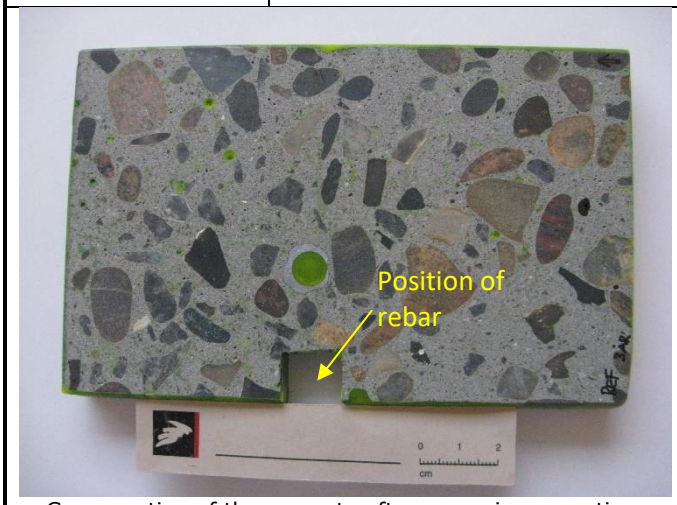
Plastic paste cracks and adhesion cracks are frequent in the surface region of the concrete. Fluorescent light.



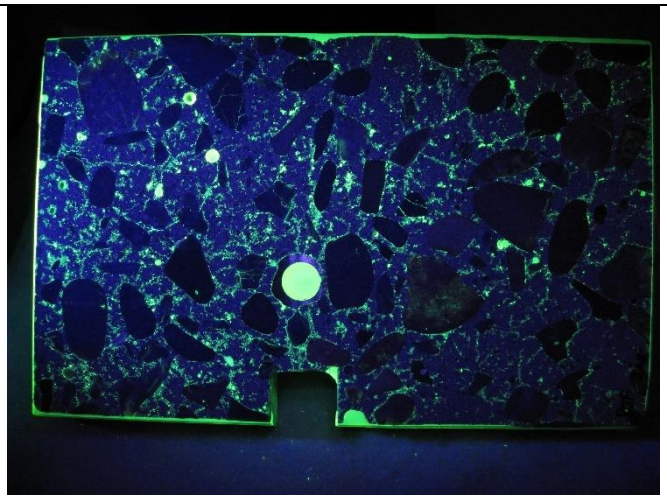
The porous surface region seen in polarised light. The crack visible can be traced to a depth of 6mm.

Sample ID	Reference, REF, plane section # REF, thin section # 8189-ref
Age	3 years and 10 ½ months
Observations	Macroscopically the concrete appears well consolidated with few cracks visible (typically less than 10µm in width). The paste appears with a grey tint. The surface of the concrete is relative plane, finely rippled and occasionally covered with small calcite crystals, forming a 0.02mm thick crust. The paste of the outer 0.2-0.6mm appears generally with an increased porosity and contains some, short plastic paste defects, in the form of paste defects and adhesion cracks at the paste/aggregate interface. Fine plastic crack is observed vertical to the surface to a depth of 14mm. The paste in the outer 0.6 to 2.3 mm of the concrete surface is carbonated. The average carbonation depth is 1.1 mm (average of ten readings, std=0.5). Carbonated paste is further seen along surface cracks to depths of 12mm. Where the paste is more intensively carbonated the apparent w/c ratio is lower. A 0.04mm thick highly opaline zone appears in front of the carbonated paste. Between the calcite crust and the carbonated paste few spots of de-calcified paste are visible when viewed in X-polarised light. The paste contains a relative fine-grained Portland cement with about 20vol% fly ash. Rather large crystals of calcium hydroxide appear in the paste as well as in many of the air voids. The air content is estimated to 4-5vol%. Small needle shaped ettringite crystals are present in many air voids. Gypsum is not observed. Microscopically the paste appears somewhat inhomogeneous with some micro-cracks. The w/c ratio is estimated to 0.40 - 0.45, however, in some areas as in the surface region the apparent w/c reached 0.60. Passive ASR is observed in few flint grains.

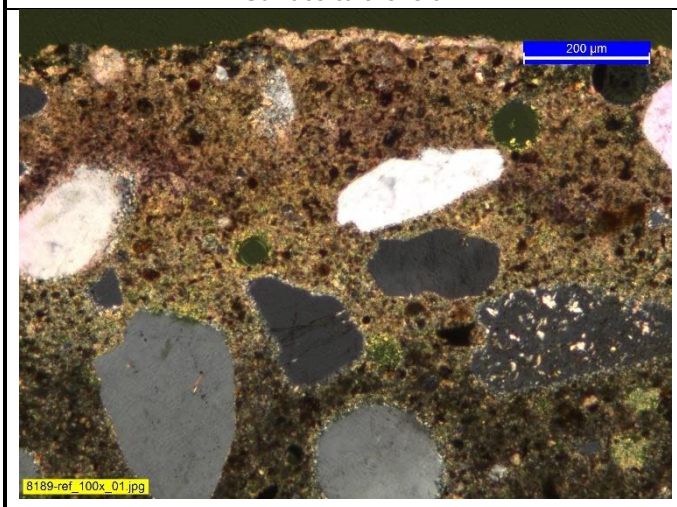
Sample ID	Reference, REF, plane section # REF, thin section # 8189-ref
Age	3 years and 10 ½ months



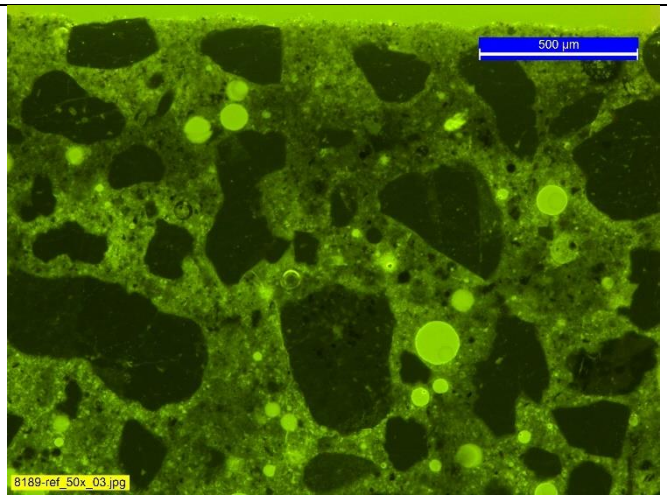
Cross section of the concrete after epoxy impregnation. Surface to the left.



