Kalgoorlie Consolidated Gold Mines (KCGM) – Gold Ore Processing Plant, Fimiston WA

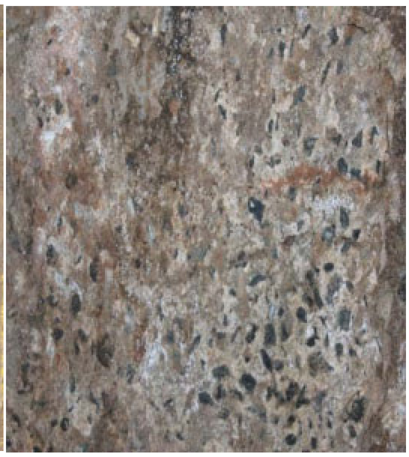
The table and graphs below summarise the results of SEM, petrographic & penetrability testing by materials consultants RSK (UK). Tests were conducted on concrete core samples made "WITH" & "WITHOUT" Cementaid **Everdure CALTITE** impermeability & durability ingredient, after up to 17 years wet/dry cycling with concentrated chloride, sulphate & magnesium salt solutions at elevated temperature.

With two years longer exposure and despite on-site abuse resulting in approx. 25% increase in w:c ratio, the Everdure CALTITE concrete is shown to completely effectively resist chloride penetration as well as sulphate corrosion attack. The non-Caltite concrete demonstrates severe chloride contamination to more than 70mm depth, with active reinforcement, elevated sulphate levels consistent with chemical attack to 25mm depth and significantly reduced residual service life.

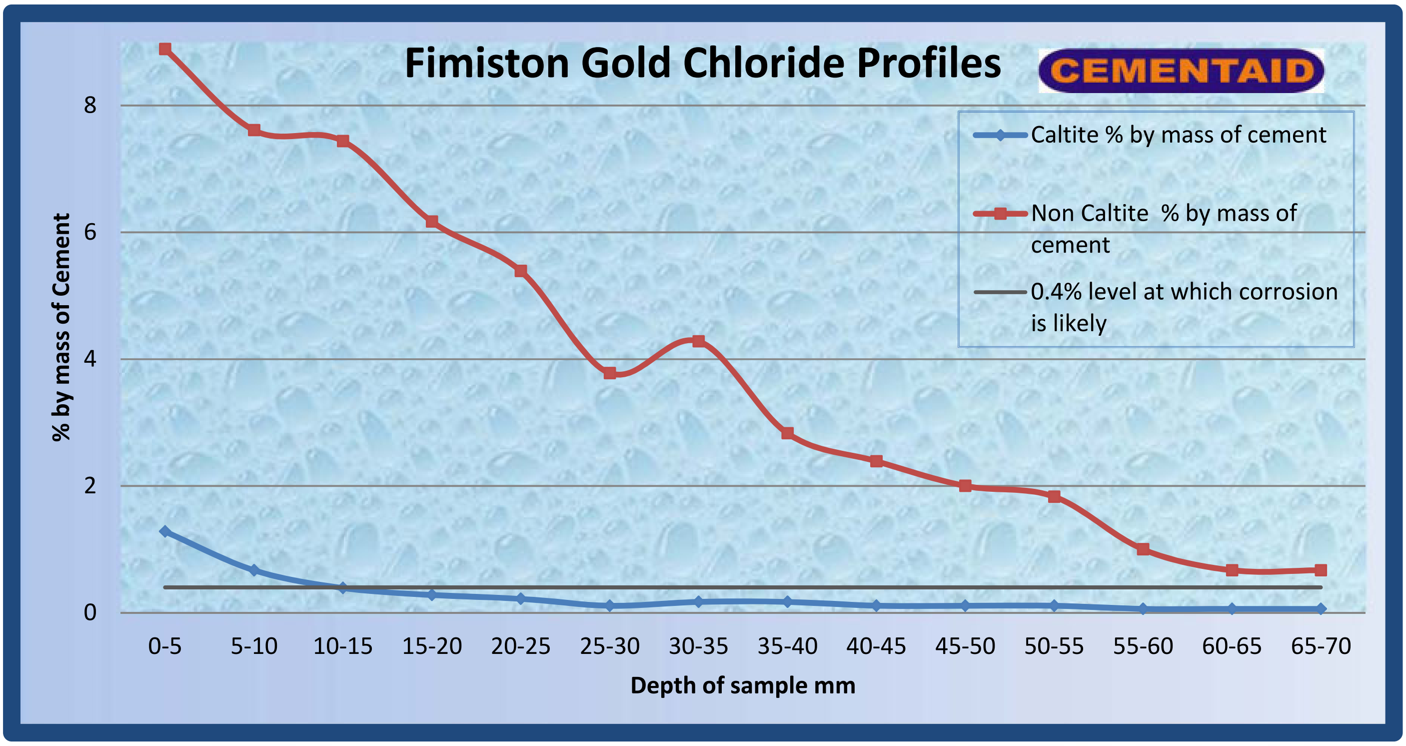
RSK Environment (UK) Materials Consultants		
Ore Processing Plant, Fimiston WA Kalgoorlie Consolidated Gold Mines (KCGM)		
Concrete Grade: 40MPa	**WITH Caltite**	**WITHOUT Caltite**
Age at Sampling & Testing	**17 years**	**15 years**
Petrographic Examination		
Cracking	Rare micro-cracks	Sporadic to common micro-cracks
ASR	Rare deposits	Sporadic to common deposits
Surface Erosion	None	Outer 3mm Sulfate Attack
Water Absorption (BS1881: Part.2)	0.43%	2.27%
Rate of Absorption (ASTM C1585-04)	19 mm/√s x 10^{-4}	62 mm/√s x 10^{-4}
Permeable Voids (ASTM C642-06)	10.20%	12.00%
Cement Content (BS 1881-124: 1988)	446 Kgs/m^3	423 Kgs/m^3
W/C ratio (BS 1881-124: 1988)	0.55 *	0.45
Chloride Profile By mass of cement		
Depth 0-5mm	1.28%	8.89%
Depth 10-15mm	0.39	7.44%
Depth 65-70mm	0.06	0.67%
Rate of Chloride Duffusion	9.575 x 10^{-14} m^2/s	1.465 x 10^{-12} m^2/s
Sulfate Profile By mass of cement		
Depth 0-5mm	5.06%	18.33%
Depth 5-10mm	4.72%	8.50%
Depth 20-25mm	3.78%	5.44%

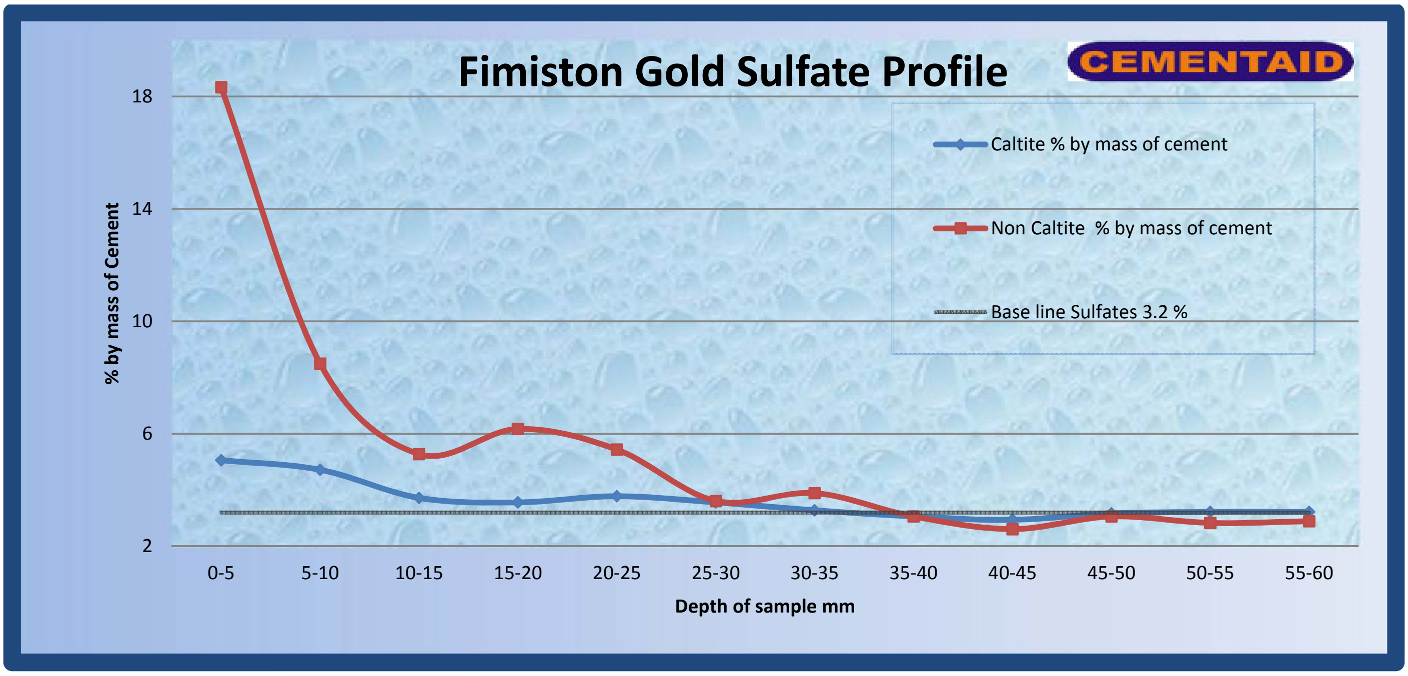
Surface Appearance
at location of core samples

[* Probable on-site water addition]



WITH Caltite **WITHOUT Caltite**





Despite the unusually extreme conditions, the report's authors conclude that the CALTITE concrete is likely to deliver an additional *"..few decades"* service-life (i.e. up to 50+ years), while the non-Caltite concrete is *"..already nearing the end of its useable service-life.."* after only 15 years.

Specified by Minproc Hatch (WA) using an Absorption-based performance specification, the performance of the CALTITE concrete reported by RSK demonstrates that the use of absorption and/or sorptivity is the simplest, most cost-effective & time-proven safe method of assessing, specifying & ensuring the durability of reinforced concrete under severe exposure conditions. RSK's Research Report and the time-proven effective Absorption-based Performance Specification for Design-Life Durability are available now from the Cementaid Technical Service Centre in your world region.

Cementaid (WA Pty. Ltd)

Fimiston Plant, Kalgoorlie-Boulder

Concrete Testing – Caltite and non-Caltite Concrete

284188-01 (04)

FEBRUARY 2013

CONTENTS

TABLES

FIGURES

APPENDICES

RSK DOCUMENT CONTROL

Report No.: 284188-01 (04)

Title: Fimiston Plant, Kalgoorlie-Boulder
Concrete Testing – Caltite and Non-Caltite Concrete

Client: Cementaid (W A Pty. Ltd)

Date: 14 February 2013

Office: Hemel Hempstead

Status: Final

Author	Dr Ian Blanchard Senior Consultant	**Author**	Paul Bennett Hughes Principal Scientist
Signature		Signature	
Date:	14 February 2013	Date:	14 February 2013
Technical reviewer	Dr Ian Sims Director		
Signature			
Date:	14 February 2013		

EXECUTIVE SUMMARY

On the instructions of the Cementaid International Group, RSK's Materials Consultancy has undertaken a series of laboratory tests comparing the condition and performance of concrete with and without Everdure Caltite hydrophobic pore-blocking ingredient. It is understood that the concrete has been routinely exposed to hypersaline and otherwise aggressive fluids in the wash-down area of a gold ore processing facility in Kalgoorlie-Boulder, Western Australia.

In total, 4 concrete cores were provided, with two including the Caltite admixture and two without. It was advised that these came from two concrete units cast at similar times (around 1995), respectively with and without Caltite admixture

The laboratory testing included examinations (petrography and SEM/EDX), physical testing of density and absorption, and chemical testing of chloride and sulfate content at depth increments from the outer surface of the cores, plus cement content and water/cement ratio determinations.

The results of these laboratory tests consistently show that the Caltite concrete has performed better than the conventional concrete in this aggressive setting, despite having a higher w/c ratio than the Non-Caltite concrete, 0.55 as opposed 0.45. Normally, a low water/cement ratio is considered advantageous for concrete durability and compressive strength, but the Caltite concrete has shown that this is not always the case. Additionally, it is understood that the Caltite concrete has been subject to 2 years longer exposure in severe conditions.

Petrographically, there is evidence of only rare ASR gel development in voids in the Caltite concrete, insufficient to cause any deterioration, while the non-Caltite concrete exhibits sporadic to common ASR gel development in voids and microcracks. Additionally, the conventional concrete shows evidence of sulfate attack to the surface that is absent from the Caltite concrete.

The physical tests show that the Caltite concrete has lower absorption and absorption rates than the conventional concrete.

Chemical testing showed that the non-Caltite concrete had been very badly affected by the ingress of chlorides with the outer 70mm exceeding the levels that represent a risk of corrosion to embedded steel. Consequently, the reinforcement steel in the non-Caltite concrete is at risk of corrosion. By comparison, the Caltite concrete showed only a slight elevation of chloride in the outer layers, with only the outer 15mm exceeding the levels that would indicate a risk to embedded steel. As the Client advised that the steel is significantly deeper than this, the risk of corrosion is minimal and so the structure should continue to operate successfully.

Similarly, the sulfate gradients show that the non-Caltite concrete had a greatly elevated sulfate content at the outer surface, with markedly elevated levels (consistent with chemical attack) to 25mm depth. By comparison the Caltite concrete showed only a slight sulfate elevation and only affecting the outermost 10mm.

Overall therefore, it is apparent that the Caltite concrete is performing well compared to the non-Caltite concrete, both with regard to resisting the aggressive environment and in maintaining its enhanced water and salt resistance.

The information given in this summary is necessarily incomplete and is provided for initial briefing purposes only. The summary must not be used as a substitute for the full text of the report

1 INTRODUCTION

1.1 Instructions

On the instructions of Mr Paul Mundell of Cementaid (WA Pty. Ltd) by email dated 11 November 2011, RSK have undertaken a comparative laboratory assessment of concrete samples from concrete elements within the Fimiston Plant, Kalgoorlie-Boulder, Western Australia. Two of the samples comprised 'normal' concrete, whereas the other two samples comprised a similar mix to the first two samples, but included the Everdure Caltite ingredient.

The Client advised that both concrete types were produced by the same premix supplier, using similar mix designs (other than the inclusion/exclusion of Caltite) as indicated in **Table 1.1**.

Table 1.1: Advised mix designs as used

Grade: 40N Slump: 120mm	Caltite Mix	Conventional Mix
Cement kg/m^3	440	440
20mm kg/m^3	520	520
14mm kg/m^3	380	380
10mm kg/m^3	260	260
Sand kg/m^3	650	650
Water litres	156	185
Caltite litres	30	-
Superplasticiser litres	2.3	2.3

1.2 Background

The Client advised that the concrete samples with and without Caltite had been taken from structures cast respectively 17 and 15 years ago (cast in 1994 and 1996) at a gold ore processing facility at Fimiston, WA. Further, the Client advised that the samples have been subject to an aggressive, hot and dry environment and provided data sheets of the saline water that was used to wash down the plant (see **Table 1.2**), including the exposed concrete.

Table 1.2: Chemical Composition of Water Used at the Plant to Wash Equipment

	Scheme water	Saline water	Unit
Maximum temperature	31	--	°C
Conductivity	100	--	25° micormhos/cm
Total Dissolved Solids	250	158,000 – 217,000	mg/l
pH	7.5 – 8.5	5.3 – 7.25	
Fe++	0.4	--	mg/l
Ca++	28	640 – 1050	mg/l
Mg++	15	6500 - 9000	mg/l
Cl	47	88,000 – 122,000	mg/l
NO_{3--}	0.1	--	mg/l
F-	16	--	mg/l
SO_{4--}	13	8,500 – 12,000	mg/l
CO_{3--}	--	<0.3	mg/l
Na+	--	51,100 – 70,000	mg/l
K+	--	90 - 435	mg/l

Reproduced from provided Kalgoorlie Consolidated Gold Mining (KCGM) Specification.

1.3 Caltite System

Caltite is a liquid hydrophobic pore-blocking ingredient (HPI) that is dosed into the concrete during mixing in place of some of the mixing water. Additionally, a high range water-reducing admixture is also used to provide a high quality, dense and low permeability concrete. The Caltite material is designed to line the pore and capillary structure of the hardened cement paste, reversing normal capillary suction and physically blocking capillaries when subjected to hydrostatic pressure.

The technical literature further advises that Caltite has two distinct waterproofing actions:

1) Firstly there is the reaction of the ‘hydrophobic’ components of Caltite with cement components that fundamentally changes surface tension. Pores and capillaries throughout the entire mass of the concrete become inherently water-repelling (hydrophobic) and non-absorptive. This addresses the predominant mechanism by which water enters and is transmitted through concrete: absorption.

2) In the second action, discrete polymer globules, moving with the bleed water, coalesce under hydrostatic pressure to form a physical plug in the capillaries, thereby physically blocking the capillaries and minimising water ingress.

1.4 Objective

The purposes of the laboratory assessment were to determine the relative performances of the concrete samples with and without the Caltite ingredient after up to 17 years of service in an aggressive environment and try to derive meaningful data that would allow for the calculation of the service life of the concrete.

2 SAMPLES AND TEST ASSIGNMENT

2.1 Samples

A summary of the samples received is shown in **Table 2.1**.

Table 2.1: Summary of Samples

RSK Sample Ref	Client Sample Ref	Description	Date received	Core diameter, mm	Core length, mm
11674/C1	1	Caltite concrete	05.10.11	95	242
11674/C2	2	Caltite concrete	05.10.11	95	240
11674/C3	3	Non-Caltite concrete	05.10.11	95	241
11674/C4	4	Non-Caltite concrete	05.10.11	95	238

2.2 Laboratory Test Schedule

Tests were assigned to the concrete cores as detailed in **Table 2.2**.

Table 2.2: Test Assignment

Test Method	11674/ C1	11674/ C2	11674/ C3	11674/ C4
	Caltite concrete		Non-Caltite concrete	
Petrographic examination[1]	✓		✓	
Scanning electron microscopy	✓		✓	
Water absorption[2]	✓		✓	
Rate of absorption[3]		✓**		✓**
Voids in hardened concrete[4]		✓***		✓***
Cement content[5]				
Original water/cement ratio[5]		✓		✓
Chloride content[5]	✓****		✓****	
Sulfate content[5]	✓*****		✓*****	

** 2 depths: 0-50mm and 150-200mm, *** 3 depths: 50-80mm, 80-110mm and 110-150mm, **** 15 depth intervals from the outer surface, ***** 13 depth intervals from the outer surface

[1] ASTM C856-11. Standard practice for petrographic examination of hardened concrete. ASTM International, West Conshohocken, Pa, USA

[2] BS 1881-122: 1983. Testing concrete – Part 122: Method for determination of water absorption. British Standards Institution, London, UK.

[3] ASTM C1585-04. Standard test method for measurement of rate of absorption of water by hydraulic-cement concretes. ASTM International, West Conshohocken, Pa, USA

[4] ASTM C642-06, Standard test method for density, absorption and voids in hardened concrete, ASTM International, West Conshohocken, Pa, USA

[5] BS 1881-124: 1988. Testing concrete – Part 124: Methods for analysis of hardened concrete. British Standards Institution, London, UK

3 LABORATORY RESULTS

3.1 Petrographic Examination

Detailed results of the petrographic examinations are included in **Appendix A** and are summarised in **Table 3.1**.

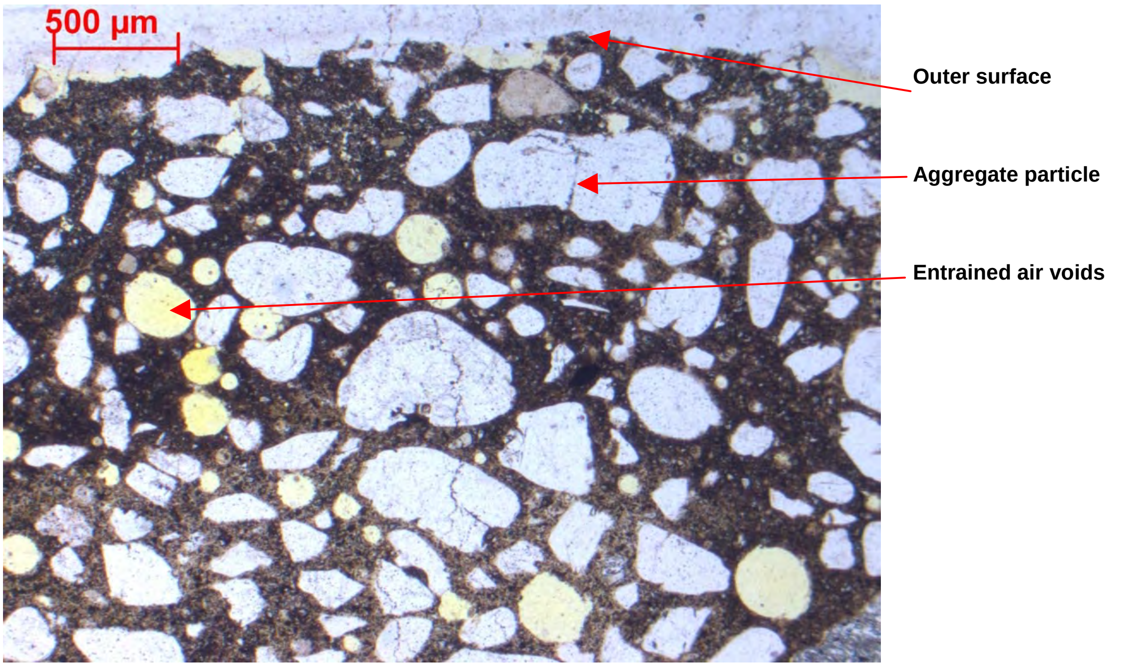
Table 3.1: Summary of Petrographic Examination Findings.

RSK Sample Ref	11674/C1	11674/C3
Description	**Caltite concrete**	**Non-Caltite concrete**
Composition		
Coarse aggregate max. size, mm	20	20
Coarse aggregate type	Crushed rock (gneiss)	Crushed rock (gneiss)
Fine aggregate max. size, mm	5	5
Fine aggregate type	Natural quartzitic sand	Natural quartzitic sand
Cement type	Portland-type	Portland-type
Admixture	Yes - Caltite	None
Mineral additions	None	None
Mix quality		
Well-mixed?	Yes	Yes
Degree of compaction	Good	Good
Maximum air void size, mm	4	3
Excess voidage, %	0.5	0.5
Estimated original water/cement ratio range	High end of the normal range (0.35 to 0.65)	Normal range (0.35 to 0.65)
Condition		
Max. depth of carbonation, mm	2.5	3.2
Presence of cracking?	Rare microcracks running through the cement matrix between fine aggregate particles	Sporadic to common microcracks running through the cement matrix and coarse aggregate particles
Presence of ASR?	Rare deposits observed partially lining air voids No reaction sites observed.	Sporadic to common deposits lining air voids within the cement matrix and microcracks running through the cement matrix and aggregate particles.
Presence of secondary ettringite?	None	None
Presence of leaching?	None	None
Evidence of reinforcement corrosion?	None	None
Condition of the surface	Good	The outer 3mm of the concrete exhibits a sulfate-attacked zone. The zone shows partial replacement of the cement matrix by sulfate deposits. Further analysis by SEM-EDX would be required to confirm the composition of the attacked zone.
Other comments		
	The outer surface was formed, whilst the inner surface was freshly fractured.	The outer surface was worn, whilst the inner surface was freshly fractured.