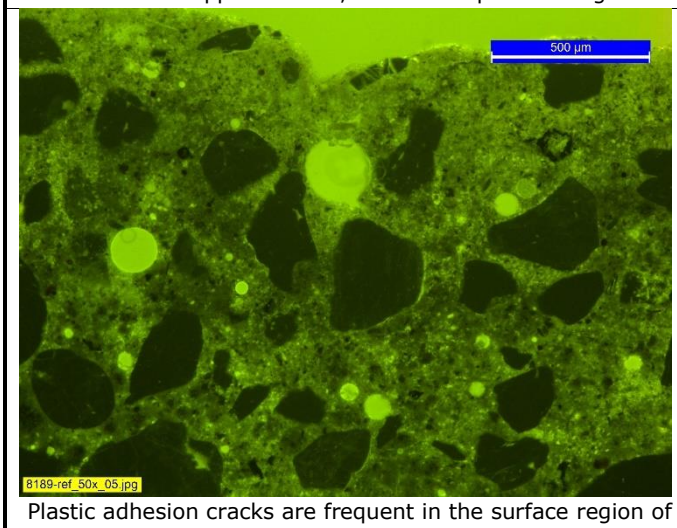
The same section as to the left, seen in UV-light. Only few micro-cracks are observed in the concrete.



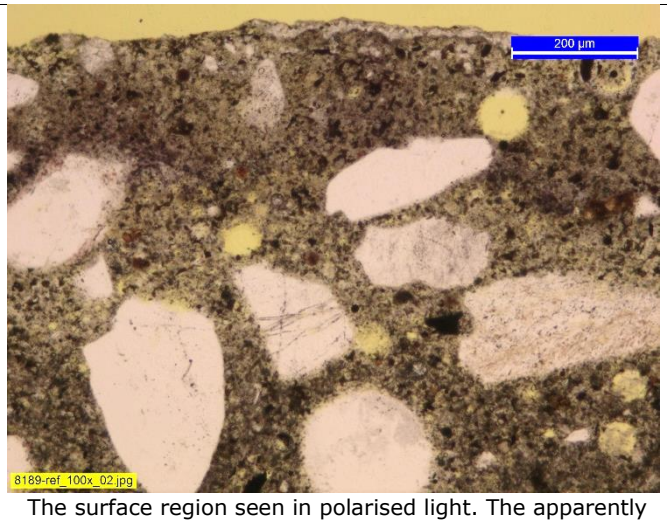
A thin calcite crust is occasionally covering the carbonated concrete surface. Few places the paste just under the calcite crust appears black, leached. X-polarised light.



The carbonated surface appears with an increased porosity. The interface in front of the carbonated zone is seen as a dense band. Fluorescent light.



Plastic adhesion cracks are frequent in the surface region of the concrete. Fluorescent light.

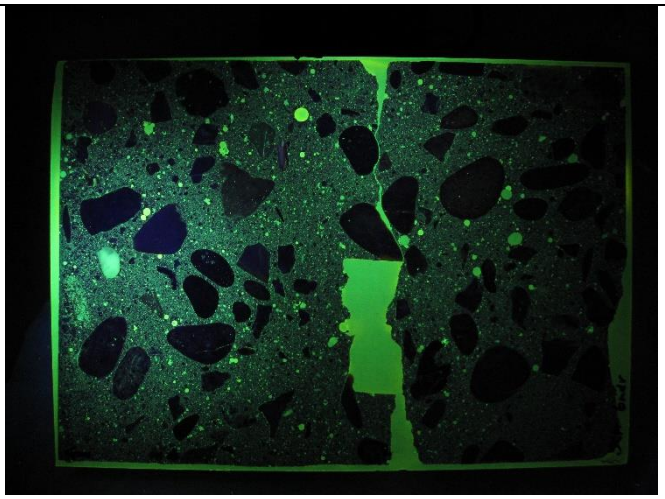


The surface region seen in polarised light. The apparently denser paste under the calcite crust is intensively carbonated.

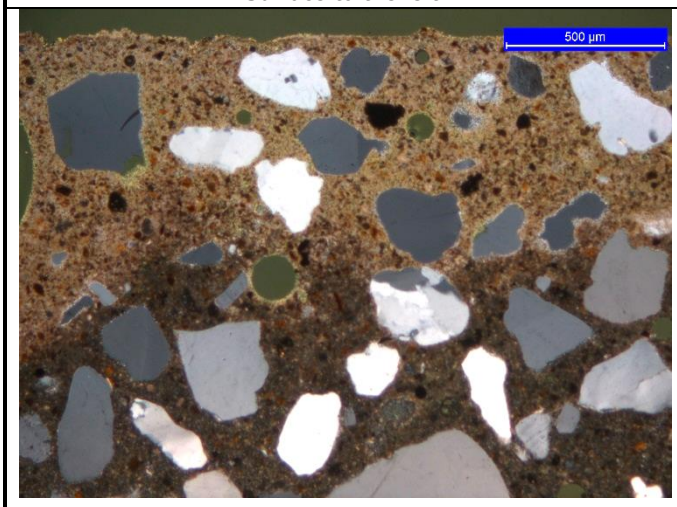
Sample ID	SCM, plane section # SCM, thin section # 7581-scm
Age	6 months
Observations	Macroscopically the concrete appears relatively well compacted with only few paste cracks. The concrete appears mortar-rich. The paste appears with a brown tint. The surface of the concrete is relative plane, and finely rippled. Few small calcite crystals are present on the surface. Minor amounts of small paste defects are present at the surface region of the concrete. Few plastic microcracks are seen vertical to the surface. The paste in the outer 0.7 to 1.2 mm of the concrete surface is extensively carbonated. The average carbonation depth is 0.9 mm (average of ten readings, std=0.2). The paste contains a relative fine-grained Portland cement with fine limestone and minor fly ash. Orange particles, calcined clay, is distinctly observed throughout the paste. The paste appears with an opaline shine, which makes observation of calcium hydroxide difficult. The air content appears relatively low, estimated to 3-4vol%. No sign of ettringite or gypsum are seen in air voids. Microscopically the paste appears relatively homogeneous throughout with few micro-cracks in the interior paste and in the concrete surface. The general w/c ratio is estimated to 0.40 - 0.43, however. The paste porosity varies slightly in the carbonated paste compared to the interior.