Photomicrographs of selected features are shown in **Figures 3.1** for the Caltite concrete and **3.2** for the reference, non-Caltite, concrete.

Figure 3.1: Photomicrographs of features within Caltite concrete

VIEW OF THE OUTER SURFACE



VIEW OF ASR DEPOSITS WITHIN AN AIR VOID

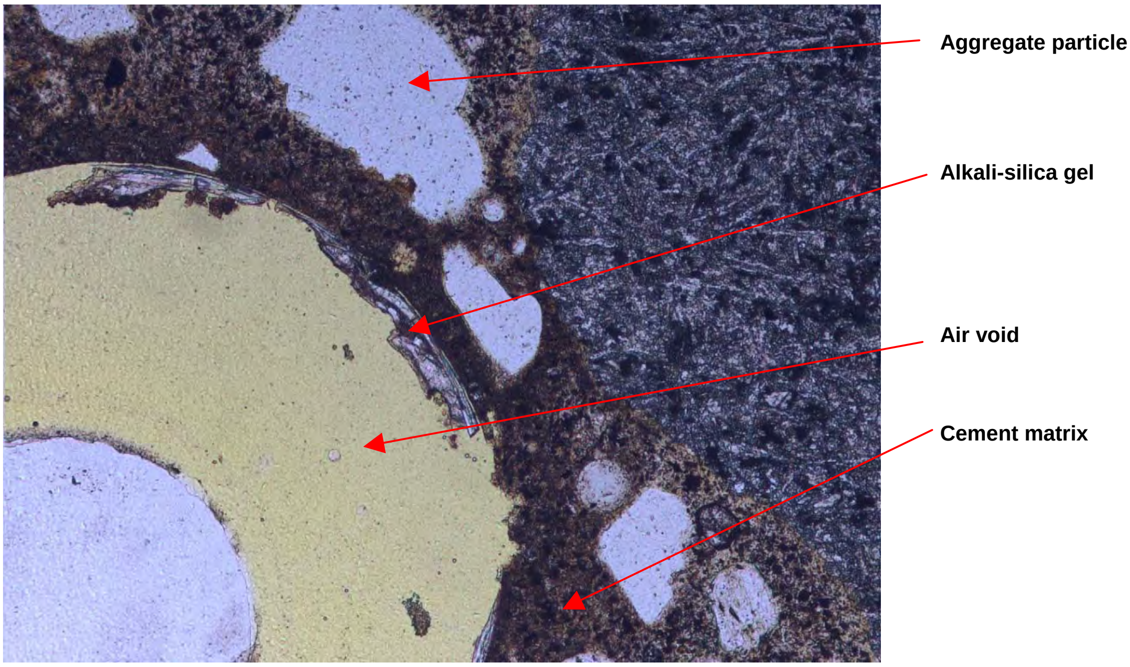
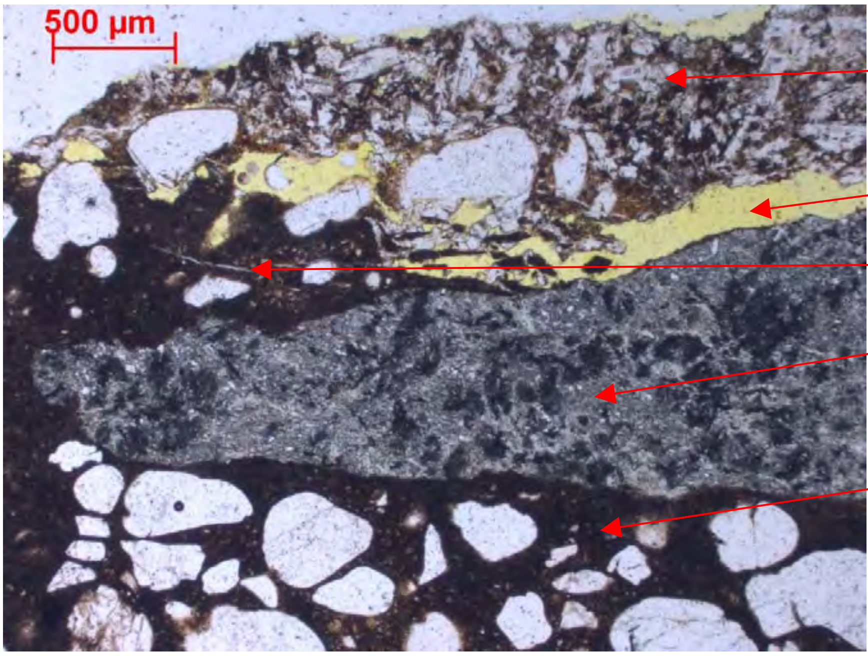


Figure 3.2: Photomicrographs of features within non-Caltite concrete

SULFATE-ATTACKED SURFACE



Sulfate deposits replacing the cement matrix

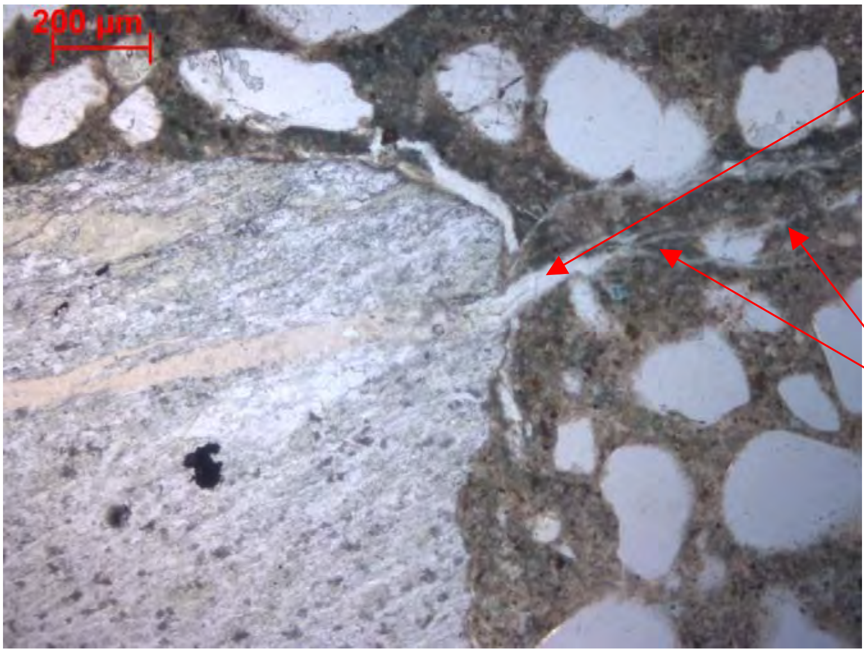
Delamination

Microcracks infilled by sulfate deposits

Aggregate particles

Cement matrix

ALKALI-SILICA REACTION



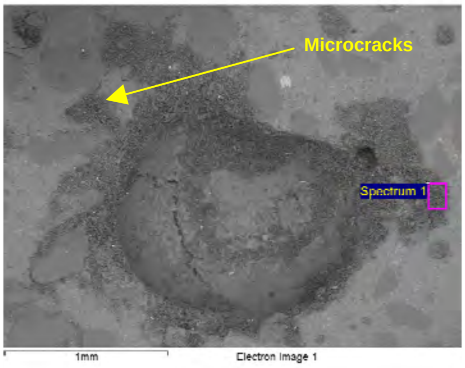
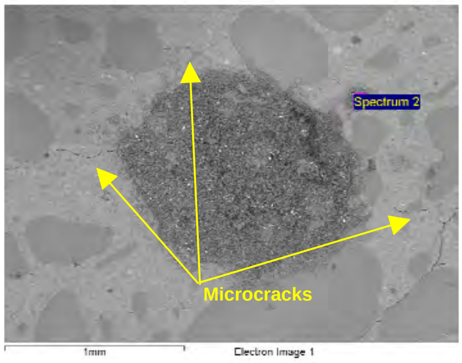
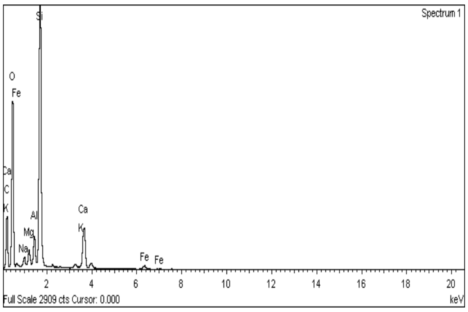
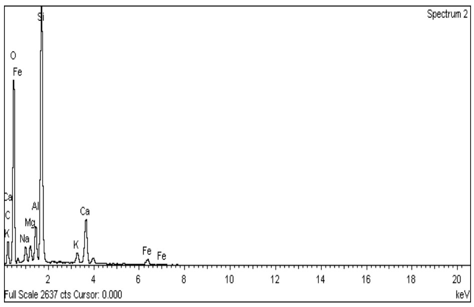
Alkali-silica gel

Microcracks running through the cement matrix and aggregate particles

3.2 Scanning Electron Microscopy

Detailed results of the petrographic examinations and compositional analysis are included in **Appendix A** and summarised in **Table 3.3.**

Table 3.3: Summary of SEM Findings

Sample	Caltite concrete (C1)	Non-Caltite concrete (C3)
SEM/EDX	Low proportion of microcracks (relative to C3). Secondary deposits in this specimen only contained leached silica and metal ions, not ASR gel	Heavily microcracked. Secondary deposits in this specimen only contained leached silica and metal ions, not ASR gel
Photomicrograph		
Description	General view of deposits within a small air void. The deposits primarily comprised silica, with smaller quantities of iron, calcium and potassium.	General view of deposits within a small air void. The deposits primarily comprised silica, with smaller quantities of iron, calcium and potassium. Microcracks were commonly observed running through the cement matrix.
Spectra		

The SEM analyses were concentrated on confirming the texture of the cement matrix and the characterisation of any deposits, eg alkali-silica gel, within air voids and microcracks within the main body of the concrete. The SEM was not focussed on the upper surfaces of the concretes, which would, in the case of the non-Caltite sample, have included the presence of sulfate-attack.

3.3 Results of Physical Testing

Detailed results of the physical tests are included in **Appendix B** and summarised in **Table 3.4**.

Table 3.4: Summary of Physical Test Results

Test	Method	Units	Caltite concrete	Non-Caltite concrete
BS 1881-122*	Density	kg/m^3	2270	2400
	Measured absorption	%	0.36	1.88
	Corrected absorption	%	0.43	2.27
ASTM C642**	Volume of permeable pore space (voids)	%	10.2	12.0
ASTM C1585***	Initial Rate of Absorption**	mm/√s x 10^{-4}	19 (R^2 = 0.98)	62 (R^2 = 0.99)
	Secondary absorption	mm/√s x 10^{-4}	10 (R^2 = 0.99)	15 (R^2 = 0.98)

*Mean of three test specimens. Core diameter was 95mm (standard specifies ideally 75mm).

** Mean of three test specimens. Individual portions were less than 350cm^3 in volume.

***Mean of two test specimens.

3.4 Chemical Test Results

3.4.1 Chloride and sulfate content

Detailed test results for the chloride and sulfate content determinations are shown in **Appendix B**, whilst a summary of findings is shown in **Table 3.6**.

Table 3.5: Summary of Chloride and Sulfate Chemical Test Results

Depth (mm)	Chloride by mass cement (%)				Sulfate by mass cement (% SO_3)*			
	11675 C1		11675 C3		11675 C1		11675 C3	
	Caltite		Non-Caltite		Caltite		Non-Caltite	
	By mass of cement, %*	By mass sample, %	By mass of cement, %*	By mass sample, %	By mass of cement, % SO_3*	By mass sample, %	By mass of cement, % SO_3*	By mass sample, %
0-5	1.28	0.23	8.89	1.60	5.06	0.90	18.33	3.30
5-10	0.67	0.12	7.61	1.37	4.72	0.85	8.50	1.53
10-15	0.39	0.07	7.44	1.34	3.72	0.67	5.28	0.95
15-20	0.28	0.05	6.17	1.11	3.56	0.64	6.17	1.11
20-25	0.22	0.04	5.39	0.97	3.78	0.80	5.44	0.98
25-30	0.11	0.02	3.78	0.68	3.56	0.64	3.61	0.65
30-35	0.17	0.03	4.28	0.77	3.28	0.59	3.89	0.70
35-40	0.17	0.03	2.83	0.51	3.06	0.55	3.06	0.55
40-45	0.11	0.02	2.39	0.43	2.94	0.53	2.61	0.47
45-50	0.11	0.02	2.00	0.36	3.17	0.57	3.06	0.55
50-55	0.11	0.02	1.83	0.33	3.22	0.58	2.83	0.51
55-60	0.06	0.01	1.00	0.18	3.22	0.58	2.89	0.52
60-65	0.06	0.01	0.67	0.12	--	--	--	--
65-70	0.06	0.01	0.67	0.12	--	--	--	--
Inner surface	0.06	0.01	2.67	0.48	2.72	0.49	3.39	0.61

* Cement content assumed to be 18%, as indicated by the mix design provided by the Client.

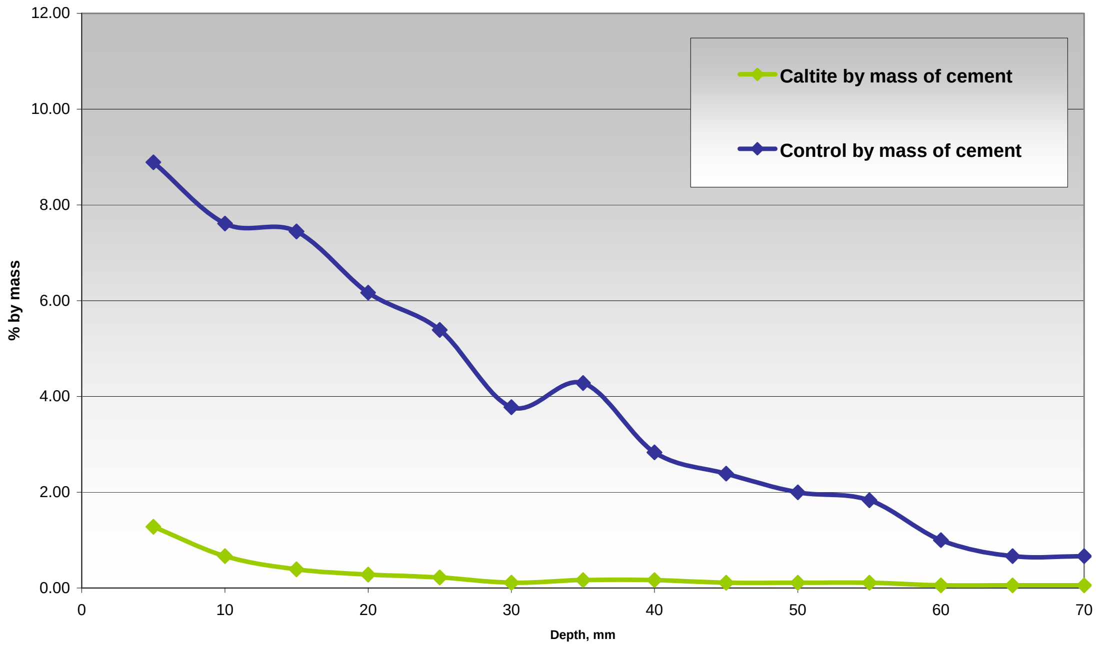
Graphs of the chloride contents against depth are shown in **Figure 3.3**.

Graphs of the sulfate contents against depth are shown in **Figure 3.4**.

Figure 3.3: Summary of Chloride content

11674/C1 – Caltite concrete & 11674/C3 – Control concrete

By mass of cement



By mass of sample

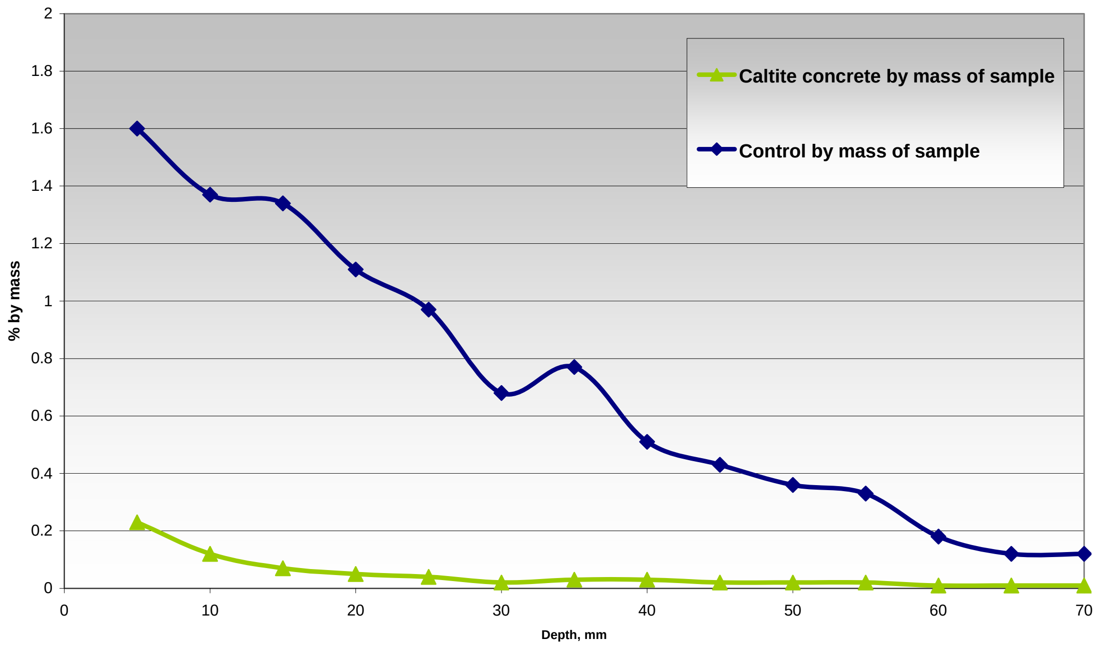
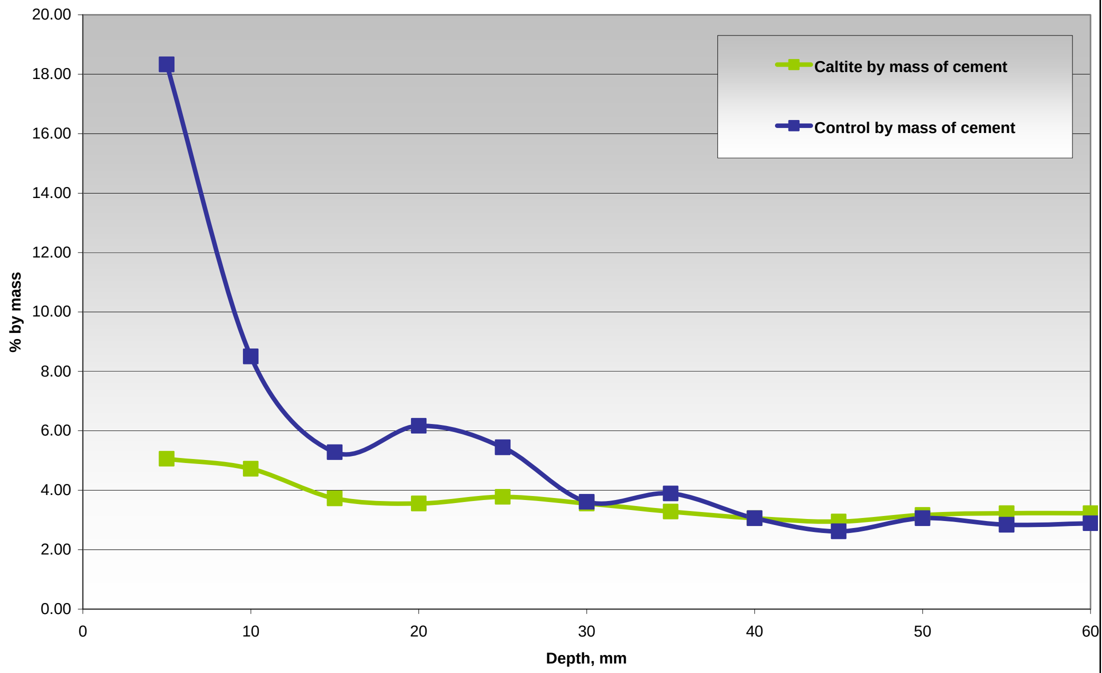
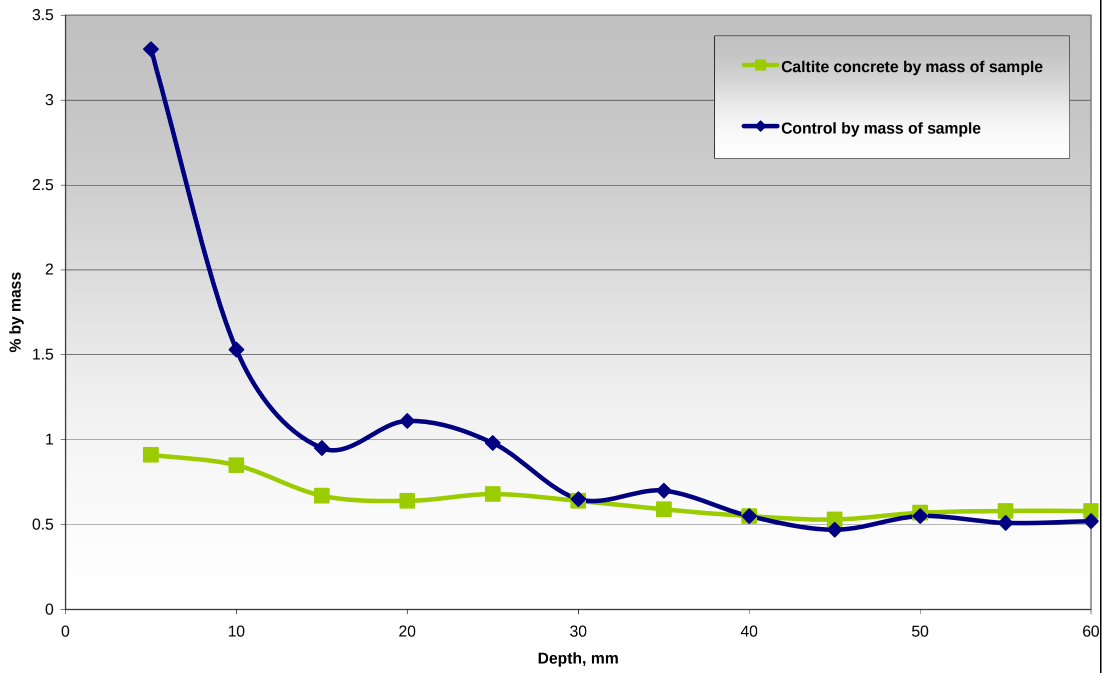


Figure 3.4: Summary of Sulfate content

11674/C1 – Caltite concrete & 11674/C3 – Control concrete
By mass of cement



By mass of sample



3.4.2 Cement content and original water/cement ratio

Detailed test results for the chloride and sulfate content determinations are shown in **Appendix B**, whilst a summary of findings is shown in **Table 3.7**.

Table 3.7 Cement content and original water/cement ratio

RSK Sample Ref	Client Sample Ref	Cement content, kg/m^3	Cement content, %	Capillary porosity, % by mass	Water/cement ratio*
11675/C2	#2 Caltite	446	19.8	19.8	0.5 (0.548)
11675/C4	#4 Non-Caltite	423	18.8	18.8	0.5 (0.453)

*The standard states for the determination to be reported to one decimal place. However, to show the difference in the values the result is shown to three decimal places, to show how rounding the figure has masked the difference.

4 DISCUSSION

4.1 Concrete Condition

As detailed in the introduction, these concrete samples were cores taken after up to 17 years in service in a setting where aggressive hyper-saline water is frequently in contact with the concrete. The presence of frequent wetting and drying cycles in this setting would most probably accelerate the degradation. Additionally, the fluids present are potentially aggressive, both because of the moderately low pH of the saline fluids causing a potential risk of acid attack, and of magnesium in combination with sulfate, potentially increasing the extent of damage should sulfate attack occur because of the production of a soluble reaction product.

The petrographic examination showed that the conventional (non-Caltite) concrete included abundant microcracks; these could be from the original casting of the concrete or from its subsequent deterioration. The petrographic examination showed that the outer surface of the reference (non-Caltite) concrete exhibited evidence of sulfate attack, in the form of the development of secondary sulfate minerals in the outer 3mm, with associated amorphous iron-rich deposits derived from the hardened cement paste. Sulfate minerals were also observed in rare microcracks running parallel to the outer surface. Some areas of the outer surface exhibited a pitted texture, possibly indicting where areas of softened sulfate-attacked concrete had worn/washed away. The sulfates had probably derived from the sulfate-rich wash down waters, which penetrated the upper surface of the porous non-Caltite concrete, once they crystallised they soften the cement matrix and can cause degradation. Scanning electron microscopy (SEM) coupled with energy dispersive X-ray analysis (EDXA) would enable chemical maps to be produced of the upper deteriorated surface of the concrete and confirm the presence and distribution of various chemical and compounds.

Hand specimen examination of the non-Caltite concrete showed the presence of ‘sweaty patches’ around coarse aggregate particles, and this was confirmed to be sporadic to abundant development of alkali-silica gel, mainly at this stage precipitating in voids and microcracks emanating from gneiss coarse aggregate particles. Alkali-silica reaction (ASR) is a reaction that attacks the cement-aggregate boundary or in some cases causes degradation of the aggregates and occurs for concrete with a primarily silicate aggregate (in this case, a gneiss coarse aggregate and a quartz sand fine aggregate) in the presence of fluids and moderately high sodium and potassium levels. These alkali metals can be derived from within the concrete (mainly from the cement and occasionally also from the aggregate) or from external sources such as the strongly saline solutions used in the mine (these being approximately 4 to 6 times more saline than conventional sea water). As such, the setting of this concrete appears to be highly conducive to the occurrence of alkali-silica reaction, although there is a lack of specific guidance on limiting values for external solutions contributing alkalis to hardened concrete.

The Caltite concrete was estimated by petrography as apparently being of slightly higher water/cement ratio that the conventional concrete[6], which was confirmed by the chemical analysis (0.55 for the Caltite concrete and 0.45 for the non-Caltite concrete). Additionally, the petrography suggested some localised variability in the microporosity of the concrete, with areas of higher apparent microporosity being associated with microcracks. Some bleeding channels were also observed between coarse aggregate particles and the cement matrix. However, the overall abundance of microcracks was markedly lower in this concrete than in the conventional concrete.

There was no evidence of acid attack and secondary sulfate deposits in the near-surface parts of the Caltite concrete. In addition, the development of ASR gel was very restricted, with only rare secondary mineralisation being observed in air voids. As such, it is reasonable to conclude that the Caltite concrete has proven to be significantly more durable in service and less susceptible to degradation by reaction with the aggressive fluids present on this site. Indeed, the Caltite concrete would appear to have a reasonable further service life (perhaps up to several decades) before the degradation becomes severe, while the conventional concrete is nearing the end of its useful service life.

[6] The Client advises that the Caltite concrete was installed during very high summer temperatures average daytime max = 41ºC), perhaps resulting in addition of extra water to the wet concrete mix on site (to maintain workability). This may explain the higher than anticipated water/cement ratio.

4.2 Physical Testing

Water absorption, in accordance with the British Standard test method, is significantly better for the Caltite concrete than for the conventional concrete, with the corrected (for geometry and sample size) absorption values being 0.71 and 1.87% respectively.

The ASTM C642, VPV, results show similar pattern to the other absorption tests with the Caltite concrete giving lower values than the non-Caltite concrete, 10.2% and 12.0% respectively.

The rate of absorption, as determined by the ASTM C1585 test method also showed that the Caltite concrete was significantly more resistant than the conventional concrete. The initial rate of absorption (19mm/s$^{1/2}$ for the Caltite concrete compared with 62 mm/s$^{1/2}$ for the normal concrete) shows the initial absorption is about 30% as rapid when the Caltite is present. The secondary absorption is also markedly lower (10 mm/s$^{1/2}$ compared with 15 mm/s$^{1/2}$), although the difference is less marked as the pores in the concrete become filled.

4.3 Chemical Tests

4.3.1 Chloride Gradients

The ingress of chlorides into a concrete causes a significant risk to any embedded reinforcing steel within the concrete unit. British Standard[7] guidance suggests that levels in excess of 0.4% chloride by mass of cement are likely to pose an enhanced risk of corrosion to the reinforcing steel.

In this case, the Caltite concrete exhibits elevated chloride concentration for the outermost three depth increments (0-5, 5-10 and 10- 15mm increments from the outer surface), with the chloride concentration % by mass of cement decreasing from 1.28% on the surface to 0.39% for the third depth increment (10 to 15mm). The chloride content further into the unit falls below the levels (typically taken as 0.4% for conventional reinforced concrete, although lower for pre-stressed concrete) where it would be considered as posing a risk to reinforcement, indicating that the Caltite concrete should continue to provide effective protection to the buried steel reinforcement.

By contrast, the conventional concrete shows much more elevated chloride levels in the near surface increments, an order of magnitude higher than for the Caltite, with all depth increments to 70mm remaining well above the 0.4% value considered to represent a risk (lowest determined value being 0.67% by mass of cement). As such, any embedded steel in this concrete is at high risk of corrosion and of causing damage to the concrete element.

The chloride diffusion results, based upon Fick's second law, were 1.465 x 10^{-12} m^2/s for the non-Caltite concrete and 9.575 x 10^{-14} m^2/s for the Caltite concrete. These values indicate that the non-Caltite concrete is more susceptible to chloride ingress than the Caltite concrete.

4.3.2 Sulfate Gradient

Normal CEM1 type cement contains a moderate amount of sulfate in the form of gypsum or hemihydrate, to act as a retarder of early setting. Typically, this leads to a sulfate (SO_3) content of around 3% to 4% by mass of cement. Higher sulfate levels can be indicative of chemical attack of the concrete, either by sulfate attack (in alkaline conditions) or through leaching and acid attack.

In this case, both the Caltite and conventional concrete show some evidence of elevated sulfate levels in the outer portions (0 to 5mm depth). However, this elevation is relatively minor for the Caltite concrete, with a maximum of 5.1% sulfate in the outer increment and this falling back to relatively 'normal' values (less than 5% sulfate) at depths greater than 5mm.

[7] BS EN 206-1: 2000, Concrete – Part 1: Specification, performance and conformity, British Standards Institution, London, UK

By comparison, the conventional concrete has a greatly elevated sulfate concentration in the outermost increment (18.3% SO_3), only falling consistently back to 'normal' values 25mm into the concrete. Overall therefore, this demonstrates the good resistance to chemical attack of the Caltite concrete.

The reported sulfate concentrations in the saline water (sulfate concentration as SO_4 beings 8500mg/l and Mg concentrations above 1200mg/l) suggest very aggressive conditions for concrete based on the British guidance given in Special Digest 1[8]. These would be consistent with the most aggressive design class (DS-5m) if the concrete were exposed to groundwater of this composition[9]. While Section D6 4.2 of BRE SD1 states that 'the effectiveness of integral waterproofing agents in preventing sulfate attack has not yet been established', the data presented in this report suggests that Caltite has been effective under these exposure conditions.

4.3.3 Cement content

The cement content of the Caltite concrete was determined to be 446kgm/^{3}, whilst the non-Caltite concrete was determined to lower at 423kg/m^3. The specified cement content for both mixes was 440kg/m^3. BS 1881-124 states that the repeatability value for the test is 40kg/m^3, whilst the reproducibility is 60kg/m^3. Therefore, within the repeatability and reproducibility values within the standard, both samples could have exhibited cement content in line with the specification. The precision trials for this test were conducted using flint and limestone coarse aggregate. The coarse aggregate for both the Caltite and non-Caltite concrete is gneiss. There is no guidance within the standard whether gneiss would lower or increase the precision of the test.

4.3.4 Water/cement ratio

The Caltite concrete exhibited a higher capillary microporosity (19.8% by mass) compared to the non-Caltite concrete (18.8% by mass). Capillary porosity is a measure of how much of the test solution infills the pores within the specimen, which, as the name suggests, is a measure of the microporosity of the sample. The results of the chemical analyses confirm the findings of the petrographic examination that observed a higher microporosity of the cement matrix within the Caltite concrete compared to the non-Caltite concrete.

The Caltite concrete exhibited a water/cement ratio of 0.55, whereas the non-Caltite concrete exhibited a value of 0.45. The mix design value for the water/cement ratio was 0.42 for both the Caltite and the non-Caltite concrete mixes. The water/cement determinations confirm the difference in microporosity observed as part of the petrographic examination and the values determined from the capillary porosity.

---

[8] BRE Special Digest 1: 2005. Concrete in aggressive ground. Building Research Establishment, Garston, UK.

[9] It should be noted that the BRE SD1 guidance is written to allow the design of a concrete that is inherently resistant to potentially aggressive ground conditions, rather than to determine the risk to existing concrete. In this latter context, BRE SD1 can be considered as providing useful guidance information rather than giving absolute acceptance criteria.

5 CONCLUSIONS

- The petrographic examination shows that the Caltite concrete has not been subject to sulfate attack and has only undergone very minor ASR gel development in air voids. By comparison, the conventional concrete shows significant evidence of sulfate attack to the near surface layer and sporadic to common development of ASR gel in voids and microcracks.
- The physical test results appear to confirm that Caltite concrete remains significantly more water-resistant that the conventional concrete, with lower absorption and rate of absorption results. This is in spite of the higher water/cement ratio and consequent voids content determined for the Caltite concrete.
- The chloride and sulfate depth gradients show that the Caltite concrete has performed much better than the conventional concrete at resisting chloride and sulfate ingress. The Caltite concrete only shows somewhat elevated chloride contents for the outer 15mm; further into the body of the concrete, the chloride concentrations drop to levels that would not lead to corrosion of embedded steel. By contrast, the chloride content of the conventional concrete is much higher throughout, and remains above the levels that indicate a corrosion risk.
- The chloride diffusion rates indicate that the Caltite concrete is significantly more resistant to chloride ingress than the non-Caltite concrete.
- Similarly, the sulfate content of the Caltite concrete is only slightly elevated in the outer layer and decreases to a normal level at shallow depth. This suggests a good resistance to chemical attack. By comparison, the conventional concrete has a much higher sulfate concentration near the surface, and this high sulfate continues to a greater depth. This is in good agreement with the observations from the petrographic examinations.
- The cement content determinations indicate that the Caltite concrete has a marginally higher cement content than the non-Caltite concrete and also a higher original water/cement ratio. Usually, the concrete with a lower water/cement ratio should be more resistant to ingress of solutions, however, the presence of the waterproofing admixture has reduced any significant signs of deterioration.

APPENDIX A - CERTIFICATES OF EXAMINATION

Certificate no. 284188/39040a – Petrographic examination of hardened concrete (C1 – Caltite)
Certificate no. 284188/39041a – Petrographic examination of hardened concrete (C3 – non-Caltite)
Certificate no. 284188/39147a – Compositional analysis of concrete by SEM/EDX (C1 – Caltite)
Certificate no. 284188/39148a – Compositional analysis of concrete by SEM/EDX (C3 – non-Caltite)

This appendix contains 46 pages, including this one

RSK Environment Ltd
Tel: +44 (0) 1442 437500
Fax: +44 (0) 1442 437550
Email: info2@rsk.co.uk
Web: www.rsk.co.uk/stats

Materials & Structures
18 Frogmore Road
Hemel Hempstead
Hertfordshire
HP3 9RT

UKAS TESTING
0278

RSK

Certificate of Examination
ASTM C856-11
Petrographic Examination of Hardened Concrete

Your Ref.	None advised	**RSK Sample Ref.**	11675/C1
Site	Fimiston Plant, Kalgoorlie-Boulder Western Australia	**Client Sample Ref.**	#1
		Sample Type	Concrete core
Client	Cementaid (WA Pty. Ltd) 200 Star Street Welshpool Western Australia, 6105 Australia	**Location**	Not advised
		Orientation	Not advised
		Sampled by/Date	Client/Not advised
		Date of Receipt	05.10.11
		Examined by/Date	PBH/11.01.12

SAMPLE

The sample comprised a nominal 95mm diameter concrete core, approximately 242mm in length. The diameter and length of the submitted core were less than those preferred by the standard (ideally 152mm diameter and 305mm length). The Client advised that the concrete, which contained the Caltite admixture, was cast in 1994-5 and was subject to hypersaline water that is used to wash down in the gold mine.

METHODS OF EXAMINATION

A full description of the examination methods, including a glossary of descriptive terms, is given on the final sheet of this certificate.

EXAMINATION FINDINGS

The detailed petrographic examination findings are given in the following sheets of this certificate along with record colour photographs and selected photomicrographs (photographs taken through the microscope). An overview of the findings is given below.

SUMMARY OVERVIEW

Composition and Constituents	Nominal 20mm, crushed altered gneiss coarse aggregate and natural quartzitic sand fine aggregate, bound by a Portland-type cement matrix, which is advised to include the Caltite admixture.
Mix Quality	Apparently well mixed and exhibiting good compaction. Excess voidage 0.5%. The concrete exhibited sporadic rounded, probably entrained air voids (typically <200μm sized) evenly distributed throughout the cement matrix. The presence of entrained air voids suggests the presence of an admixture imparting some degree of air entrainment. Apparent water/cement ratio was estimated as being at the high end of the normal range (0.35 to 0.65). Areas of high microporosity were observed associated with microcracks, sporadic bleeding channels and partings between coarse aggregate particles and the cement matrix. It should be noted that the presence of an admixture within the cement matrix may lead to a misleading (usually underestimate) of the original water/cement ratio.
Condition	Rare microcracks ran from the outer end surface to a depth of 5mm. Rare microcracks were observed running through the cement matrix between fine aggregate particles. Rare secondary deposits, which have the appearance of alkali-silica gel, were observed partially lining air voids within the cement matrix. The presence of secondary deposits of alkali-silica gel partially lining air voids would suggest that the concrete has been subject to some degree of alkali-silica reaction (ASR). No reaction sites were observed.
Other Remarks	The outer surface was formed, whilst the inner surface was freshly fractured.

NOTE

Opinions and interpretations expressed herein are outside the scope of UKAS accreditation.

Certificate prepared by

P Bennett-Hughes

Paul Bennett-Hughes
Principal Scientist

Certificate reviewed by

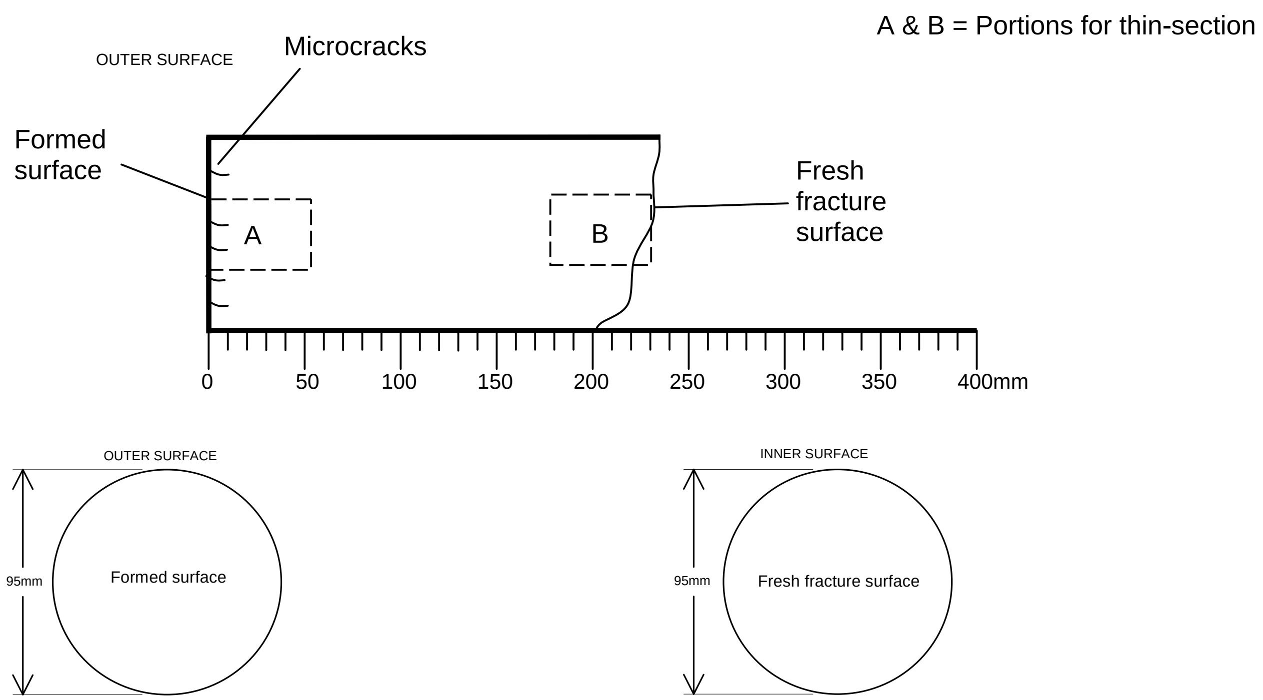
Dr Ian Sims
Director

Date of issue: 11 October, 2012

Petrographic Examination of Hardened Concrete - ASTM C856-11

RECORD DIGITAL PHOTOGRAPH			
RSK Sample Ref.	11675/C1	**Client Sample Ref.**	#1

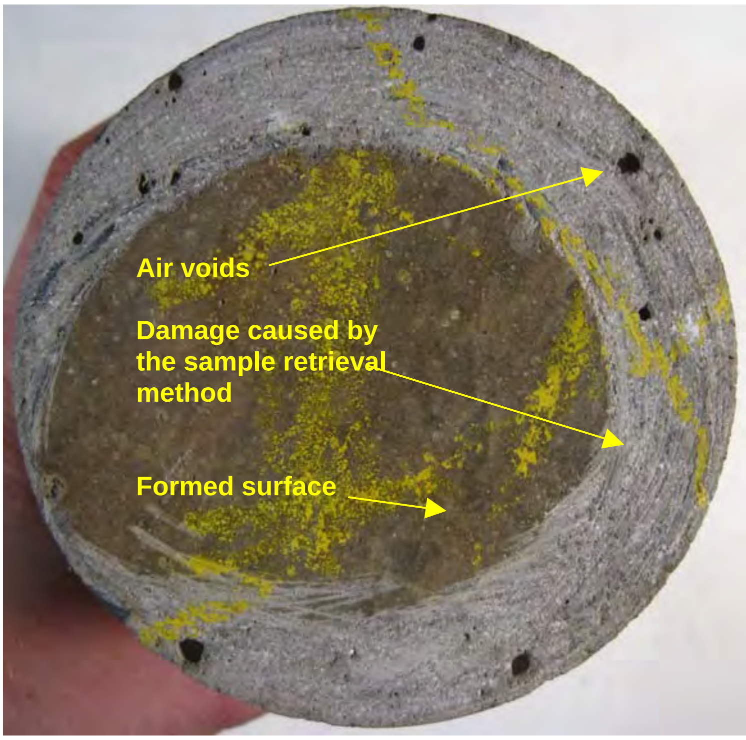
SAMPLE/CORE SKETCH



Petrographic Examination of Hardened Concrete - ASTM C856-11

RECORD DIGITAL PHOTOGRAPH			
RSK Sample Ref.	11675/C1	**Client Sample Ref.**	#1
Description	View of the outer and inner surfaces of the core. Core diameter is 95mm.		

OUTER SURFACE



INNER SURFACE

Petrographic Examination of Hardened Concrete - ASTM C856-11

AS-RECEIVED CONCRETE CORE DETAILS			
RSK Sample Ref.	11675/C1	**Client Sample Ref.**	#1
Maximum Length, mm	242	**Diameter, mm**	95
Minimum Length, mm	209	**Number of Pieces**	1
Nature of Outer Surface	Formed surface	**Nature of Inner Surface**	Fresh fracture surface
Portion Described	Representative thin-sections sawn from 0-50mm and 200-242mm depth from the outer surface.		

AGGREGATE DETAILS	
Coarse Aggregate *(incl. type, nominal max. size, shape, grading, distribution and orientation)*	Crushed rock, nominal 20mm maximum sized, angular to sub-angular, continuously graded, evenly distributed and randomly orientated particles.
Coarse Aggregate, Constituents *(incl. hardness, colour and approx. percent of lithological types present, alteration, weathering and general features of engineering significance)*	Wholly Hard, light/dark grey altered GNEISS, with a variable content of calcite and chlorite.
Cement:Aggregate Bond	Good, only sporadic interfacial partings in evidence.
Additional Observations *(incl. evidence of deterioration etc)*	None.
Fine Aggregate *(incl. type, nominal max. size, shape, grading, distribution and orientation)*	Natural quartzitic sand, 5mm nominal maximum sized, sub-rounded to sub-angular, evenly distributed and randomly orientated particles.
Fine Aggregate, Constituents *(incl. hardness, colour and approx. percent of lithological types present, alteration, weathering and general features of engineering significance)*	Major Hard, translucent grey/white QUARTZ. Minor Hard, translucent grey/white QUARTZITE.
Cement:Aggregate Bond	Good, only sporadic interfacial partings in evidence.
Additional Observations *(incl. evidence of deterioration etc)*	None.