Sample ID	SCM, plane section # SCM, thin section # 7581-scm
Age	6 months

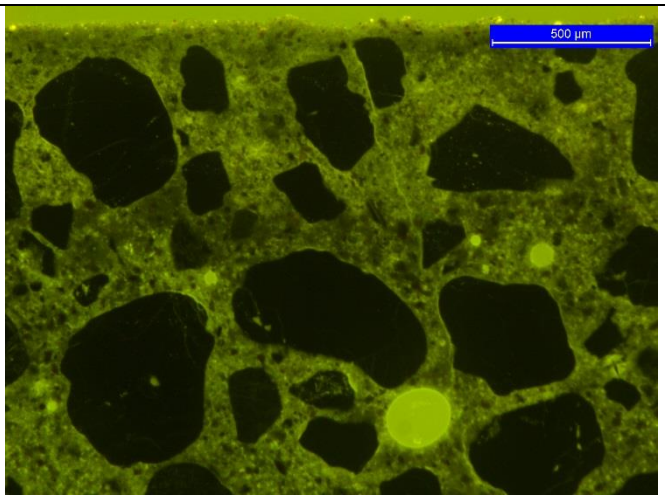
Cross section of the concrete after epoxy impregnation. A fracture zone is positioned at the level of the rebars. Surface to the left.



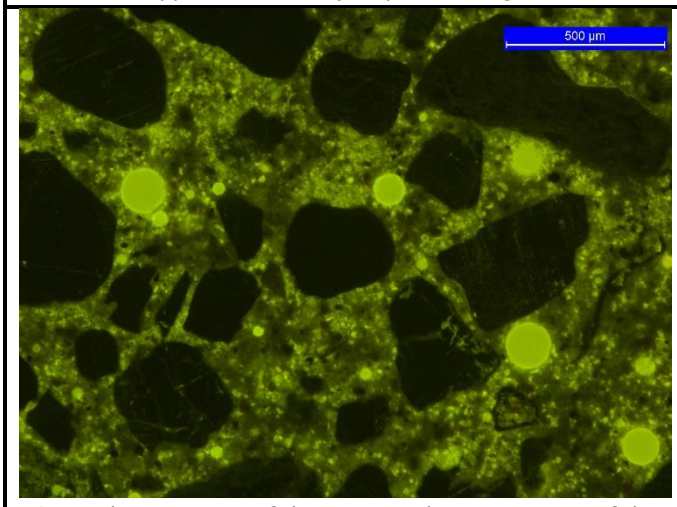
The same section as to the left, seen in UV-light. The paste appears rather homogeneous with only few visible cracks.



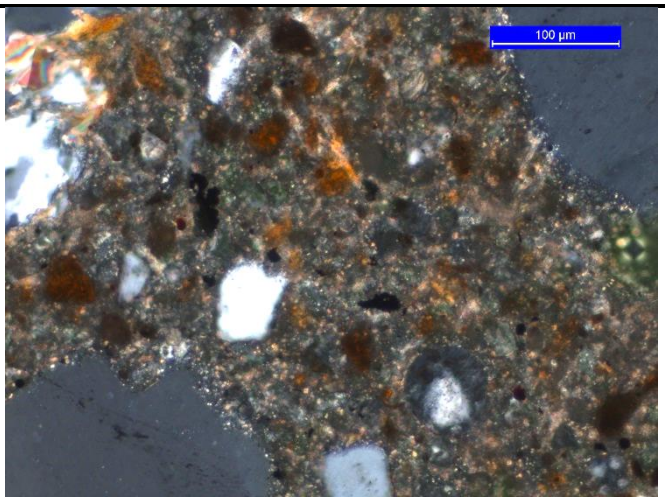
The concrete surface is extensively carbonated (paste appears brownish). X-polarised light.



A micro-crack is observed within the surface. Variation in the capillary porosity appears in the carbonated area.



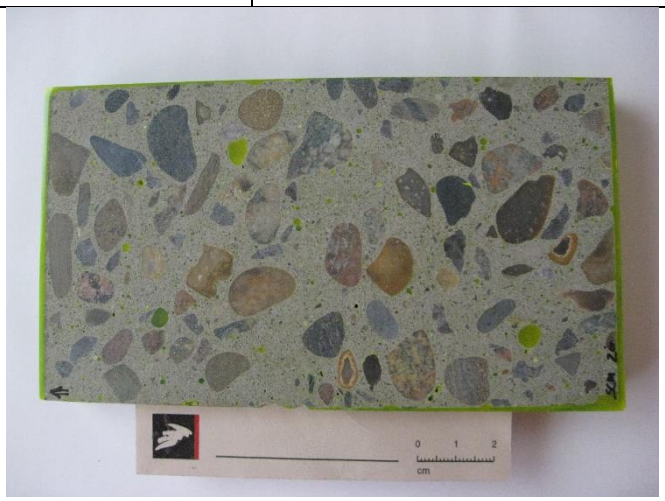
General appearance of the paste in the interior part of the concrete. Fluorescent light.