Petrographic Examination of Hardened Concrete - ASTM C856-11

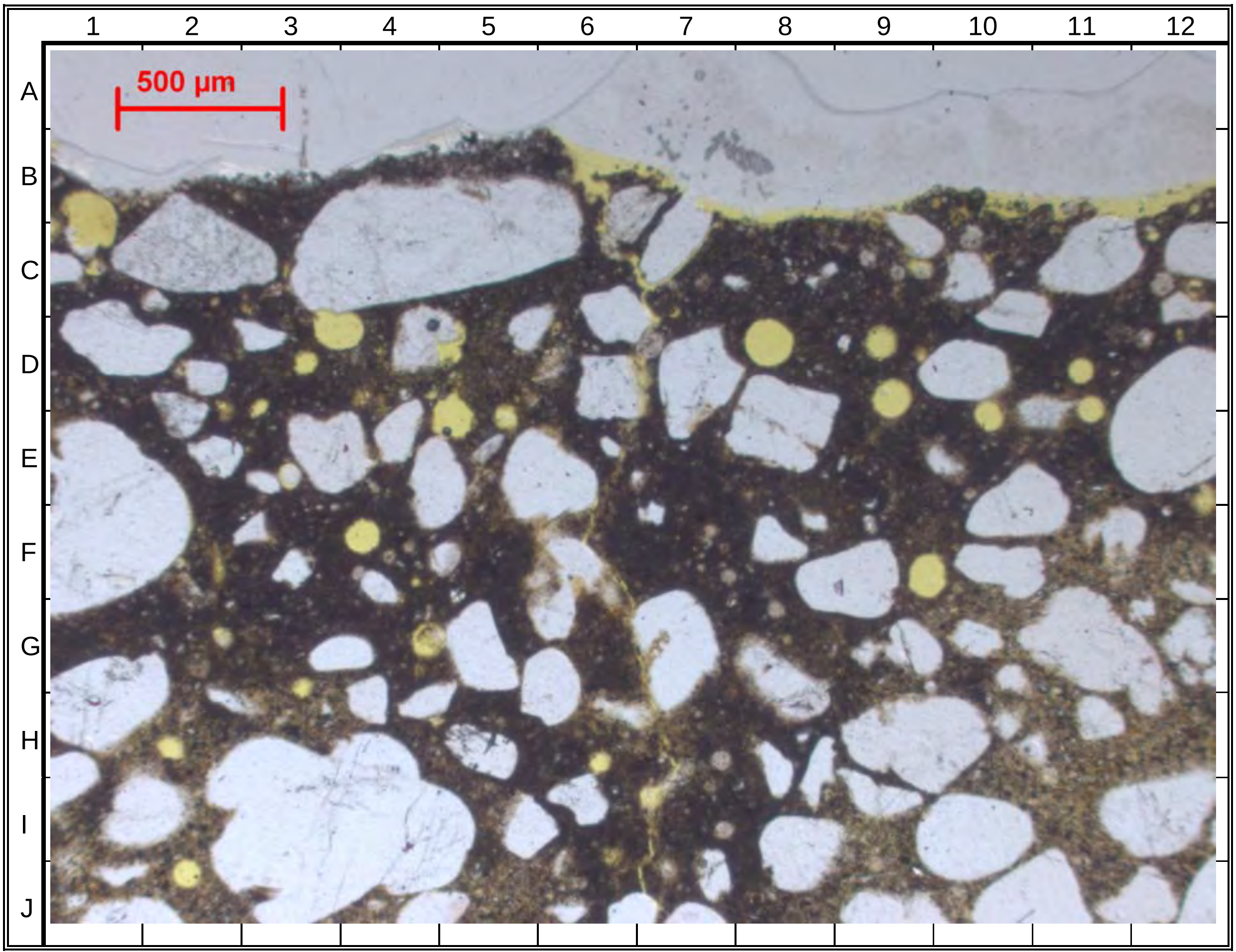
RSK Sample Ref.	11675/C1	Client Sample Ref.	#1

CONCRETE FEATURES	
Apparent Cement Type and Matrix Details *(Portland, High Alumina, White, PBC, etc and incl. hardness, colour, colour distribution and matrix distribution)*	Moderately hard, medium grey, evenly distributed Portland-type cement matrix. Exhibiting sporadic, typically small to medium sized, randomly distributed, unhydrated and hemi-hydrated cement grains.
Mineral Additions• *(incl. type, size, relative abundance, distribution and shape)*	None observed.
Air Void Details and Compaction *(incl. air void max. size, shape, distribution, orientation, presence of entrainment, excess voidage)*	4mm maximum, typically <2mm sized, irregular, evenly distributed and randomly orientated entrapped air voids. Estimated excess voidage 0.5%. The concrete exhibited sporadic rounded, probably entrained air voids (typically <200μm sized) evenly distributed throughout the cement matrix. The presence of entrained air voids suggests the presence of an admixture imparting some degree of air entrainment.
Microporosity and Water/Cement Ratio# *(incl., microporosity variations and relation to other features; assessment of original water/cement ratio)*	The cement paste typically exhibited normal to high microporosity, indicative of an overall original water/cement ratio at the high end of the normal range (0.35 to 0.65). Areas of high microporosity were observed associated with microcracks, sporadic bleeding channels and partings between the cement matrix and coarse aggregate particles. It should be noted that the presence of an admixture within the cement matrix may lead to a misleading (usually underestimate) of the original water/cement ratio.
Carbonation* *(incl. depths, variations and relation to surface cracking)*	The outer surface of the concrete was carbonated to a maximum depth of 2.5mm. The cement matrix bordering the microcracks running from the outer surface was partially carbonated to a depth of 5mm.
Portlandite *(incl. size, shape, abundance and distribution of crystallites)*	The uncarbonated cement matrix exhibited common to frequent, small to medium sized, portlandite crystallites that were evenly distributed.
Other Concrete Details *(incl. applied finishes, inclusions and impurities)*	The outer surface of the sample was formed, whilst the inner surface was freshly fractured.
Reinforcement *(incl. types, sizes, depths, orientations, evidence of corrosion)*	None present.
Evidence of Cracking *(incl. crack styles, abundance and relation to other features)*	Rare microcracks ran from the outer surface to a depth of 5mm. Rare microcracks were observed running through the cement matrix between fine aggregate particles.
Presence of Deposits *(incl. gel, sulfates, carbonates, oxides, soot and their location, abundance and distribution)*	Rare secondary deposits of alkali-silica gel were observed partially lining air voids within the cement matrix.
Other Observations *(incl. sweaty patches, matrix alteration, bleeding, segregation, plastic settlement, loss of bond, embedded items)*	Rare secondary deposits, which have the appearance of alkali-silica gel, were observed partially lining air voids within the cement matrix. The presence of secondary deposits of alkali-silica gel partially lining air voids would suggest that the concrete has been subject to some degree of alkali-silica reaction (ASR). No reaction sites were observed.

• some mineral additions are not easily identified by optical microscopy (eg. microsilica, metakaolin)
* sometimes assisted by phenolphthalein indicator solution
\# estimated by fluorescence microscopy

Petrographic Examination of Hardened Concrete - ASTM C856-11
High-Power Microscopical Observations

PHOTOGRAPH TAKEN USING LEICA DMRX

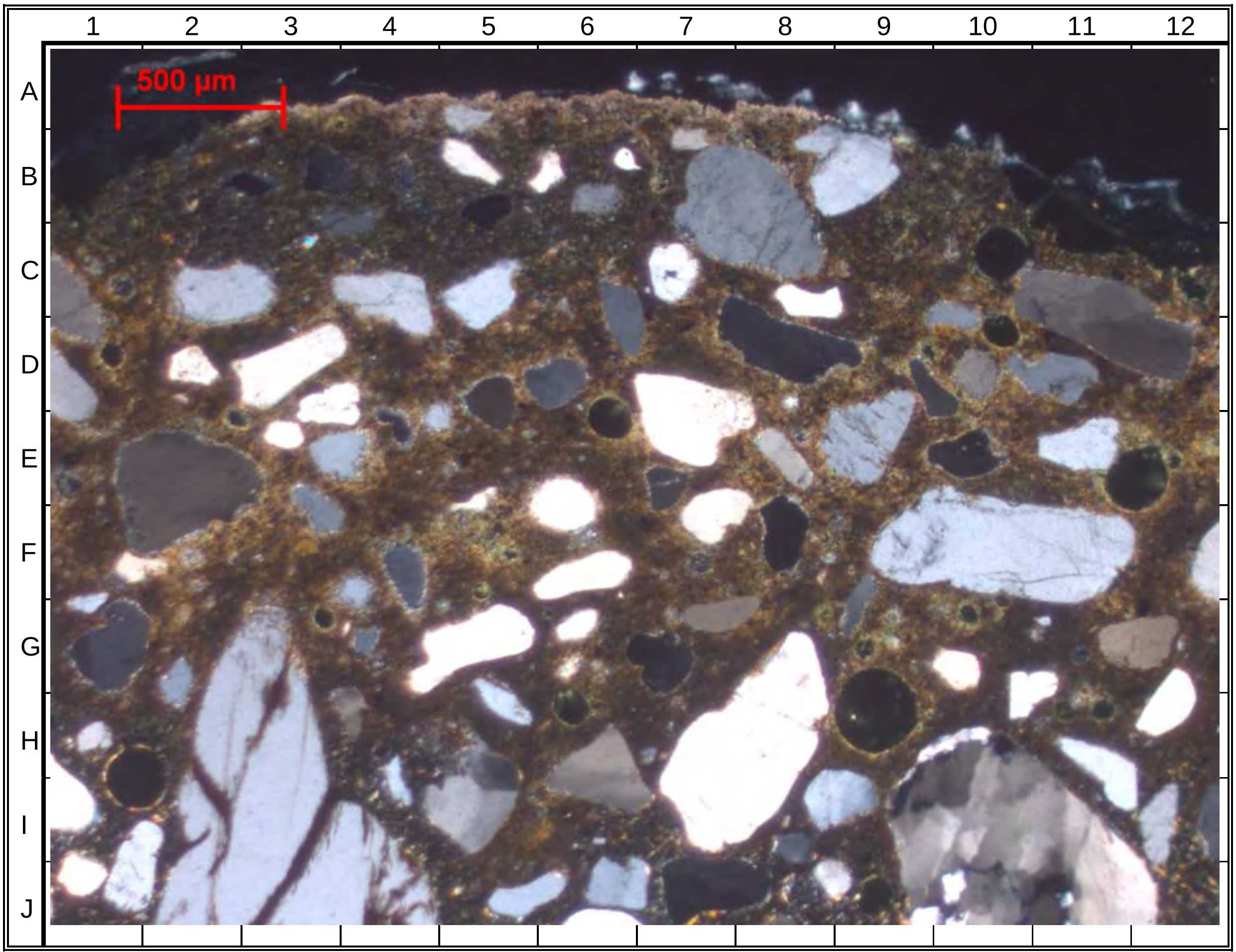


RECORD DIGITAL PHOTOMICROGRAPH			
RSK Sample Ref.	11675/C1	**Client Sample Ref.**	#1
Approx. Mag^n	x35	**Approx. Scale**	10mm = 285µm
Portion Described	Concrete	**Viewing Light**	Plane-polarised
Description	General view of the outer surface (B1 to B12) of the concrete, showing quartz (white, F1) fine aggregate particles, bound by Portland-type cement matrix (brown, G2). Entrained air voids are shown yellow (D9). A microcrack running from the outer surface is shown yellow (B6 to J6/7).		

Petrographic Examination of Hardened Concrete - ASTM C856-11

High-Power Microscopical Observations

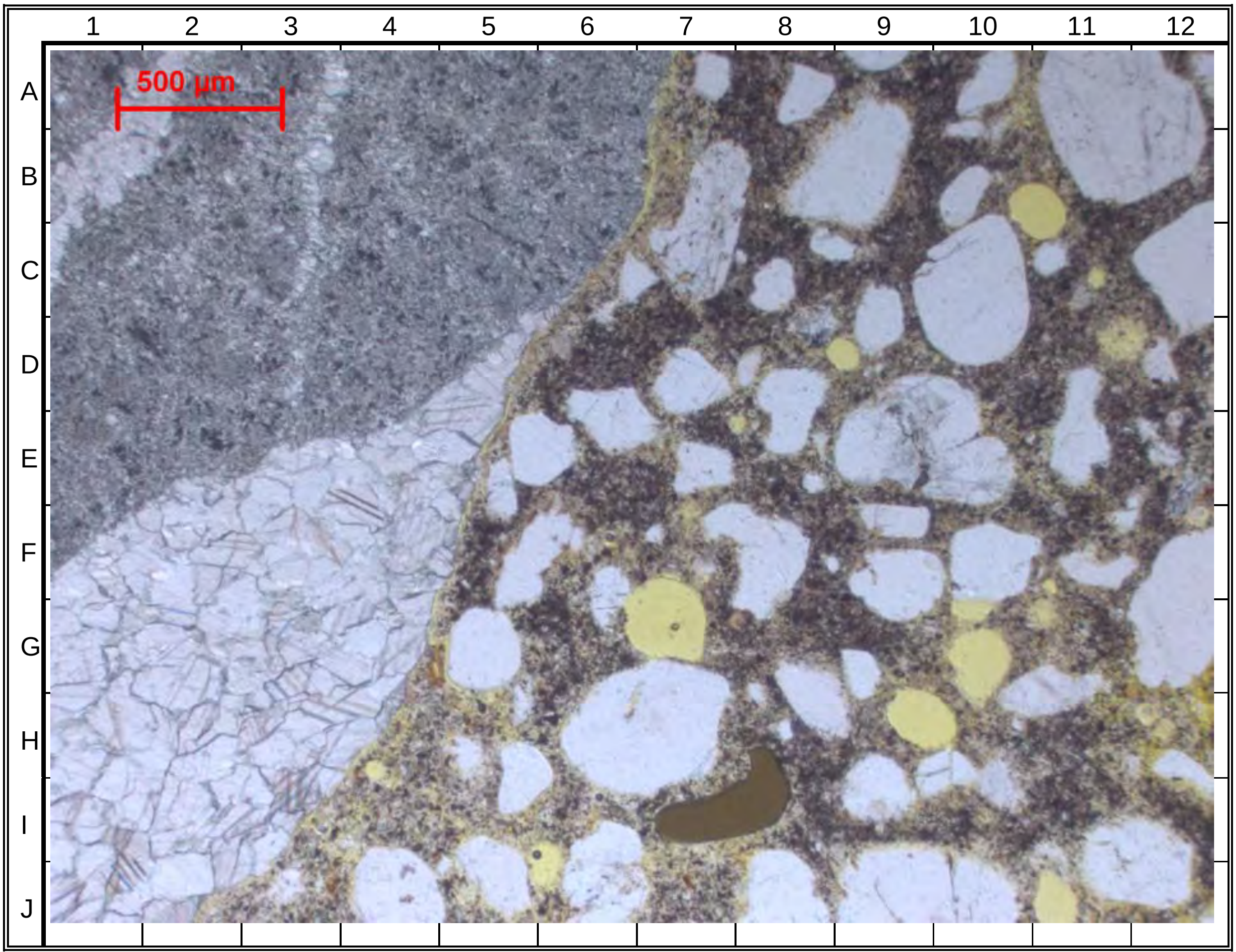
PHOTOGRAPH TAKEN USING LEICA DMRX



RECORD DIGITAL PHOTOMICROGRAPH			
RSK Sample Ref.	11675/C1	**Client Sample Ref.**	#1
Approx. Mag^n	x35	**Approx. Scale**	10mm = 285µm
Portion Described	Concrete	**Viewing Light**	Cross-polarised
Description	General view of the outer surface (B1 to C12) of the concrete, showing quartz (white/grey, I3) fine aggregate particles, bound by carbonated Portland-type cement matrix (brown, E4). Air voids are shown black (H9).		

Petrographic Examination of Hardened Concrete - ASTM C856-11
High-Power Microscopical Observations

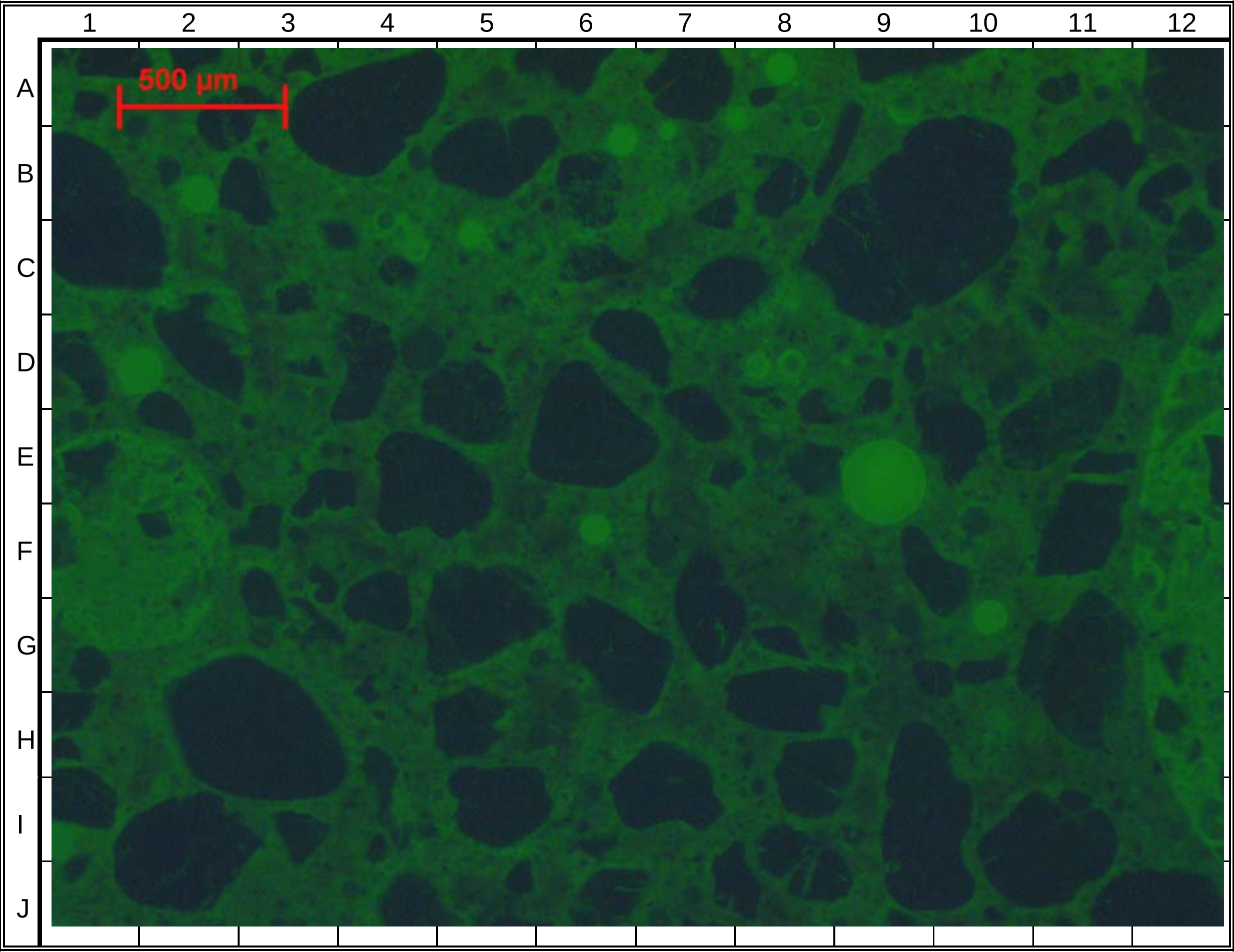
PHOTOGRAPH TAKEN USING LEICA DMRX



RECORD DIGITAL PHOTOMICROGRAPH			
RSK Sample Ref.	11675/C1	**Client Sample Ref.**	#1
Approx. Mag^n	x35	**Approx. Scale**	10mm = 285µm
Portion Described	Concrete	**Viewing Light**	Plane-polarised
Description	General view of the concrete, showing weathered gneiss (light/dark grey, D3) coarse aggregate and quartz (white, A11) fine aggregate particles, bound by Portland-type cement matrix (light/dark brown, D6). Air voids are shown yellow (H10).		

Petrographic Examination of Hardened Concrete - ASTM C856-11
High-Power Microscopical Observations

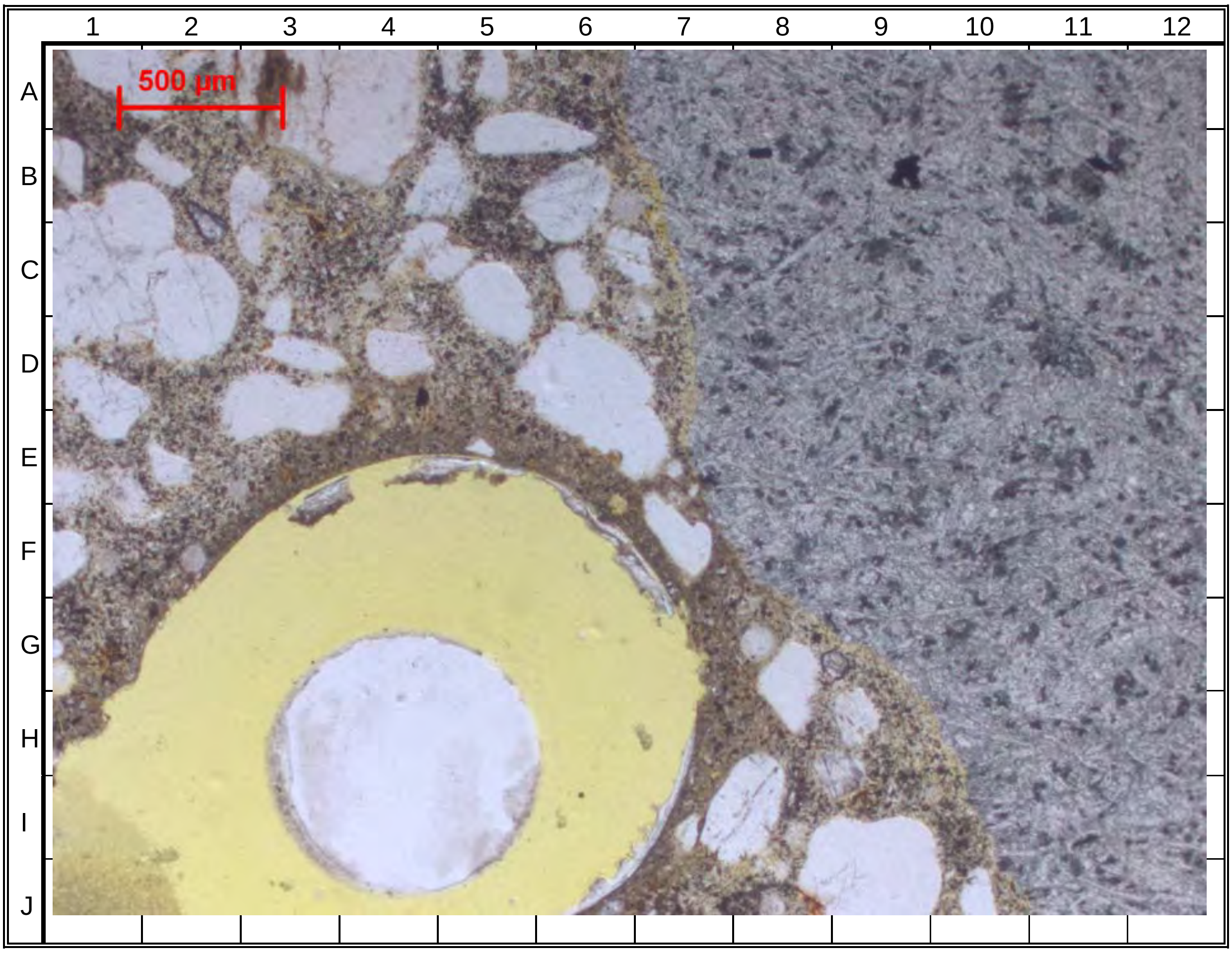
PHOTOGRAPH TAKEN USING LEICA DMRX



RECORD DIGITAL PHOTOMICROGRAPH			
RSK Sample Ref.	11675/C1	**Client Sample Ref.**	#1
Approx. Mag^n	x35	**Approx. Scale**	10mm = 285µm
Portion Described	Concrete	**Viewing Light**	Reflected fluorescent
Description	General view of the concrete, showing the variable normal (dull green, F7) to high (brighter green, C5) microporosity of the cement matrix. Air voids are shown brightest green (E9).		

Petrographic Examination of Hardened Concrete - ASTM C856-11
High-Power Microscopical Observations

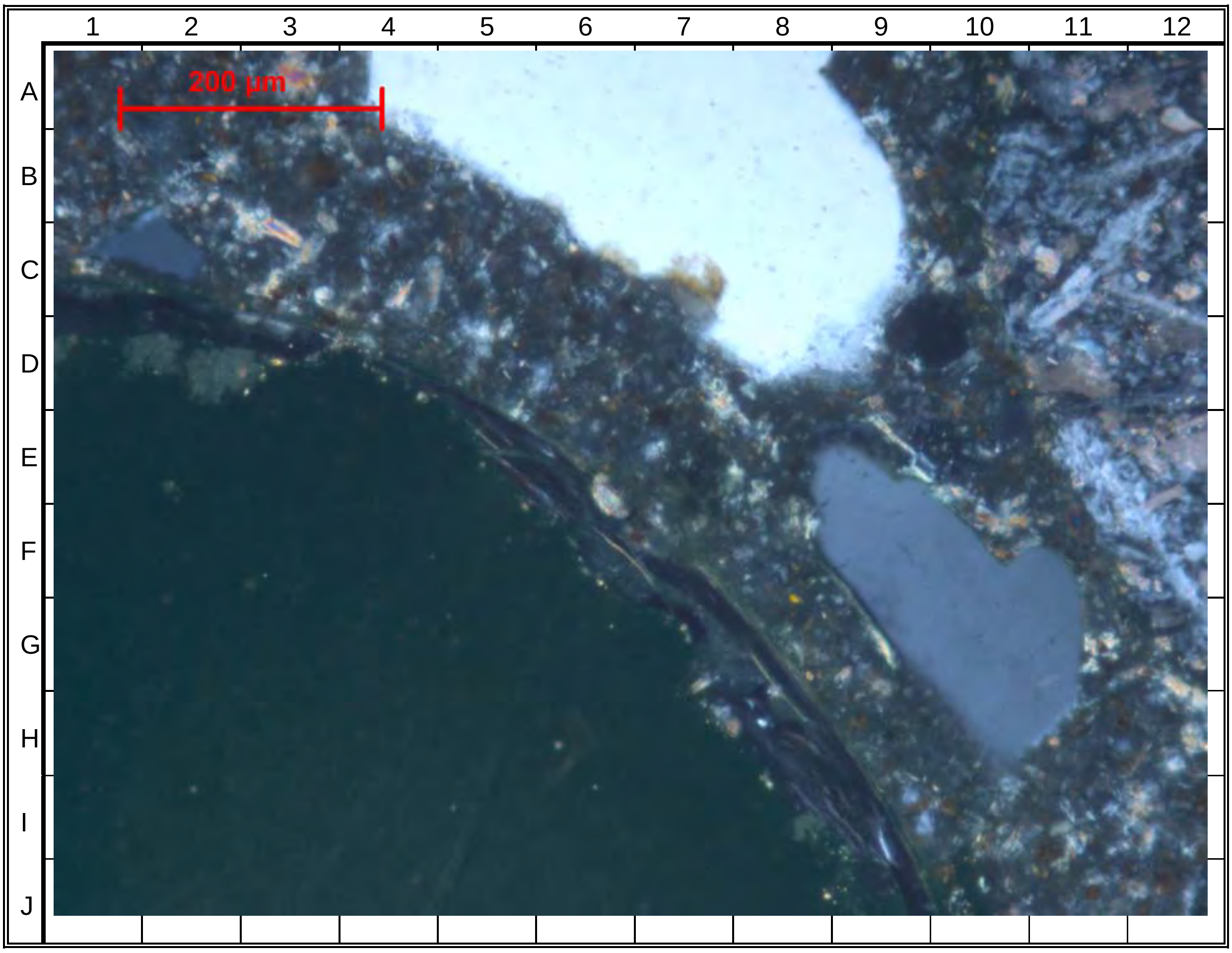
PHOTOGRAPH TAKEN USING LEICA DMRX



RECORD DIGITAL PHOTOMICROGRAPH			
RSK Sample Ref.	11675/C1	**Client Sample Ref.**	#1
Approx. Mag^{n}	x35	**Approx. Scale**	10mm = 285µm
Portion Described	Concrete	**Viewing Light**	Plane-polarised
Description	General view of the concrete, showing secondary alkali-silica gel (light brown, F6) partially lining an air void (yellow, I2). Another view of alkali-silica gel deposits is shown on Sheet 11.		

Petrographic Examination of Hardened Concrete - ASTM C856-11
High-Power Microscopical Observations

PHOTOGRAPH TAKEN USING LEICA DMRX



RECORD DIGITAL PHOTOMICROGRAPH			
RSK Sample Ref.	11675/C1	**Client Sample Ref.**	#1
Approx. Mag[n]	x150	**Approx. Scale**	10mm = 67µm
Portion Described	Concrete	**Viewing Light**	Cross-polarised
Description	Close view of the concrete, showing secondary deposits of alkali-silica gel (black, C/D1 to J9) partially lining an air void (black, G1).		

Petrographic Examination of Hardened Concrete - ASTM C856-11

Methods of Examination

The submitted concrete sample was subjected to a petrographic examination following methods recommended by ASTM C856-11, Standard Practice for Petrographic Examination of Hardened Concrete. Estimation of excess voidage was carried out in accordance with Concrete Society Technical Report No 11, including Addendum (1987), Concrete Core Testing For Strength. The examination was supplemented (where required) by the determination of the cement type following methods given in BS 1881: Part 124: 1988. When the concrete is suspected to contain high alumina cement, the examination is supplemented by taking guidance from BRE Digest 392, Assessment of existing high alumina cement concrete construction in the UK, March 1994.

The sample was first visually and low-power microscopically examined using a high quality Leica MZ8 binocular zoom microscope employing magnifications up to x50. A record colour photograph of the sample was prepared along with a diagram illustrating the main features of interest. A low-power photomicrograph (a photograph taken through the microscope) is sometimes prepared to illustrate certain features of importance.

The initial examination was used to determine the most appropriate location for a medium-area (75 x 50mm) thin-section to be taken for further, more detailed microscopical examination. The thin-section was prepared from a diamond sawn slice which had been both consolidated with, and vacuum impregnated by, an epoxy resin usually containing an ultraviolet light sensitive fluorescent dye. In some cases (eg concretes suspected to contain thaumasite), a pair of thin-sections is produced, one using fluorescent dye and one free of fluorescent dye. Where the specific cement type (eg ‘ordinary’ Portland or ‘sulfate-resisting’ Portland) was required a highly polished specimen was also prepared for examination of the matrix in reflected light.

Both the thin-section and polished specimen were examined using a high quality Leica DMRX multi-functional microscope employing various magnifications up to x630. The thin-section was examined using transmitted plane-polarised and cross-polarised illuminations. The polished specimen was examined using reflected, polarised and brightfield illuminations. One or more record colour photomicrographs were prepared to illustrate certain microscopical features of importance. The thin-section was also examined under reflected ultraviolet illumination to allow an assessment of the void and micropore structure, evidence of cracking and any other features of relevance. The highly polished specimen was etched using appropriate solutions and vapours to assist with the identification of residual particles of unhydrated cement and any non-reacted mineral additions.

Glossary of Terms Used in the Descriptions

Aggregate abundance	Major	*>10%*
	Minor	*2 to 10%*
	Trace	*<2%*
Carbonation	Complete	*no residual cement matrix other than occasional unreacted relics*
Increasing Carbonation	Partial	*evidence of mixed carbonate crystallites with isotropic matrix*
	Faint	*occasional carbonate crystallites, <25% of the area*
Compaction	≤0.5%	*very good*
	>0.5% - ≤3.0%	*≤3.0% = good (ie normal for structural concrete)*
Increasing Compaction	>3.0% – ≤5.0%	*medium*
	>5.0% - ≤10.0%	*poor*
	>10.0%	*Very poor*
Cracks	Fine microcracks	*<1μm wide*
Increasing Width	Microcracks	*1-10μm wide*
	Fine cracks	*10-100μm wide*
	Cracks	*100μm-1mm*
	Large cracks	*>1mm wide*
Frequency	Rare	*only found by thorough searching*
	Sporadic	*only occasionally observed during normal examination*
Increasing Frequency	Common	*easily observed during normal examination*
	Frequent	*easily observed with minimal examination*
	Abundant	*immediately apparent to initial examination*

Hardness	Very soft	*can be penetrated easily by a finger*
	Soft	*scores with a fingernail*
Increasing Hardness	Moderately soft	*scores using a copper coin*
	Moderately hard	*scores easily with a penknife*
	Hard	*not easily scored with a penknife*
	Very hard	*cannot be scored with a steel point*
Portlandite (Matrix)	Small	*<20μm*
	Medium	*20-60μm*
	Large	*60-100μm*
	Very large	*>100μm*
Relict cement	Small	*<20μm*
	Medium	*20-60μm*
	Large	*60-100μm*
	Very large	*>100μm*
Water/cement ratio	Low	*<0.35*
	Normal	*0.35-0.65*
	High	*>0.65*
Voids	Entrained	*Typically round in shape and <100μm in diameter (taken to be all voids <1mm diameter when undertaking air content analyses).*
	Entrapped	*typically irregular in shape and >1mm in diameter*

RSK Environment Ltd
Tel: +44 (0) 1442 437500
Fax: +44 (0) 1442 437550
Email: info2@rsk.co.uk
Web: www.rsk.co.uk/stats

Materials & Structures
18 Frogmore Road
Hemel Hempstead
Hertfordshire
HP3 9RT

UKAS TESTING
0278

RSK

Certificate of Examination
ASTM C856-11
Petrographic Examination of Hardened Concrete

Your Ref.	None advised	**RSK Sample Ref.**	11675/C3
Site	Fimiston Plant, Kalgoorlie-Boulder Western Australia	**Client Sample Ref.**	#3
		Sample Type	Concrete core
Client	Cementaid (WA Pty. Ltd) 200 Star Street Welshpool Western Australia, 6105 Australia	**Location**	Not advised
		Orientation	Not advised
		Sampled by/Date	Client/Not advised
		Date of Receipt	05.10.11
		Examined by/Date	PBH/11.01.12

SAMPLE

The sample comprised a nominal 95mm diameter concrete core, approximately 241mm in length. The diameter and length of the submitted core were less than those preferred by the standard (ideally 152mm diameter and 305mm length). The Client advised that the concrete, which did not contain Caltite admixture, was cast in 1994-5 and was subject to hypersaline water that is used to wash down in the gold mine.

METHODS OF EXAMINATION

A full description of the examination methods, including a glossary of descriptive terms, is given on the final sheet of this certificate.

EXAMINATION FINDINGS

The detailed petrographic examination findings are given in the following sheets of this certificate along with record colour photographs and selected photomicrographs (photographs taken through the microscope).

SUMMARY OVERVIEW

An overview of the findings is given on Sheet 2.

NOTE

Opinions and interpretations expressed herein are outside the scope of UKAS accreditation.

Certificate prepared by

P Bennett-Hughes

Paul Bennett-Hughes
Principal Scientist

Certificate reviewed by

Dr Ian Sims
Director

Date of issue: 25 October, 2012

Petrographic Examination of Hardened Concrete - ASTM C856-11

RSK Sample Ref.	11675/C3
Client Sample Ref.	#3
Sample Type	Concrete core
Location	Not advised
Orientation	Not advised
Sampled by/Date	Client/Not advised
Date of Receipt	05.10.11
Examined by/Date	PBH/11.01.12

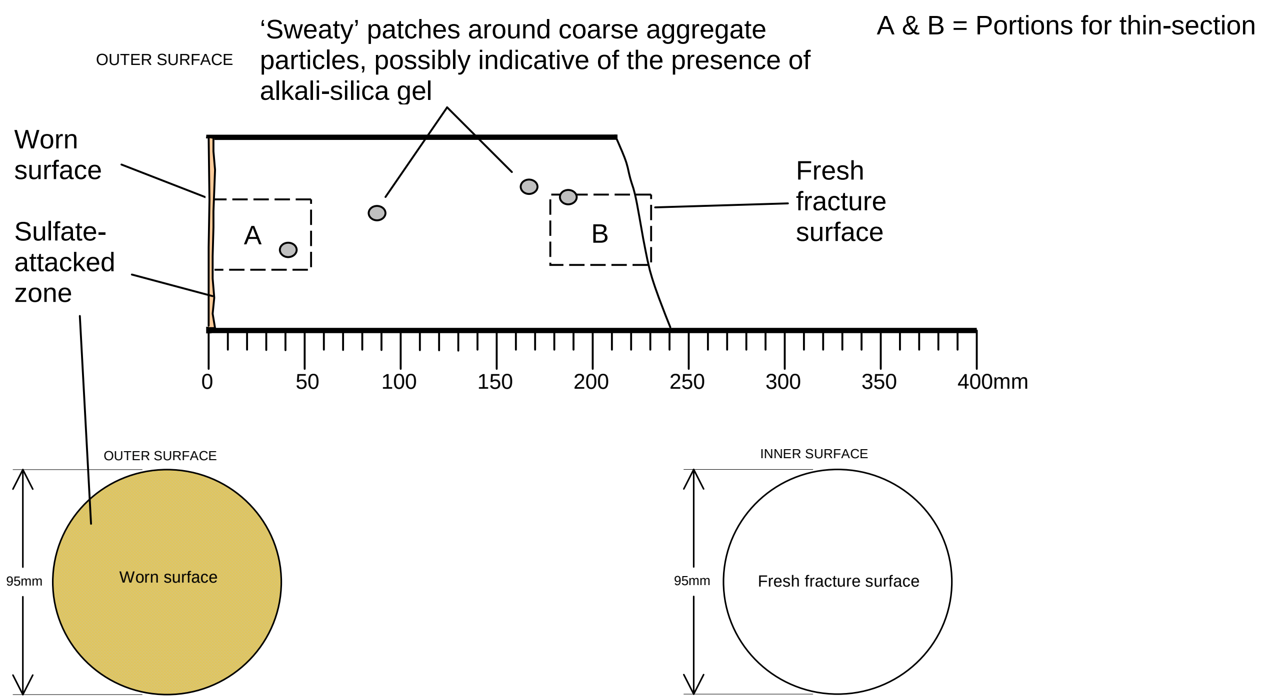
Summary of Findings

Composition and Constituents	Nominal 20mm, crushed altered gneiss coarse aggregate and natural quartzitic sand fine aggregate, bound by a Portland-type cement matrix.
Mix Quality	Apparently well mixed and exhibiting good compaction. Excess voidage 0.5%. The concrete exhibited frequent rounded, probably entrained air voids (typically <400μm sized) evenly distributed throughout the cement matrix. The presence of entrained air voids suggests the presence of an admixture imparting some degree of air entrainment. Apparent water/cement ratio was estimated as being in the normal range (0.35 to 0.65). In general, areas of high microporosity were observed associated with microcracks and partings between coarse aggregate particles and the cement matrix. A zone of high microporosity was observed within the outer 5mm of the concrete, and is possibly associated with acid-attack.
Condition	Microcracks within the outer 3mm of the outer end surface were partially infilled by sulfate deposits, which appears to have led to partial delamination in some places. The zone exhibited partial replacement of the cement matrix by sulfate deposits. The presence of these deposits infilling microcracks and replacing the cement matrix suggests that the concrete has been subject to some degree of sulfate attack. In order to confirm the minerals within the outer 3mm of the concrete is is recommended that the concrete is subject to scanning electron microscopy (SEM). In hand-specimen, sporadic ‘sweaty’ patches, possibly indicative of the presence of alkali-silica gel, were observed associated with coarse aggregate particles. In thin-section, sporadic to common secondary deposits of alkali-silica gel were observed partially lining air voids within the cement matrix and infilling microcracks running through the cement matrix and aggregate particles. The presence of secondary deposits of alkali-silica gel partially lining air voids suggests that the concrete has been subject to some degree of alkali-silica reaction (ASR). Veins comprising microcrystalline silica within coarse aggregate particles appeared to be one of the sources of the reaction.
Other Remarks	The outer surface was formed, whilst the inner surface was freshly fractured.

Petrographic Examination of Hardened Concrete - ASTM C856-11

RECORD DIGITAL PHOTOGRAPH			
RSK Sample Ref.	11675/C3	**Client Sample Ref.**	#3

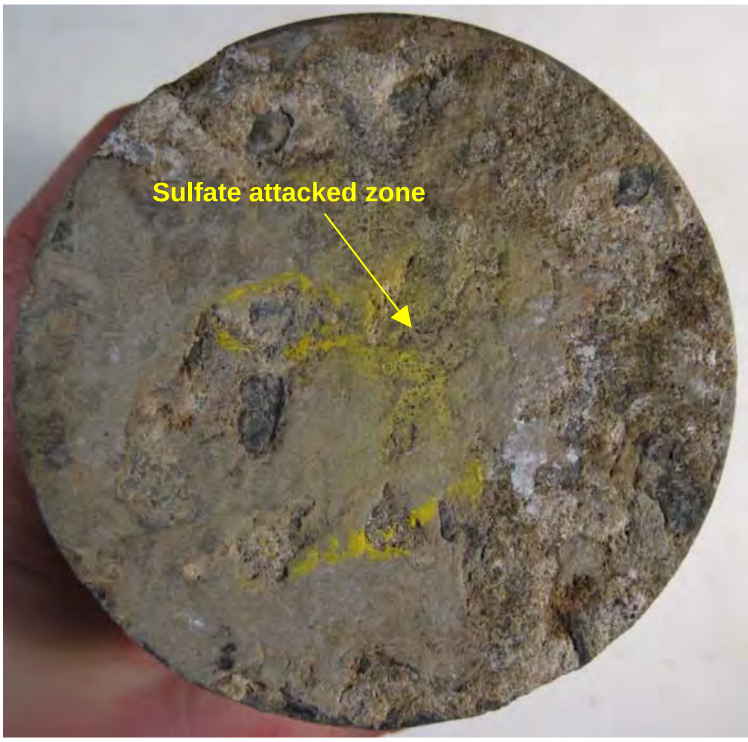
SAMPLE/CORE SKETCH



Petrographic Examination of Hardened Concrete - ASTM C856-11

RECORD DIGITAL PHOTOGRAPH			
RSK Sample Ref.	11675/C3	**Client Sample Ref.**	#3
Description	View of the outer and inner surfaces of the core. Core diameter is 95mm.		

OUTER SURFACE



INNER SURFACE

Petrographic Examination of Hardened Concrete - ASTM C856-11

AS-RECEIVED CONCRETE CORE DETAILS			
RSK Sample Ref.	11675/C3	**Client Sample Ref.**	#3
Maximum Length, mm	241	**Diameter, mm**	95
Minimum Length, mm	221	**Number of Pieces**	1
Nature of Outer Surface	Formed surface	**Nature of Inner Surface**	Fresh fracture surface
Portion Described	Representative thin-sections sawn from 0-50mm and 200-241mm depth from the outer surface.		

AGGREGATE DETAILS	
Coarse Aggregate *(incl. type, nominal max. size, shape, grading, distribution and orientation)*	Crushed rock, nominal 20mm maximum sized, angular to sub-angular, continuously graded, evenly distributed and randomly orientated particles.
Coarse Aggregate, Constituents *(incl. hardness, colour and approx. percent of lithological types present, alteration, weathering and general features of engineering significance)*	Wholly Hard, light/dark grey altered GNEISS, with a variable content of calcite and chlorite, which sporadically exhibited veins of microcrystalline silica.
Cement:Aggregate Bond	Good, only sporadic interfacial partings in evidence.
Additional Observations *(incl. evidence of deterioration etc)*	None.
Fine Aggregate *(incl. type, nominal max. size, shape, grading, distribution and orientation)*	Natural quartzitic sand, 5mm nominal maximum sized, sub-rounded to sub-angular, evenly distributed and randomly orientated particles.
Fine Aggregate, Constituents *(incl. hardness, colour and approx. percent of lithological types present, alteration, weathering and general features of engineering significance)*	Major Hard, translucent grey/white QUARTZ. Minor Hard, translucent grey/white QUARTZITE.
Cement:Aggregate Bond	Good, only sporadic interfacial partings in evidence.
Additional Observations *(incl. evidence of deterioration etc)*	None.