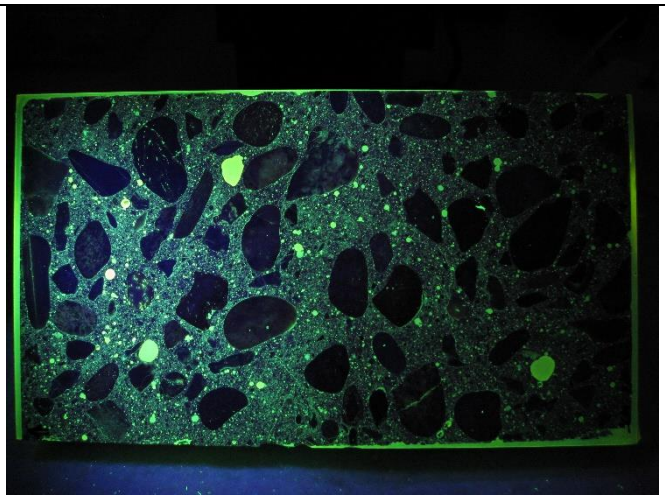
The paste appears somewhat opaline, though with visible limefines and calcined clay (orange). X-polarised light.

Sample ID	SCM, plane section # SCM, thin section # 7988-scm
Age	2 years and 4 ½ months
Observations	Macroscopically the concrete appears relatively well compacted with only few paste cracks. The paste appears with a brown tint. The surface of the concrete is relative plane, and finely rippled. The paste of the outer 1.6mm appears high porous containing small paste defects as well as adhesion cracks. In front of this porous zone a thin, highly dense paste zone is present. The paste in the outer 0.8 to 2.5 mm of the concrete surface is extensively carbonated. The average carbonation depth is 1.5 mm (average of ten readings, std=0.5). Carbonated paste along surface near voids, are seen to depths of 8mm. The paste contains a relative fine-grained Portland cement with fine limestone and minor fly ash. Orange particles, calcined clay, is distinctly observed throughout the paste. The paste appears opaline which makes observation of calcium hydroxide difficult. The air content appears relatively low, estimated to 3-4vol%. Small needle shaped ettringite crystals are present in many air voids. Gypsum is not observed. Microscopically the paste appears relatively homogeneous throughout with few micro-cracks in the interior paste and in the concrete surface. The general w/c ratio is estimated to 0.40 - 0.43, however. The paste porosity varies slightly in the carbonated paste compared to the interior.

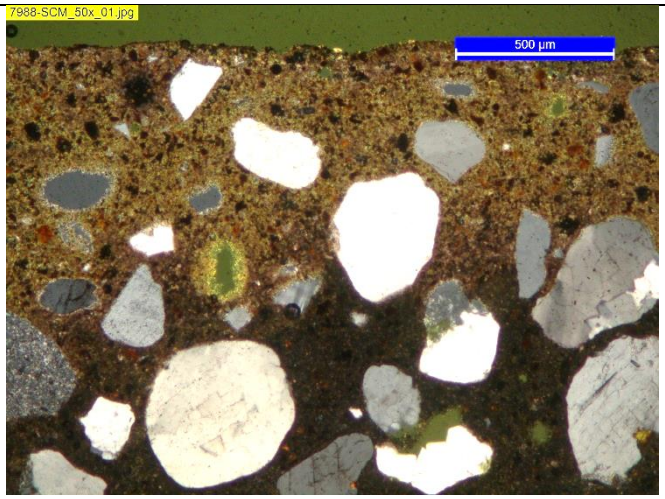
Sample ID	SCM, plane section # SCM, thin section # 7988-scm
Age	2 years and 4 ½ months



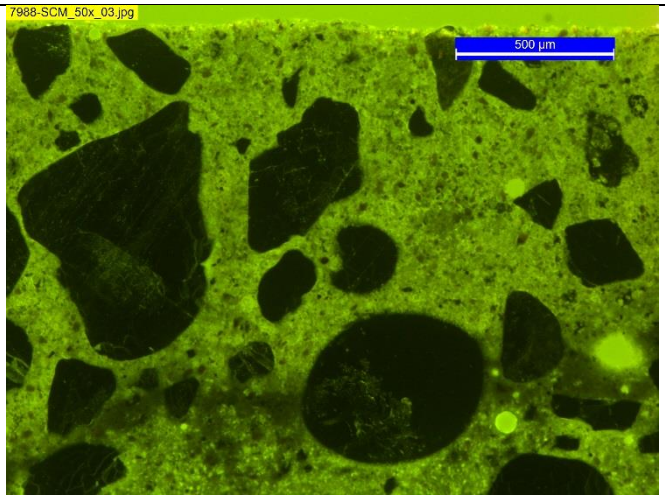
Cross section of the concrete after epoxy impregnation. Surface to the left.



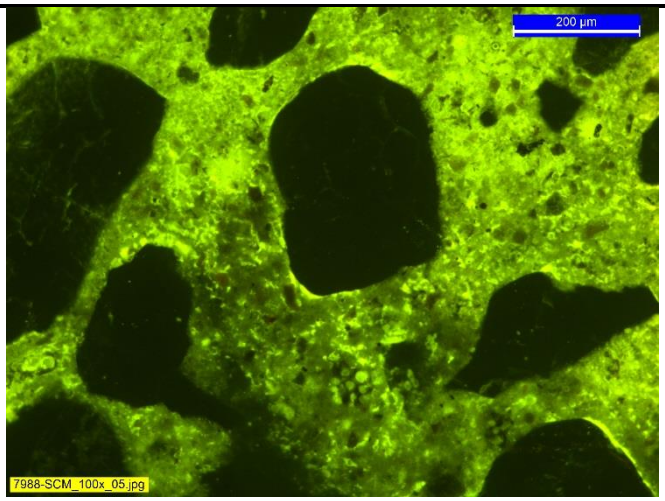
The same section as to the left, seen in UV-light. Only few microcracks are visible in the concrete.