Petrographic Examination of Hardened Concrete - ASTM C856-11

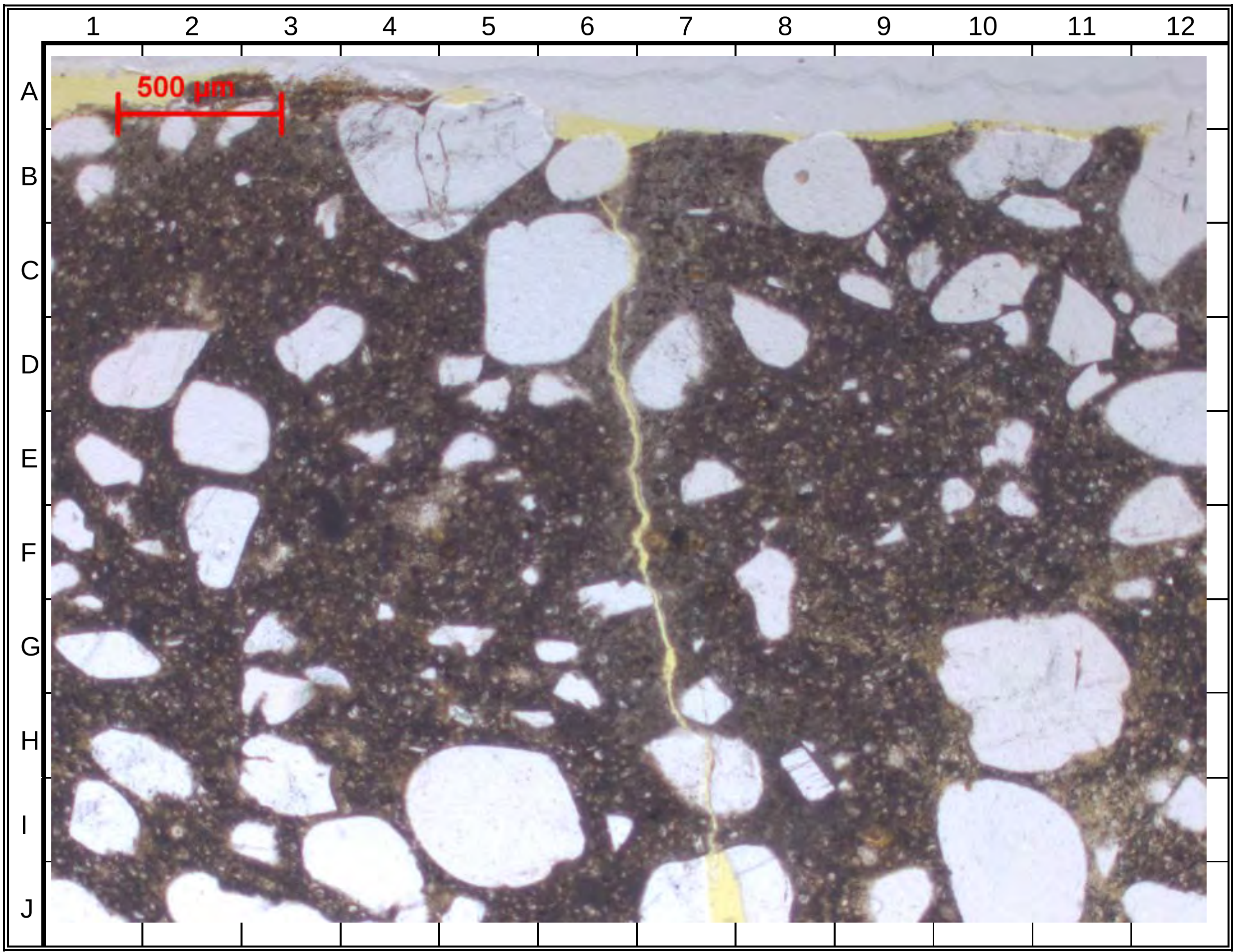
RSK Sample Ref.	11675/C3	**Client Sample Ref.**	#3

CONCRETE FEATURES	
Apparent Cement Type and Matrix Details *(Portland, High Alumina, White, PBC, etc and incl. hardness, colour, colour distribution and matrix distribution)*	Moderately hard, medium grey, evenly distributed Portland-type cement matrix. Exhibiting sporadic, typically small to medium sized, randomly distributed, unhydrated and hemi-hydrated cement grains.
Mineral Additions• *(incl. type, size, relative abundance, distribution and shape)*	None observed.
Air Void Details and Compaction *(incl. air void max. size, shape, distribution, orientation, presence of entrainment, excess voidage)*	3mm maximum, typically <2mm sized, irregular, evenly distributed and randomly orientated entrapped air voids. Estimated excess voidage 0.5%. The concrete exhibited frequent rounded, probably entrained air voids (typically <400μm sized) evenly distributed throughout the cement matrix. The presence of entrained air voids suggests the presence of an admixture imparting some degree of air entrainment.
Microporosity and Water/Cement Ratio# *(incl., microporosity variations and relation to other features; assessment of original water/cement ratio)*	The cement paste typically exhibited normal microporosity, indicative of an overall original water/cement ratio in the normal range (0.35 to 0.65). In general, areas of high microporosity were observed associated with microcracks and partings between coarse aggregate particles and the cement matrix. A zone of high microporosity was observed within the outer 5mm of the concrete, and is possibly associated with the sulfate-attack. It should be noted that the presence of an admixture within the cement matrix may lead to a misleading (usually underestimate) of the original water/cement ratio.
Carbonation* *(incl. depths, variations and relation to surface cracking)*	The outer surface of the concrete was carbonated to a maximum depth of 3.2mm. The cement matrix bordering the microcracks running from the outer surface was partially carbonated to a depth of 3.5mm.
Portlandite *(incl. size, shape, abundance and distribution of crystallites)*	The uncarbonated cement matrix exhibited common to frequent, small to medium sized, portlandite crystallites that were evenly distributed.
Other Concrete Details *(incl. applied finishes, inclusions and impurities)*	The outer surface of the sample was worn, whilst the inner surface was freshly fractured.
Reinforcement *(incl. types, sizes, depths, orientations, evidence of corrosion)*	None present.
Evidence of Cracking *(incl. crack styles, abundance and relation to other features)*	The outer 3mm of the concrete exhibited sporadic microcracks running parallel to the surface, which were partially infilled by sulfate deposits. Sporadic to common microcracks were observed running through the cement matrix and coarse aggregate particles. The microcracks were typically infilled by secondary alkali-silica gel deposits. In some cases, the origin of the microcracks appeared to align with recrystallised quartz veins in the altered gneiss coarse aggregate particles.
Presence of Deposits *(incl. gel, sulfates, carbonates, oxides, soot and their location, abundance and distribution)*	Microcracks within the outer 3mm of the surface were partially infilled by sulfate deposits. This sulfate-attacked zone, also showed partial replacement of the cement matrix by sulfate deposits. The presence of these deposits within the cement matrix will affect the strength of this zone of the concrete. In hand-specimen, sporadic 'sweaty' patches, possibly indicative of the presence of alkali-silica gel, were observed associated with coarse aggregate particles. In thin-section, sporadic to common secondary deposits of alkali-silica gel were observed partially lining air voids within the cement matrix and infilling microcracks running through the cement matrix and aggregate particles. The alkali-silica gel deposits were commonly observed associated with recrystallised quartz veins in the gneiss coarse aggregate particles.
Other Observations *(incl. sweaty patches, matrix alteration, bleeding, segregation, plastic settlement, loss of bond, embedded items)*	The presence of secondary deposits of alkali-silica gel partially lining air voids suggests that the concrete has been subject to some degree of alkali-silica reaction (ASR). Veins comprising microcrystalline silica within gneiss coarse aggregate particles were observed to be one of the sources of the reaction.

• some mineral additions are not easily identified by optical microscopy (eg. microsilica, metakaolin)
* sometimes assisted by phenolphthalein indicator solution
# estimated by fluorescence microscopy

Petrographic Examination of Hardened Concrete - ASTM C856-11
High-Power Microscopical Observations

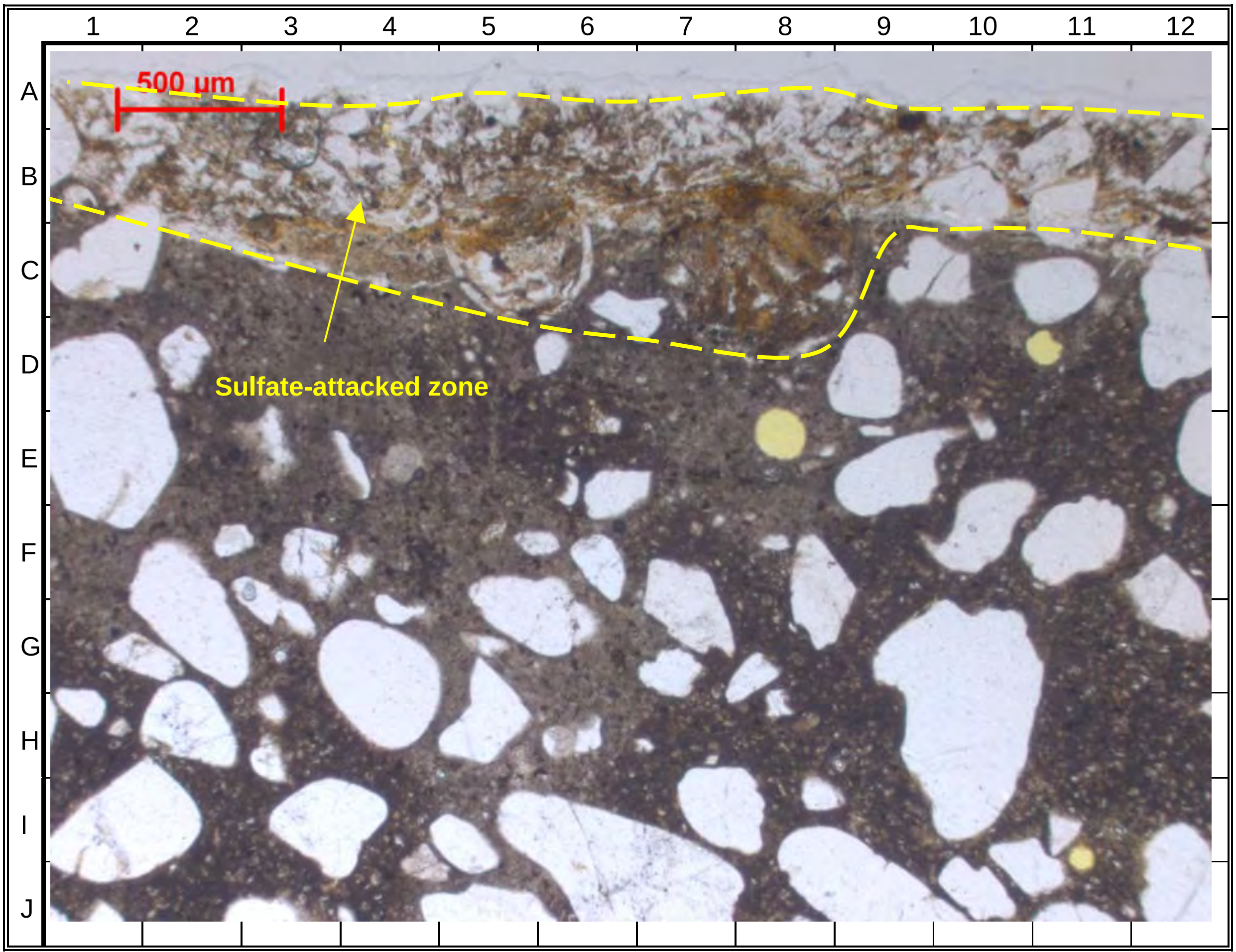
PHOTOGRAPH TAKEN USING LEICA DMRX



RECORD DIGITAL PHOTOMICROGRAPH			
RSK Sample Ref.	11675/C3	**Client Sample Ref.**	#3
Approx. Mag^n	x35	**Approx. Scale**	10mm = 285µm
Portion Described	Concrete	**Viewing Light**	Plane-polarised
Description	View of the outer surface of the concrete (A1 to A12), showing a microcrack (yellow, B6 to J7 running through the cement matrix and sporadic fine aggregate particles (white, I7).		

Petrographic Examination of Hardened Concrete - ASTM C856-11
High-Power Microscopical Observations

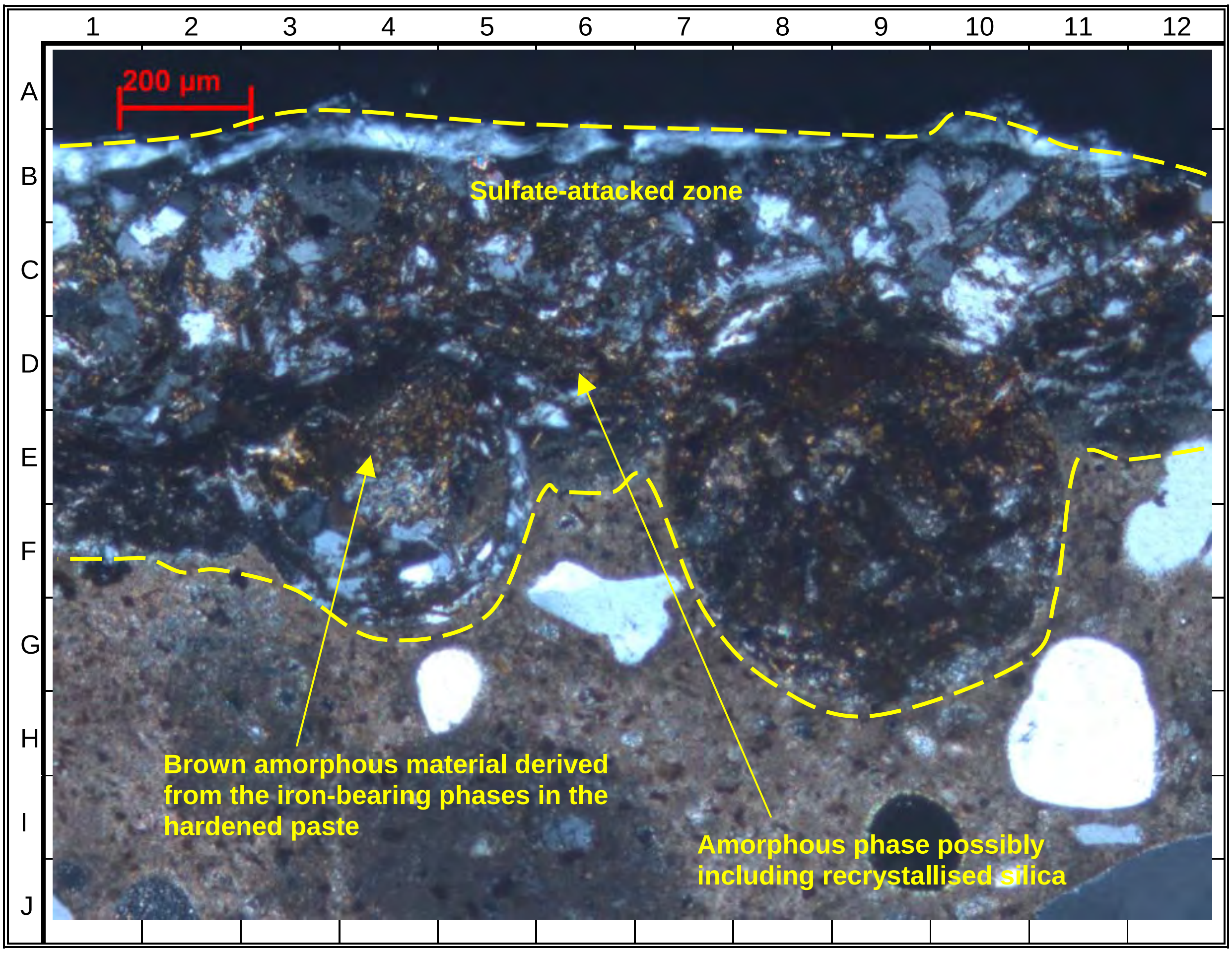
PHOTOGRAPH TAKEN USING LEICA DMRX



RECORD DIGITAL PHOTOMICROGRAPH			
RSK Sample Ref.	11675/C3	**Client Sample Ref.**	#3
Approx. Mag^{n}	x35	**Approx. Scale**	10mm = 285µm
Portion Described	Concrete	**Viewing Light**	Cross-polarised
Description	View of the outer surface of the concrete (A1 to A12), showing the sulfate-attacked surface (brown, B5). A closer view of the surface is shown on Sheet 9.		

Petrographic Examination of Hardened Concrete - ASTM C856-11
High-Power Microscopical Observations

PHOTOGRAPH TAKEN USING LEICA DMRX

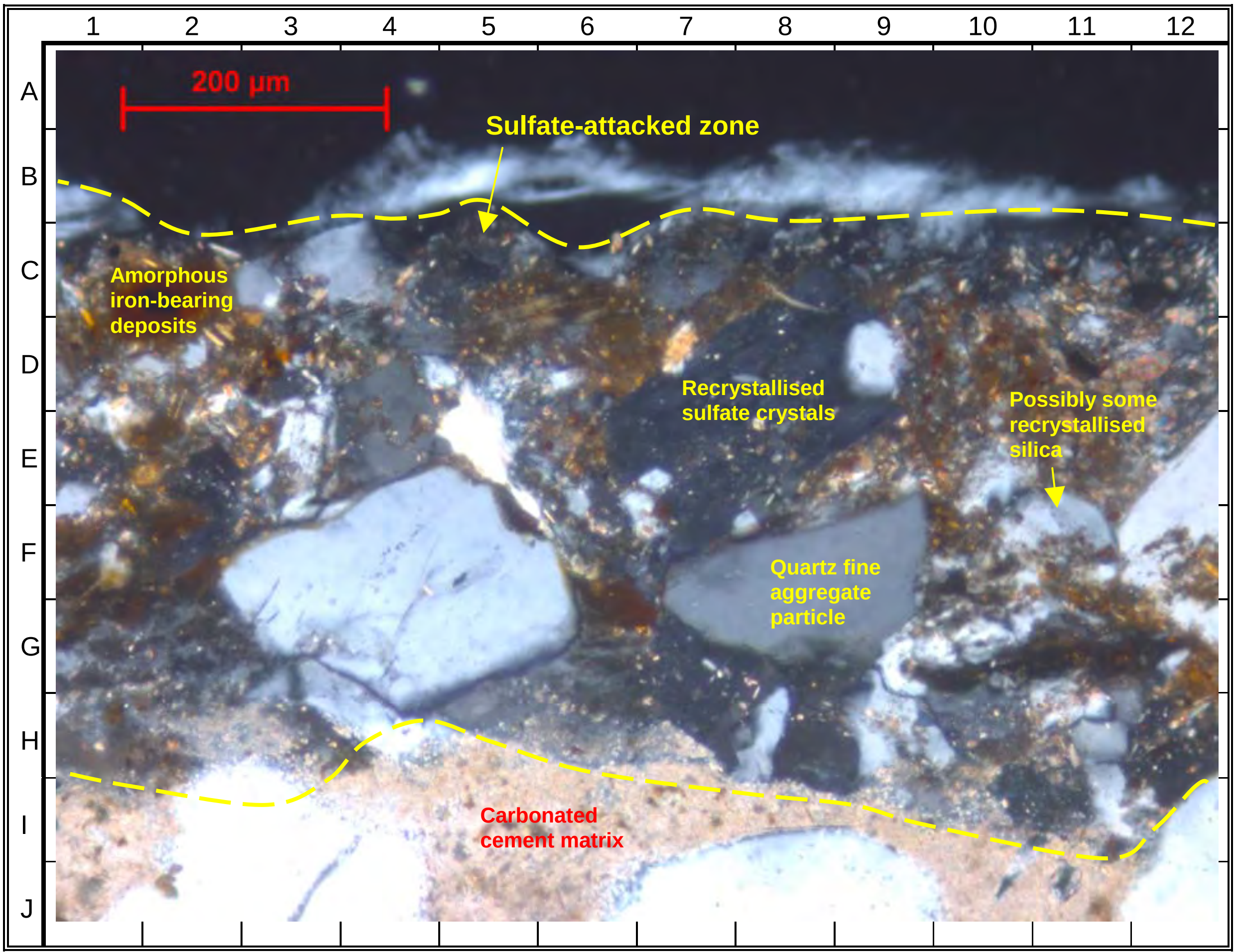


RECORD DIGITAL PHOTOMICROGRAPH			
RSK Sample Ref.	11675/C3	**Client Sample Ref.**	#3
Approx. Mag^n	x75	**Approx. Scale**	10mm = 133µm
Portion Described	Concrete	**Viewing Light**	Plane-polarised
Description	View of the surface of the concrete (B1 to B12), showing the sulfate-attacked zone, with the associated sulfate deposits. The cement matrix in the attacked zone has been primarily replaced by sulfate minerals.		

Petrographic Examination of Hardened Concrete - ASTM C856-11

High-Power Microscopical Observations

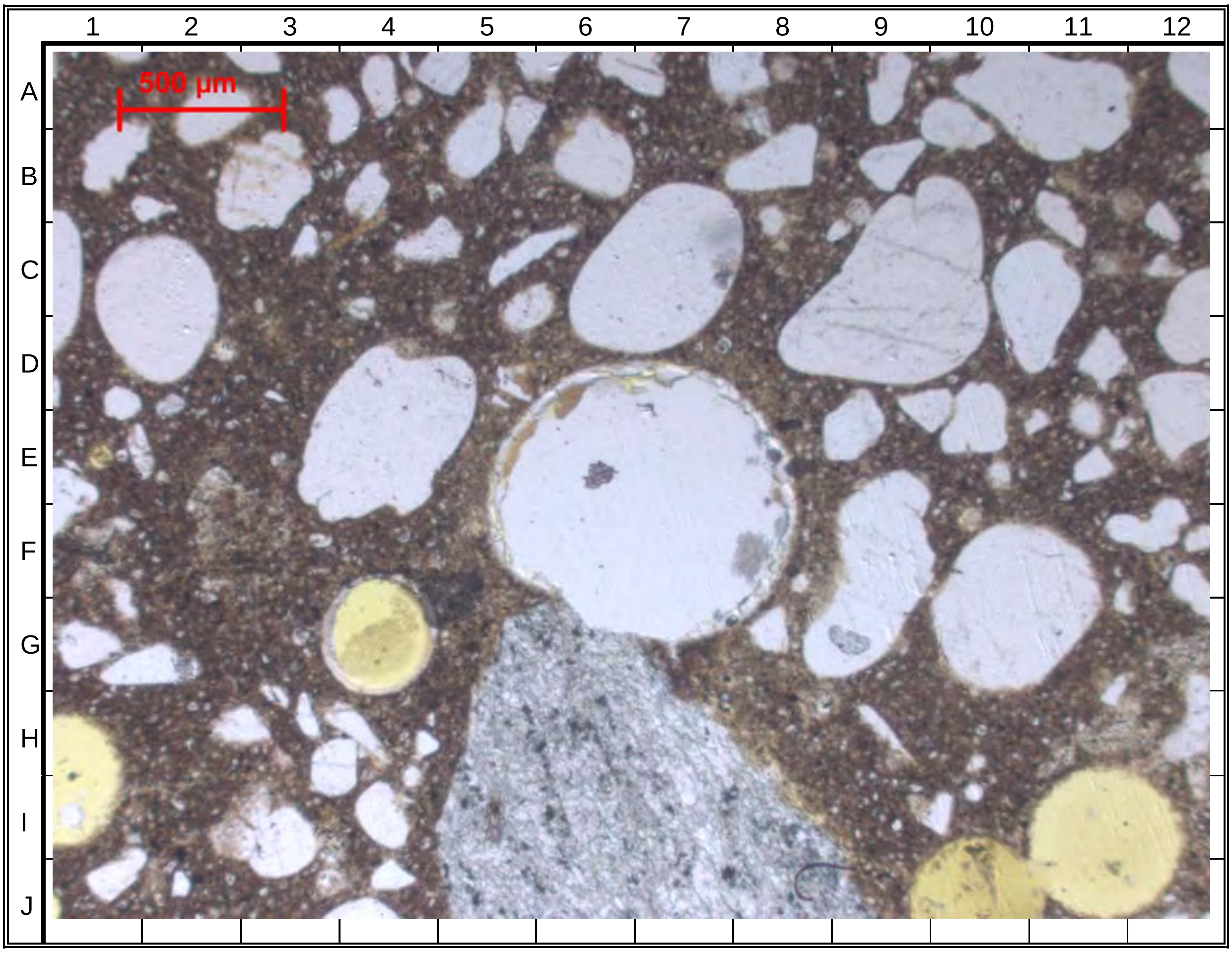
PHOTOGRAPH TAKEN USING LEICA DMRX



RECORD DIGITAL PHOTOMICROGRAPH			
RSK Sample Ref.	11675/C3	**Client Sample Ref.**	#3
Approx. Mag^n	x150	**Approx. Scale**	10mm = 67μm
Portion Described	Concrete	**Viewing Light**	Cross-polarised
Description	Close view of the concrete, showing the sulfate-attacked surface zone.		