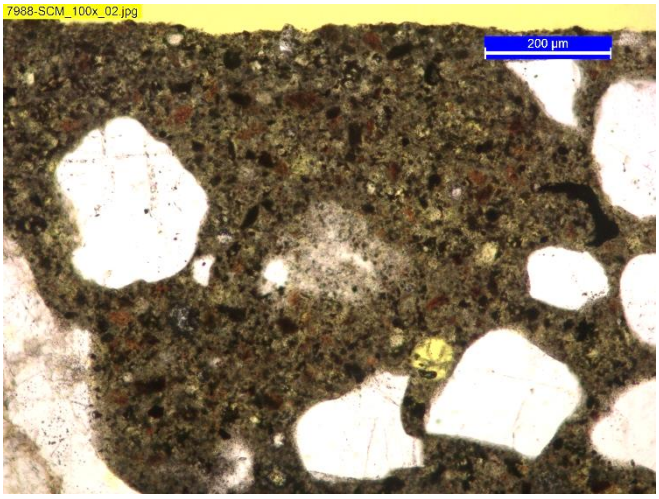
The concrete surface is extensively carbonated (paste appears brownish). X-polarised light.



The carbonated concrete surface appears highly porous. A dense paste zone is present between the porous surface and the inner denser paste. Fluorescent light.



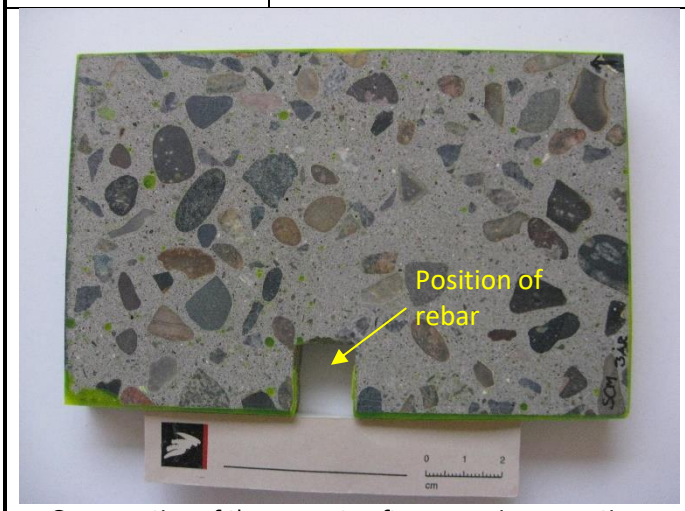
Plastic paste cracks and adhesion cracks are frequent in the porous carbonated surface region of the concrete. Fluorescent light.



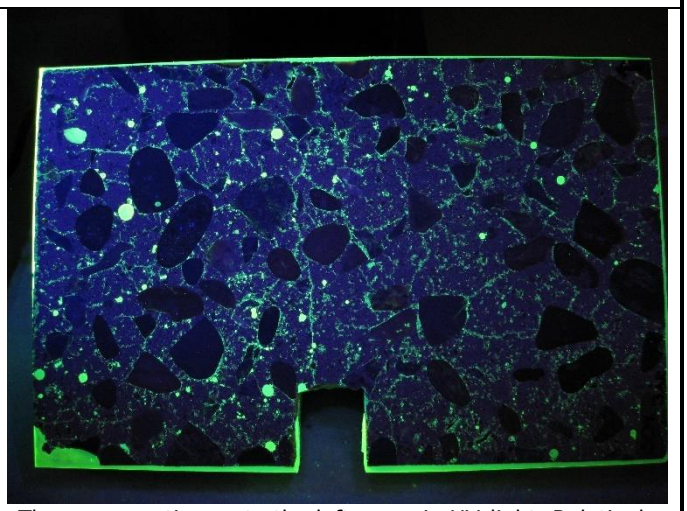
Typical appearance of the paste rich in orange particles of calcined-clay viewed in polarised light.

Sample ID	SCM, plane section # SCM, thin section # 8189-scm
Age	3 years and 10 ½ months
Observations	Macroscopically the concrete appears relatively well compacted with relatively few paste cracks. The paste appears with a brown tint. The surface of the concrete is relative plane, and finely rippled. The paste of the outer 0.6-2mm appears high porous containing small paste defects as well as adhesion cracks. In front of this porous zone a thin, highly dense paste zone is present. The paste in the outer 0.8 to 2.5 mm of the concrete surface is extensively carbonated. The average carbonation depth is 1.0 mm (average of ten readings, std=0.3). Carbonated paste along surface cracks are seen to depths of 10-12mm. The paste contains a relative fine-grained Portland cement with fine limestone and minor fly ash. Orange particles, calcined clay, is distinctly observed throughout the paste. The paste appears opaline which makes observation of calcium hydroxide difficult. The air content appears relatively low, estimated to 3-4vol%. Small needle shaped ettringite crystals are present in many air voids. Gypsum is not observed. Microscopically the paste appears relatively homogeneous throughout with few micro-cracks in the interior paste and in the concrete surface. The general w/c ratio is estimated to 0.40 - 0.43, however. The paste porosity varies slightly in the carbonated paste compared to the interior.

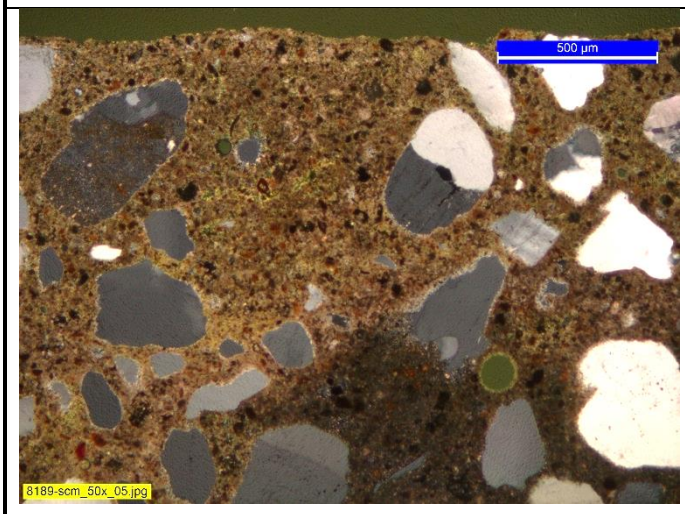
Sample ID	SCM, plane section # SCM, thin section # 8189-scm
Age	3 years and 10 ½ months