Petrographic Examination of Hardened Concrete - ASTM C856-11
High-Power Microscopical Observations

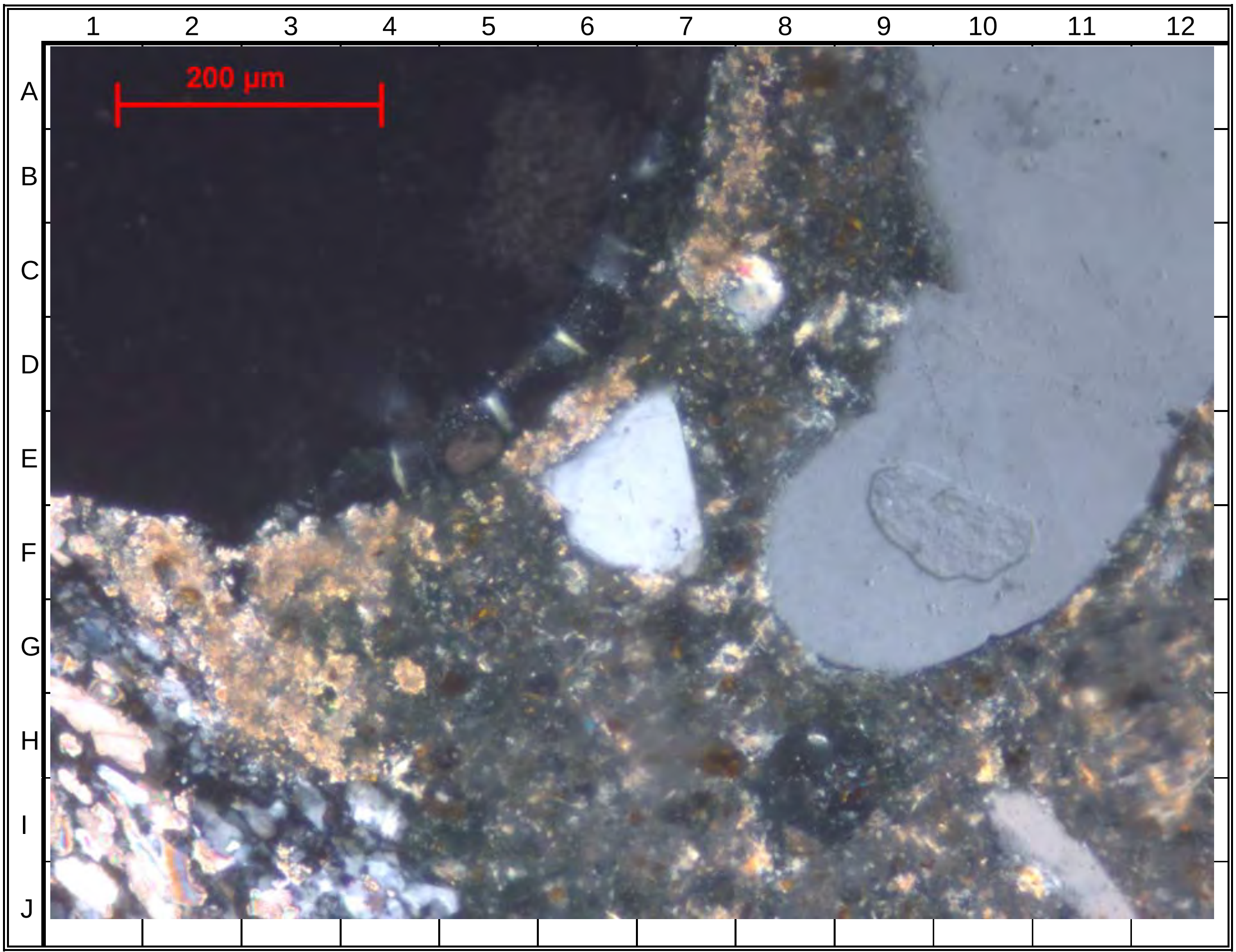
PHOTOGRAPH TAKEN USING LEICA DMRX



RECORD DIGITAL PHOTOMICROGRAPH			
RSK Sample Ref.	11675/C3	**Client Sample Ref.**	#3
Approx. Mag^n	x35	**Approx. Scale**	10mm = 285µm
Portion Described	Concrete	**Viewing Light**	Plane-polarised
Description	General view of the concrete, showing secondary alkali-silica gel deposits (white, D6) partially lining an air void (white, E6/7). Entrained air voids are shown yellow (J11). A closer view is shown on Sheet 12.		

Petrographic Examination of Hardened Concrete - ASTM C856-11
High-Power Microscopical Observations

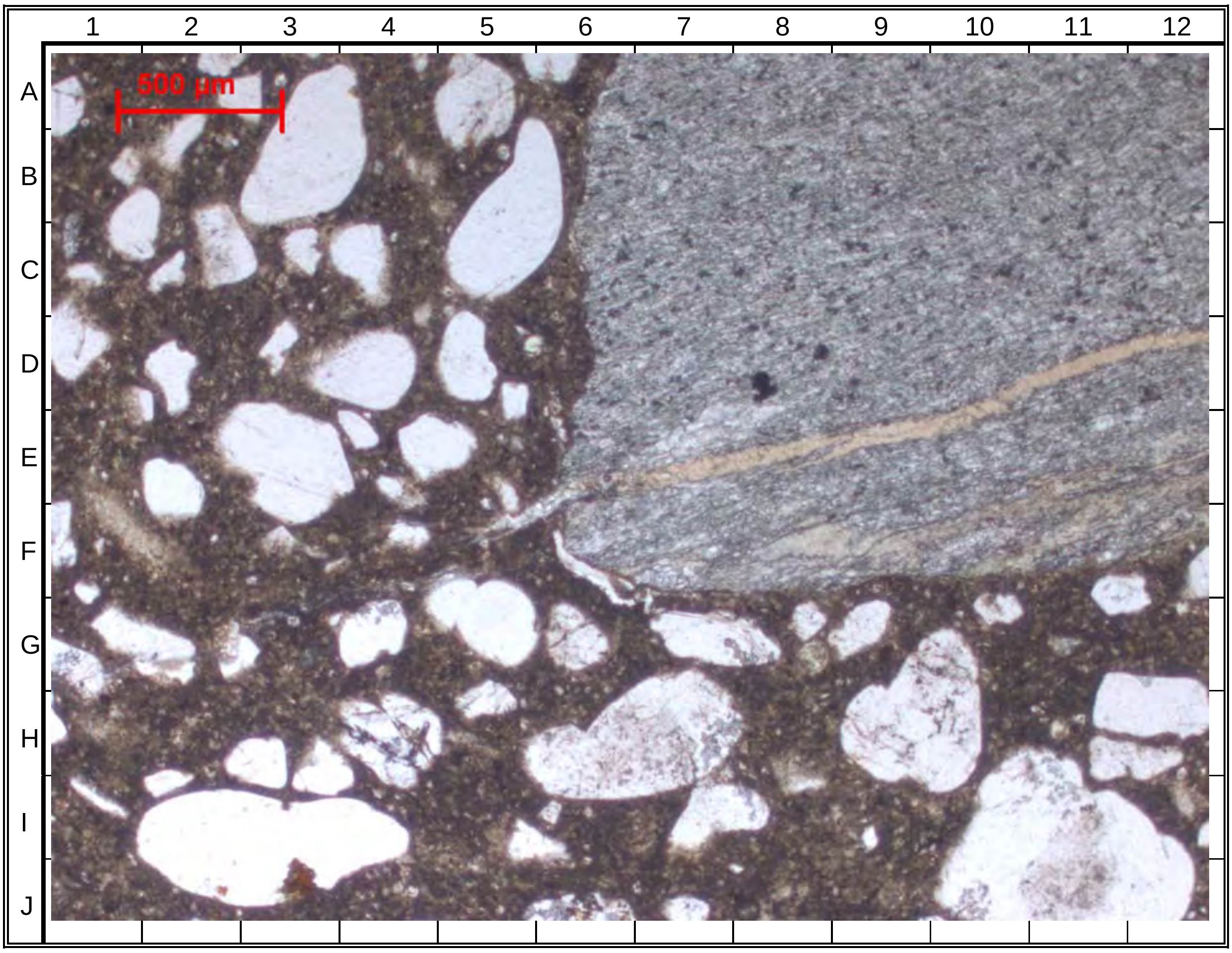
PHOTOGRAPH TAKEN USING LEICA DMRX



RECORD DIGITAL PHOTOMICROGRAPH			
RSK Sample Ref.	11675/C3	**Client Sample Ref.**	#3
Approx. Mag^{n}	x150	**Approx. Scale**	10mm = 67µm
Portion Described	Concrete	**Viewing Light**	Cross-polarised
Description	Close view of the concrete, showing secondary alkali-silica gel deposits (black/grey, E3 to A7) partially lining an air void (black, C3).		

Petrographic Examination of Hardened Concrete - ASTM C856-11
High-Power Microscopical Observations

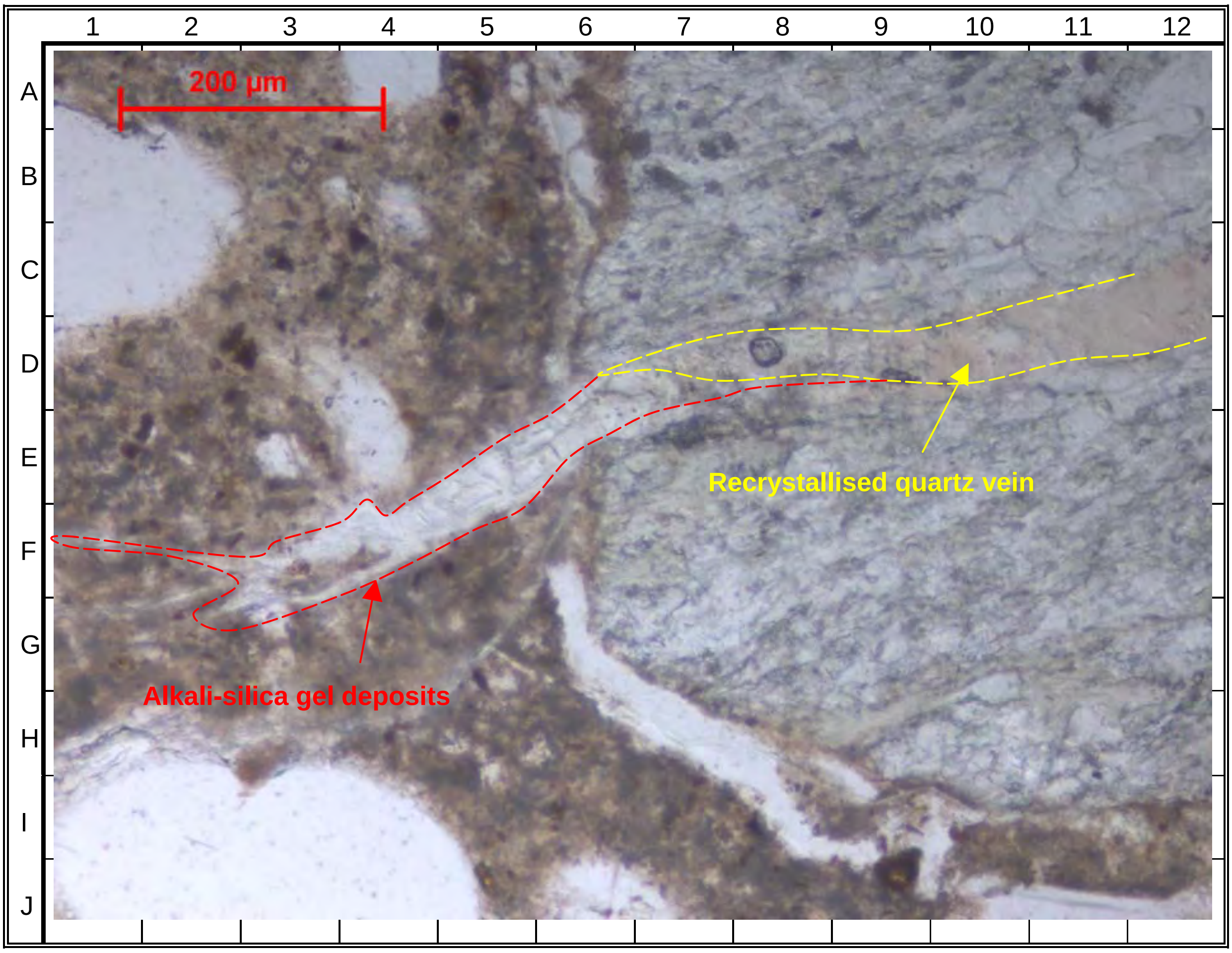
PHOTOGRAPH TAKEN USING LEICA DMRX



RECORD DIGITAL PHOTOMICROGRAPH			
RSK Sample Ref.	11675/C3	**Client Sample Ref.**	#3
Approx. Mag^n	x35	**Approx. Scale**	10mm = 285µm
Portion Described	Concrete	**Viewing Light**	Plane-polarised
Description	General view of the concrete, showing a microcrack (white/grey, G1 to F6) emanating from a coarse aggregate particle (D9), which was partially infilled by secondary alkali-silica gel deposits. A recrystallised quartz vein within a gneiss aggregate particle is shown light brown (F6 to D12). A closer view is shown on Sheet 14.		

Petrographic Examination of Hardened Concrete - ASTM C856-11
High-Power Microscopical Observations

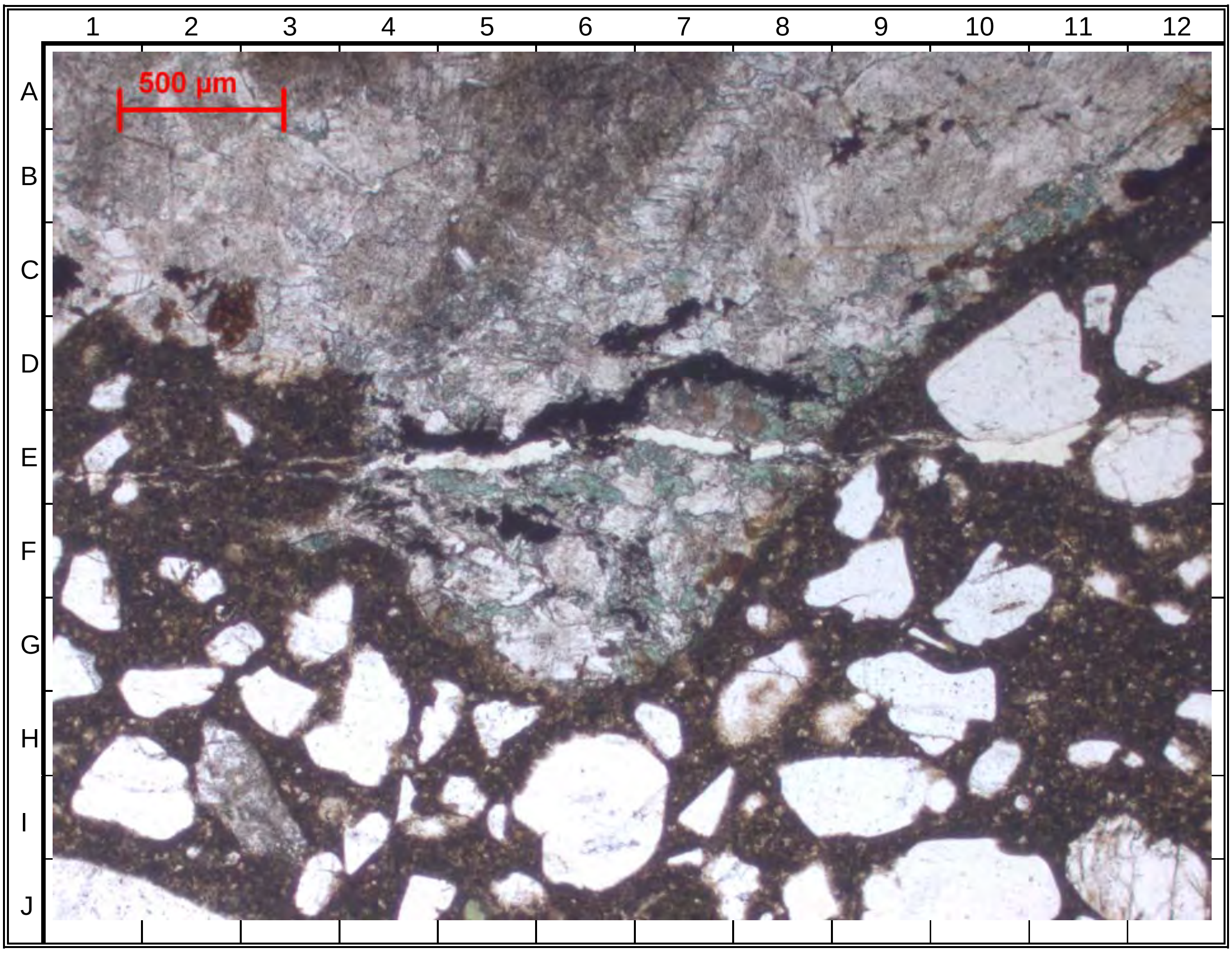
PHOTOGRAPH TAKEN USING LEICA DMRX



RECORD DIGITAL PHOTOMICROGRAPH			
RSK Sample Ref.	11675/C3	**Client Sample Ref.**	#3
Approx. Mag^{n}	x150	**Approx. Scale**	10mm = 67µm
Portion Described	Concrete	**Viewing Light**	Plane-polarised
Description	Close view of the concrete, showing secondary alkali-silica gel deposits (white, G1 to E6) partially lining a microcrack emanating from a coarse aggregate particle.		

Petrographic Examination of Hardened Concrete - ASTM C856-11
High-Power Microscopical Observations

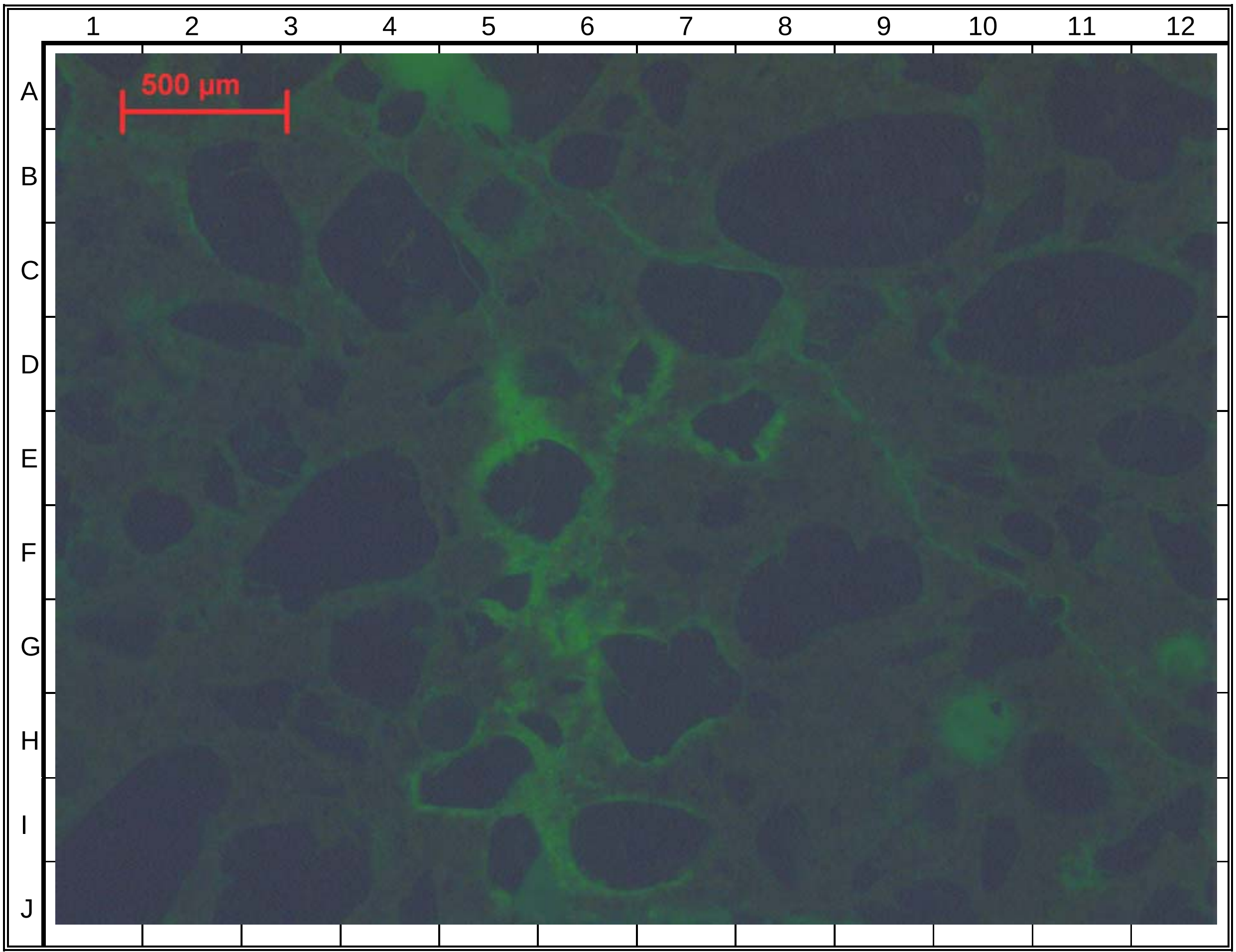
PHOTOGRAPH TAKEN USING LEICA DMRX



RECORD DIGITAL PHOTOMICROGRAPH			
RSK Sample Ref.	11675/C3	**Client Sample Ref.**	#3
Approx. Mag^n	x35	**Approx. Scale**	10mm = 285µm
Portion Described	Concrete	**Viewing Light**	Plane-polarised
Description	View of the concrete, showing a microcrack (white, E1 to E12), partially lined with alkali-silica gel deposits, running through both the cement matrix and a coarse aggregate particle.		

Petrographic Examination of Hardened Concrete - ASTM C856-11
High-Power Microscopical Observations

PHOTOGRAPH TAKEN USING LEICA DMRX



RECORD DIGITAL PHOTOMICROGRAPH			
RSK Sample Ref.	11675/C3	**Client Sample Ref.**	#3
Approx. Mag^n	x35	**Approx. Scale**	10mm = 285µm
Portion Described	Concrete	**Viewing Light**	Reflected fluorescent
Description	View of the concrete, showing a microcrack (A4 to J6), and associated high microporosity (bright green, F5), running through the cement matrix. Fine aggregate particles are shown black (B9).		

Petrographic Examination of Hardened Concrete - ASTM C856-11

Methods of Examination

The submitted concrete sample was subjected to a petrographic examination following methods recommended by ASTM C856-11, Standard Practice for Petrographic Examination of Hardened Concrete. Estimation of excess voidage was carried out in accordance with Concrete Society Technical Report No 11, including Addendum (1987), Concrete Core Testing For Strength. The examination was supplemented (where required) by the determination of the cement type following methods given in BS 1881: Part 124: 1988. When the concrete is suspected to contain high alumina cement, the examination is supplemented by taking guidance from BRE Digest 392, Assessment of existing high alumina cement concrete construction in the UK, March 1994.

The sample was first visually and low-power microscopically examined using a high quality Leica MZ8 binocular zoom microscope employing magnifications up to x50. A record colour photograph of the sample was prepared along with a diagram illustrating the main features of interest. A low-power photomicrograph (a photograph taken through the microscope) is sometimes prepared to illustrate certain features of importance.

The initial examination was used to determine the most appropriate location for a medium-area (75 x 50mm) thin-section to be taken for further, more detailed microscopical examination. The thin-section was prepared from a diamond sawn slice which had been both consolidated with, and vacuum impregnated by, an epoxy resin usually containing an ultraviolet light sensitive fluorescent dye. In some cases (eg concretes suspected to contain thaumasite), a pair of thin-sections is produced, one using fluorescent dye and one free of fluorescent dye. Where the specific cement type (eg ‘ordinary’ Portland or ‘sulfate-resisting’ Portland) was required a highly polished specimen was also prepared for examination of the matrix in reflected light.

Both the thin-section and polished specimen were examined using a high quality Leica DMRX multi-functional microscope employing various magnifications up to x630. The thin-section was examined using transmitted plane-polarised and cross-polarised illuminations. The polished specimen was examined using reflected, polarised and brightfield illuminations. One or more record colour photomicrographs were prepared to illustrate certain microscopical features of importance. The thin-section was also examined under reflected ultraviolet illumination to allow an assessment of the void and micropore structure, evidence of cracking and any other features of relevance. The highly polished specimen was etched using appropriate solutions and vapours to assist with the identification of residual particles of unhydrated cement and any non-reacted mineral additions.