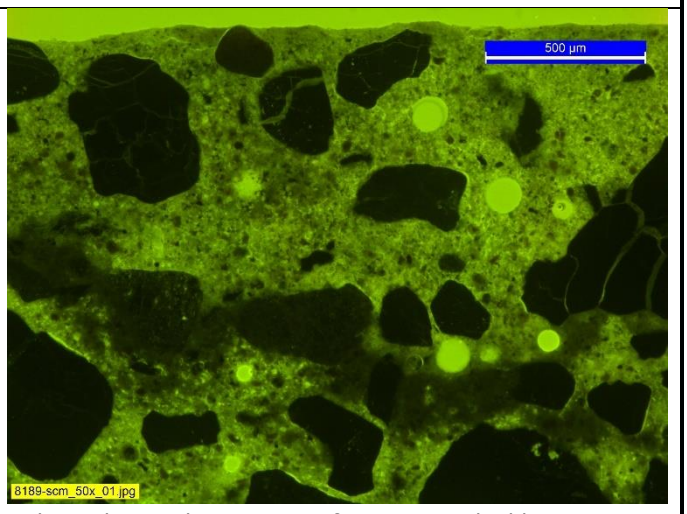
Cross section of the concrete after epoxy impregnation. Surface to the left.



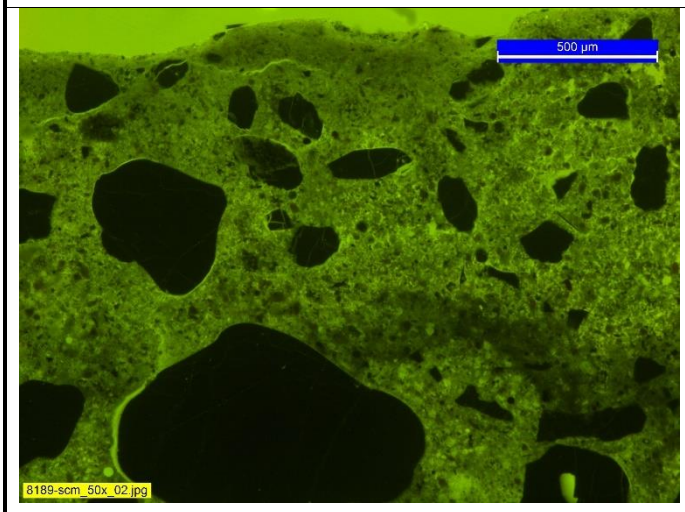
The same section as to the left, seen in UV-light. Relatively few microcracks are visible in the concrete.



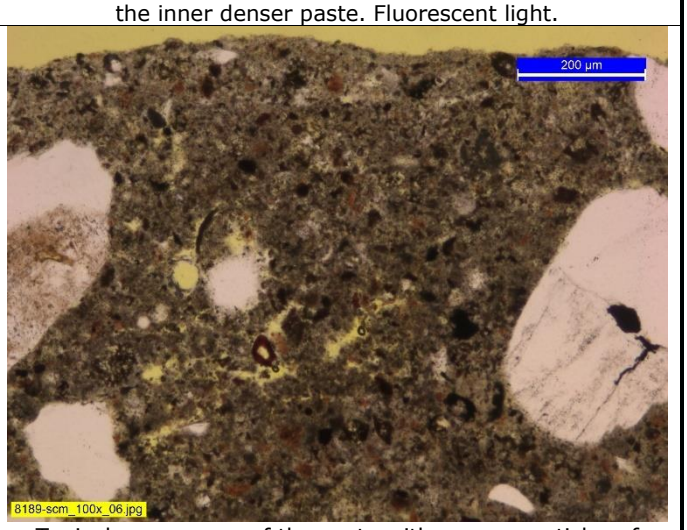
The concrete surface is extensively carbonated (paste appears brownish). X-polarised light.



The carbonated concrete surface appears highly porous. A dense paste zone is present between the porous surface and the inner denser paste. Fluorescent light.



Plastic paste cracks and adhesion cracks are frequent in the porous carbonated surface region of the concrete. Fluorescent light.

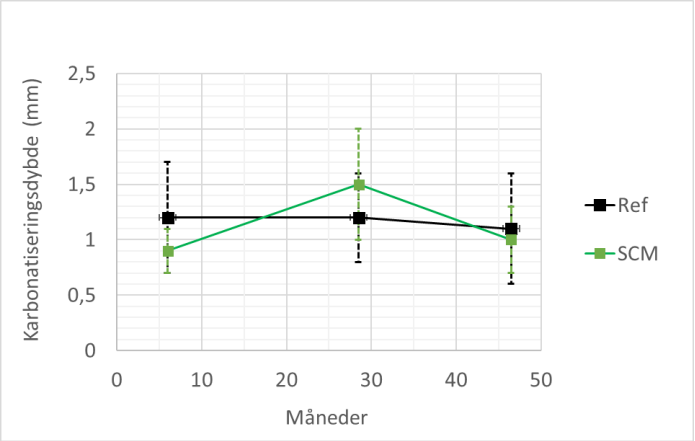


Typical appearance of the paste with orange particles of calcined-clay viewed in polarised light. Plastic defects are present.

Results from lab tests

Test method	Results
Compressive strength Date: 27-05-2015	SCM wall: length: 123.0 mm, diameter: 100 mm, strength 43.0 MPa Ref wall: length 121.2 mm, diameter: 100 mm, strength 37.4 MPa
NT Build 492 chloride diffusion coefficient 24-06-2015	Reference: 5.6 x E-12; SCM 3.2 x E-12 (Both have very good resistance to chloride ingress, according to Tang Luping)
Carbonation depth by microscopy	

Sample	Reference			SCM		
Months	6	28.5	46.5	6	28.5	46.5
Min [mm]	0.8	0.8	0.6	0.7	0.8	0.8
Max [mm]	2.3	2.2	2.3	1.2	2.5	2.5
Average [mm]	1.2	1.2	1.1	0.9	1.5	1.0
Std.	0.5	0.4	0.5	0.2	0.5	0.3



There does not (yet) seem to be a significant difference in carbonation depth between the reference and the SCM.

Sulfate attack by microscopy	There is not (yet) any signs of sulphate attack in the two walls.
[Insert name of test method, e.g. NT Build 388: Heat development]	[Test results are given here in the form of measured values, graphs, etc.]

Inspection and maintenance strategy

Areas requiring special attention

Beside the periodic general inspections, follow-up inspection should be carried out where special attention is paid to the following areas:

[Name of focus area X is inserted here, e.g. certain observed cracks]
Brief description of focus area X is given here.

[Name of focus area Y is inserted here, e.g. honeycombs]
Brief description of focus area Y is given here.

Inspection program

Suggestions for inspections program are specified here.

Appendix 1: Construction drawings

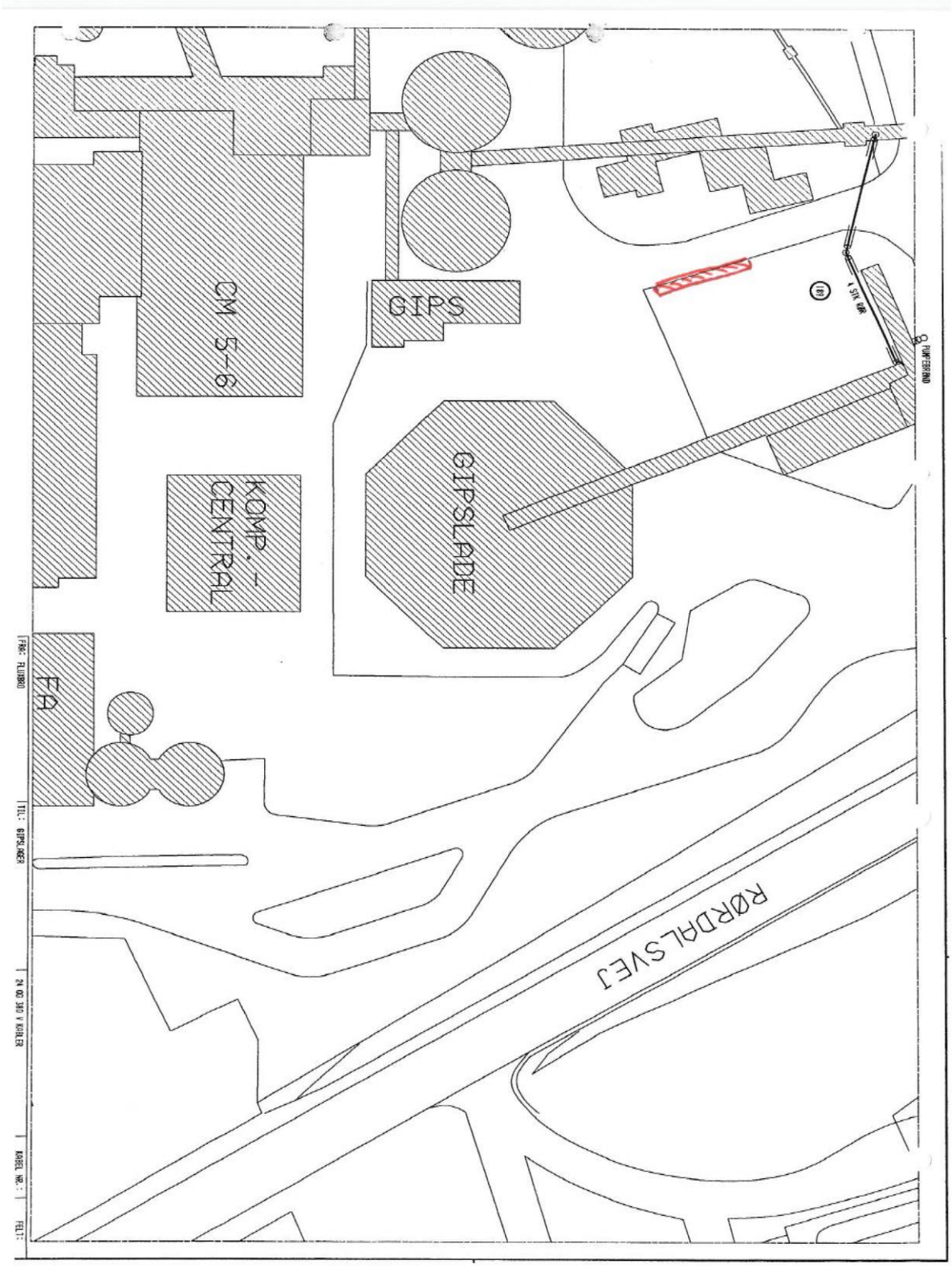


Figure 1. Location of walls

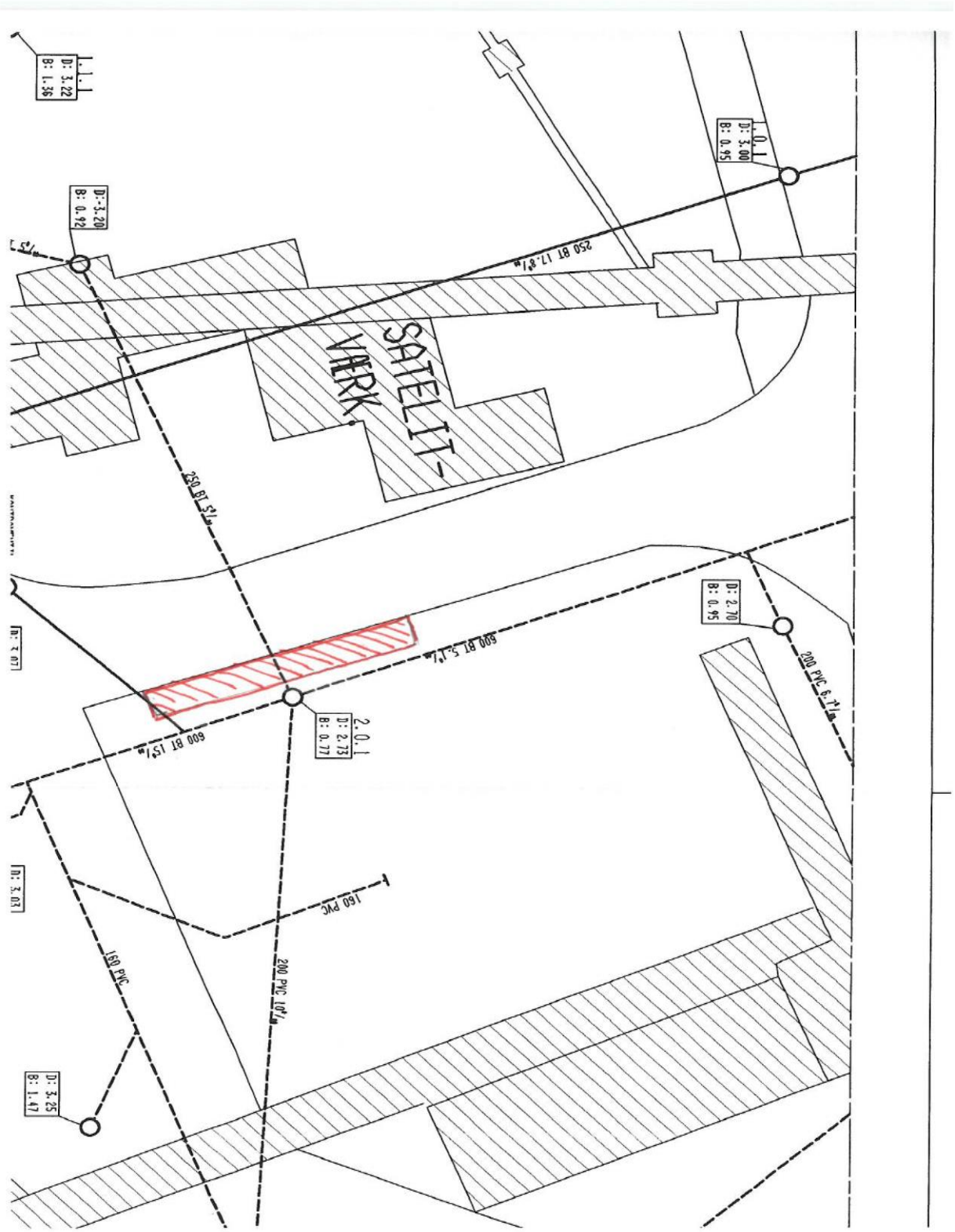


Figure 2. Location of walls

Figure 3. Reinforcement and formworks

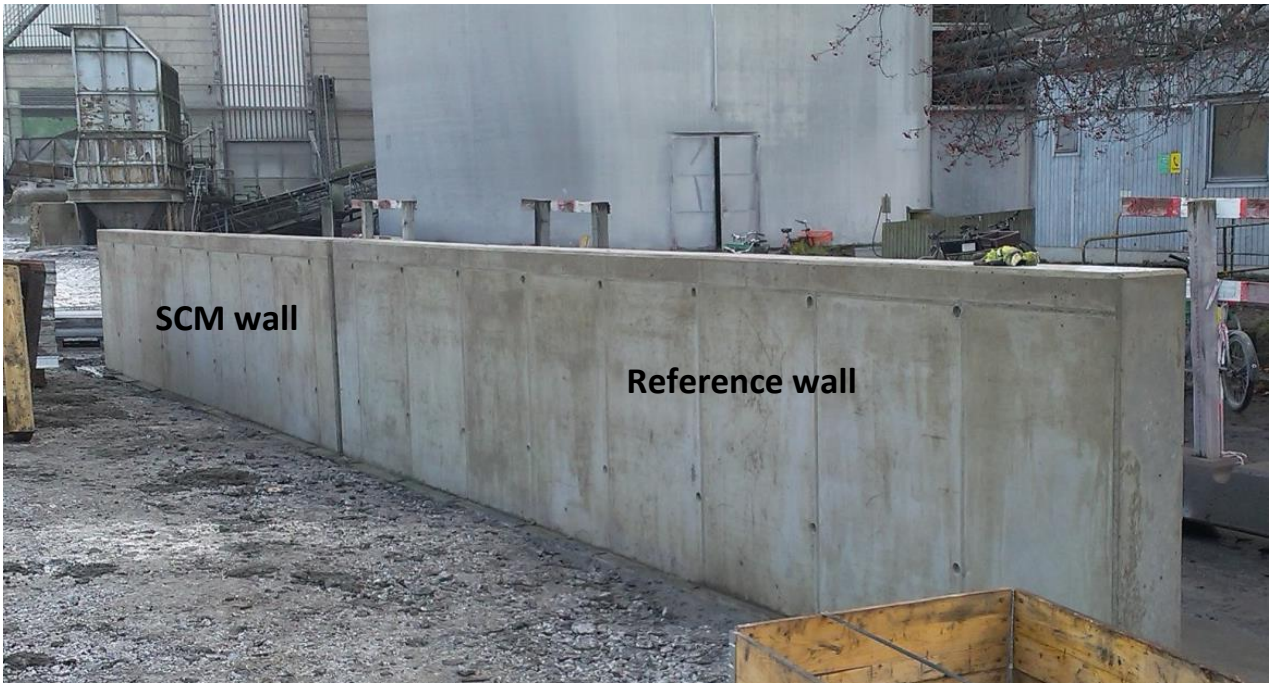


Figure 4. Visual aspect of walls after removing formworks (7-Nov-14)

Figure 5. Visual aspect of walls on 21-Jan-15

Appendix 2: Description of drilled concrete cores

Figure 6. Location of drilled concrete cores and visual aspect of walls on 19-9-18