Glossary of Terms Used in the Descriptions

Aggregate abundance	Major	*>10%*
	Minor	*2 to 10%*
	Trace	*<2%*
Carbonation (Increasing Carbonation ↑)	Complete	*no residual cement matrix other than occasional unreacted relics*
	Partial	*evidence of mixed carbonate crystallites with isotropic matrix*
	Faint	*occasional carbonate crystallites, <25% of the area*
Compaction (Increasing Compaction ↑)	≤0.5%	*very good*
	>0.5% - ≤3.0%	*≤3.0% = good (ie normal for structural concrete)*
	>3.0% – ≤5.0%	*medium*
	>5.0% - ≤10.0%	*poor*
	>10.0%	*Very poor*
Cracks (Increasing Width ↓)	Fine microcracks	*<1μm wide*
	Microcracks	*1-10μm wide*
	Fine cracks	*10-100μm wide*
	Cracks	*100μm-1mm*
	Large cracks	*>1mm wide*
Frequency (Increasing Frequency ↓)	Rare	*only found by thorough searching*
	Sporadic	*only occasionally observed during normal examination*
	Common	*easily observed during normal examination*
	Frequent	*easily observed with minimal examination*
	Abundant	*immediately apparent to initial examination*

Hardness (Increasing Hardness ↓)	Very soft	*can be penetrated easily by a finger*
	Soft	*scores with a fingernail*
	Moderately soft	*scores using a copper coin*
	Moderately hard	*scores easily with a penknife*
	Hard	*not easily scored with a penknife*
	Very hard	*cannot be scored with a steel point*
Portlandite (Matrix)	Small	*<20μm*
	Medium	*20-60μm*
	Large	*60-100μm*
	Very large	*>100μm*
Relict cement	Small	*<20μm*
	Medium	*20-60μm*
	Large	*60-100μm*
	Very large	*>100μm*
Water/cement ratio	Low	*<0.35*
	Normal	*0.35-0.65*
	High	*>0.65*
Voids	Entrained	*Typically round in shape and <100μm in diameter (taken to be all voids <1mm diameter when undertaking air content analyses).*
	Entrapped	*typically irregular in shape and >1mm in diameter*

RSK Environment Ltd
Tel: +44 (0) 1442 437500
Fax: +44 (0) 1442 437550
Email: info2@rsk.co.uk
Web: www.rsk.co.uk/stats

Materials & Structures
18 Frogmore Road
Hemel Hempstead
Hertfordshire
HP3 9RT

Compositional Analysis of Concrete

Scanning Electron Microscopy (SEM)/Energy Dispersive X-ray (EDX) Analysis

284188 – Cementaid (WA Pty. Ltd), Fimiston Plant, Kalgoorlie-Boulder, WA

Client Details			
Cementaid (WA Pty. Ltd) 200 Star Street Welshpool Western Australia, 6105 Australia			
Contact Name	Paul Mundell		
Your Reference	None advised	Order date	Not advised

Sample Details			
Sample type	Concrete, including the Caltite admixture		
Sampled by	Client	Sampling date	Not advised
RSK Reference	11675/C1	Client Sample Reference	#1
Receipt date	05.10.11	Test date	26.01.12
RSK Ref.	**Description**		
	A representative portion of the concrete was submitted for analysis.		

Methods	
Test	A full description of the examination methods is given on the final page of this certificate.

Summary of Results

The SEM/EDX analysis determined that the majority of the deposits within air voids selected for analysis were primarily comprised of silica, with minor proportions of calcium, iron and potassium. The silica is primarily derived from quartz fine aggregate particles, whereas it is likely that the calcium, iron and potassium are derived from the cement matrix.

No alkali-silica gel deposits, such as those identified in RSK certificate 284188/39040, were encountered in the specimen selected for analysis.

The texture of the cement matrix, which was advised by the Client to include the Caltite admixture, appeared greatly similar to a reference cement matrix without any admixture. However, the cement matrix exhibited a lower proportion of microcracks than the concrete that did not contain Caltite.

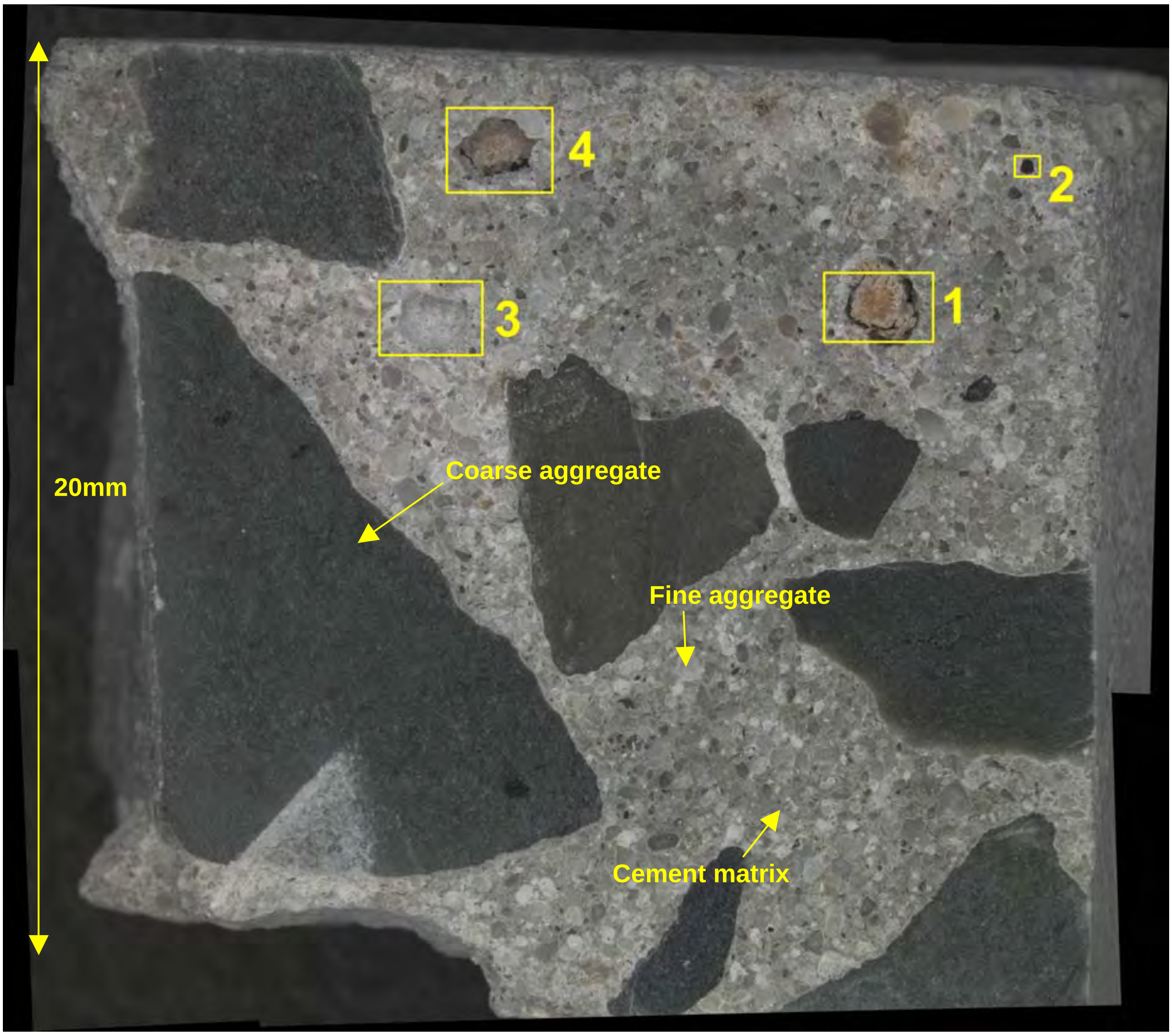
Certification			
Certificate prepared by **Paul Bennett-Hughes** Principal Scientist		Certificate reviewed by **Dr Ian Sims** Director	
Testing by	S/C Laboratory	Certificate Issue Date	30 January 2012

The results given in this certificate relate only to those samples submitted and specimens tested and to any materials properly represented by those samples and specimens.

Compositional Analysis of Concrete

Scanning Electron Microscopy (SEM) / Energy Dispersive X-ray (EDX) Analysis – Results and Discussion

RSK Sample Ref.	11675/C1	**Client Sample Ref.**	#1
Description	General view of the specimen subjected to investigation. The areas selected for analysis are shown below.		

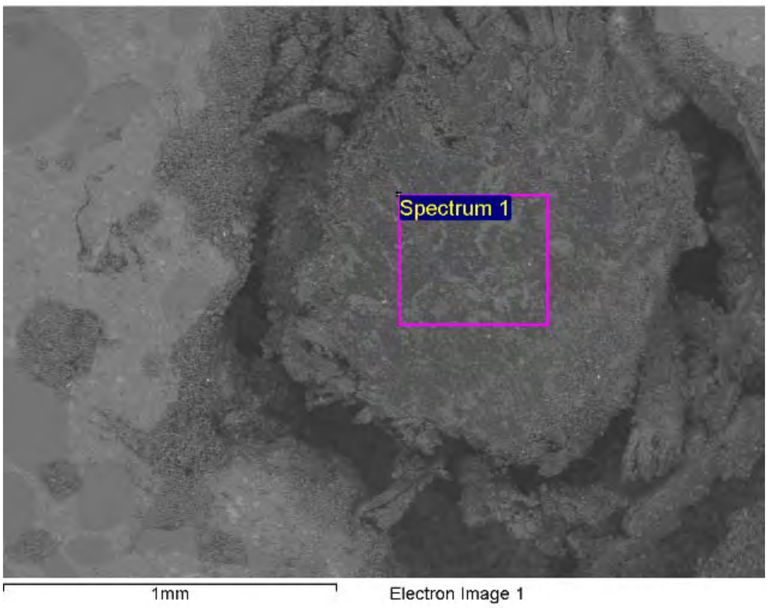


Compositional Analysis of Concrete

Scanning Electron Microscopy (SEM) / Energy Dispersive X-ray (EDX) Analysis – Results and Discussion

RSK Sample Ref.	11675/C1	**Client Sample Ref.**	#1
Analysis Location	1 (see Sheet 2)	**Figure No.**	1

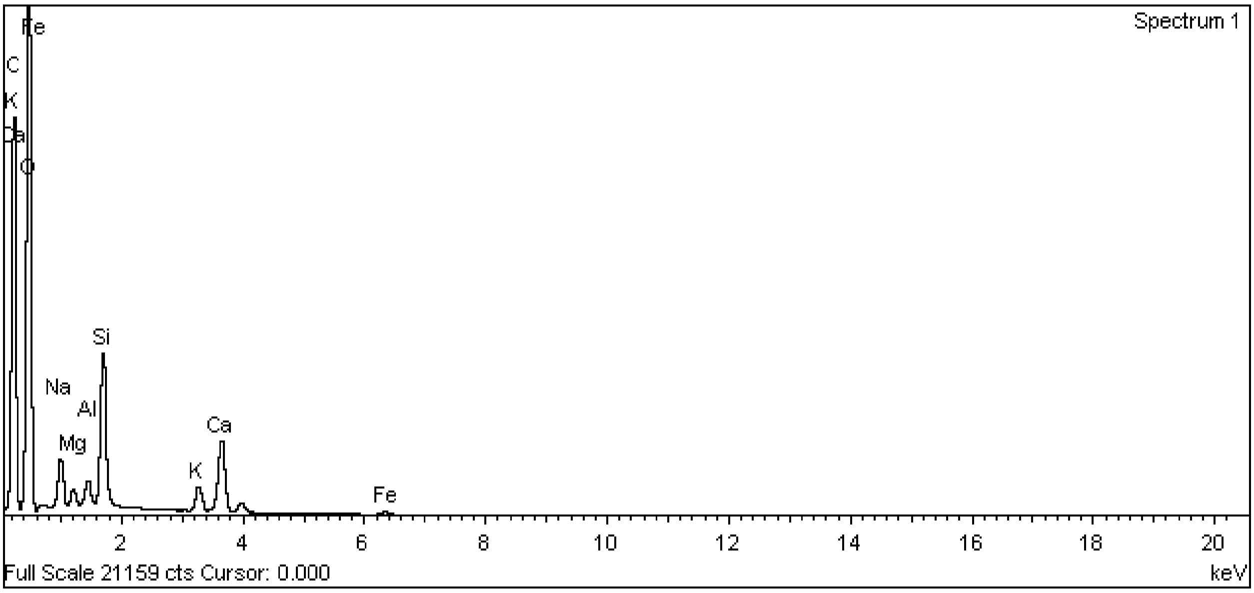
BACKSCATTERED ELECTRON IMAGE



DESCRIPTION

General view of deposits within an air void. The deposits primarily comprised potassium, calcium, iron and silica.

SPECTRUM

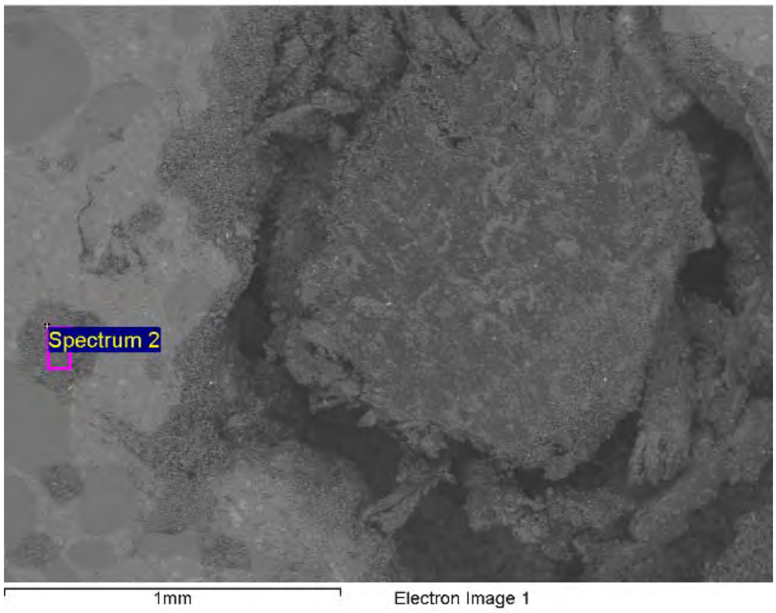


Compositional Analysis of Concrete

Scanning Electron Microscopy (SEM) / Energy Dispersive X-ray (EDX) Analysis – Results and Discussion

RSK Sample Ref.	11675/C1	**Client Sample Ref.**	#1
Analysis Location	1 (see Sheet 2)	**Figure No.**	2

BACKSCATTERED ELECTRON IMAGE

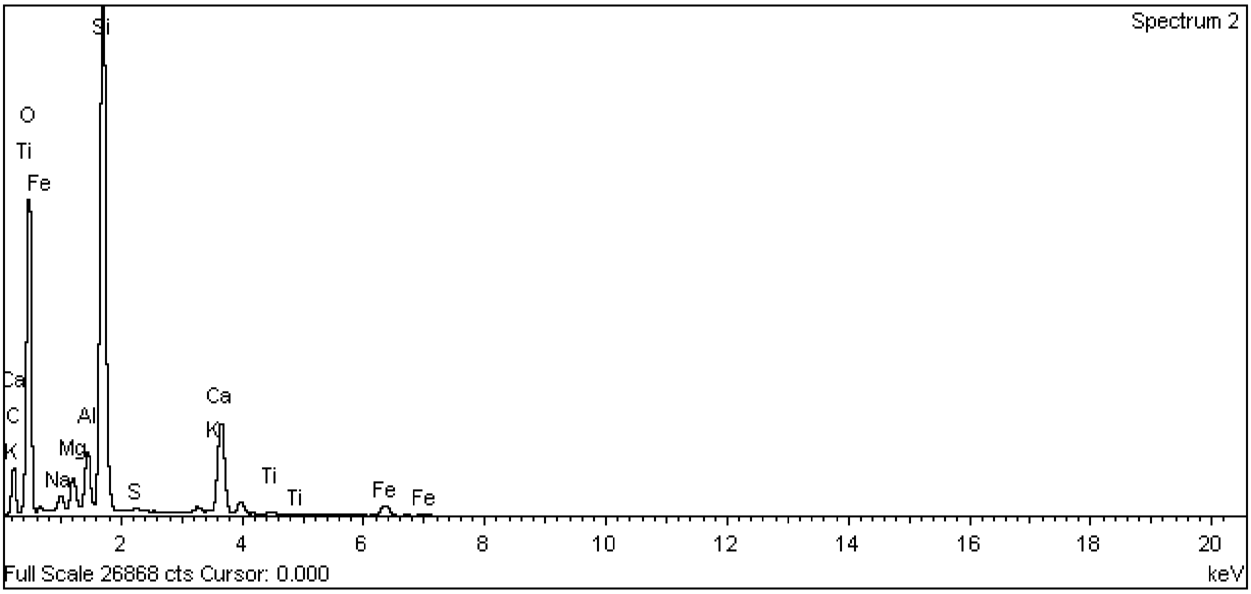


DESCRIPTION

General view of deposits within a small air void.

The deposits primarily comprised silica.

SPECTRUM

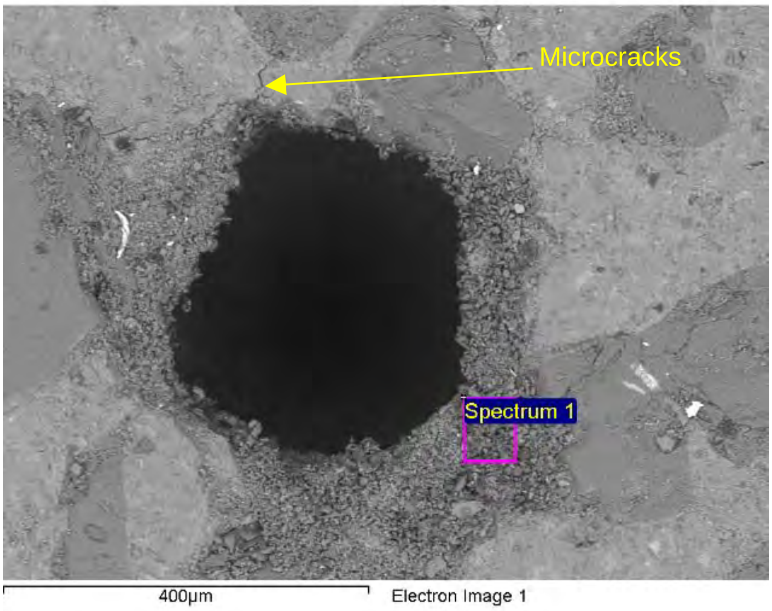


Compositional Analysis of Concrete

Scanning Electron Microscopy (SEM) / Energy Dispersive X-ray (EDX) Analysis – Results and Discussion

RSK Sample Ref.	11675/C1	**Client Sample Ref.**	#1
Analysis Location	2 (see Sheet 2)	**Figure No.**	3

BACKSCATTERED ELECTRON IMAGE

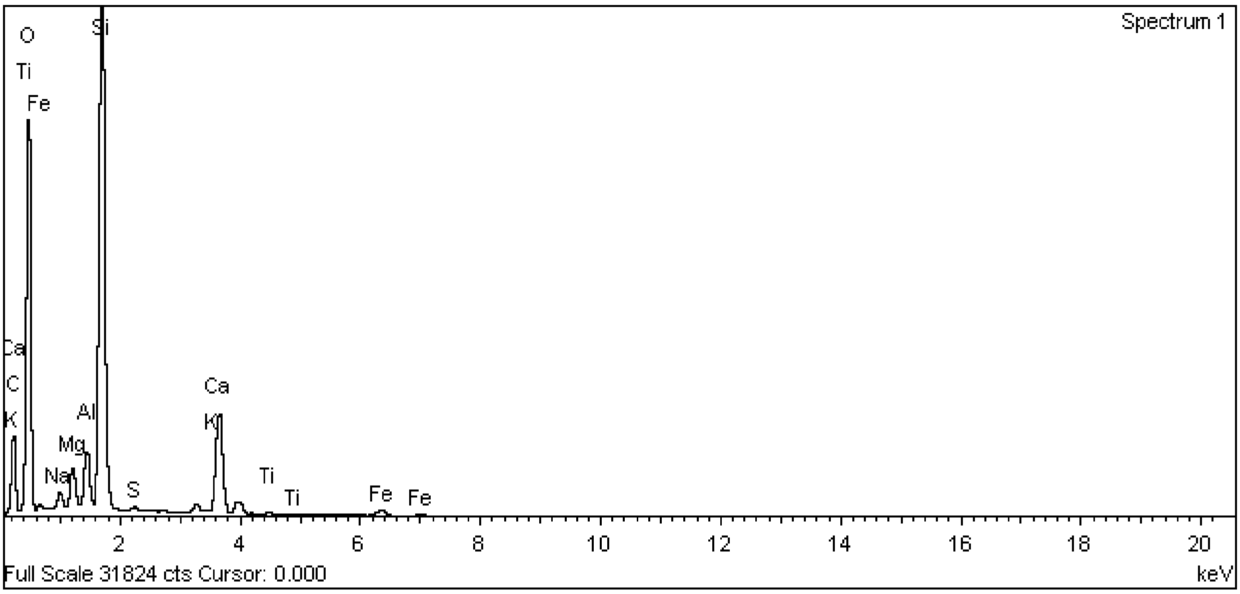


DESCRIPTION

General view of deposits within a small air void.

The deposits primarily comprised silica, with smaller quantities of iron, calcium and potassium.

SPECTRUM

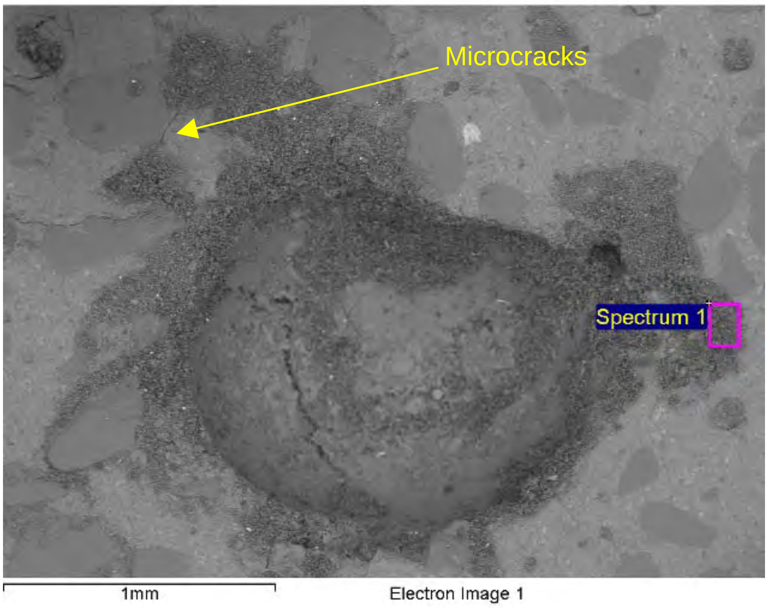


Compositional Analysis of Concrete

Scanning Electron Microscopy (SEM) / Energy Dispersive X-ray (EDX) Analysis – Results and Discussion

RSK Sample Ref.	11675/C1	**Client Sample Ref.**	#1
Analysis Location	3 (see Sheet 2)	**Figure No.**	4

BACKSCATTERED ELECTRON IMAGE

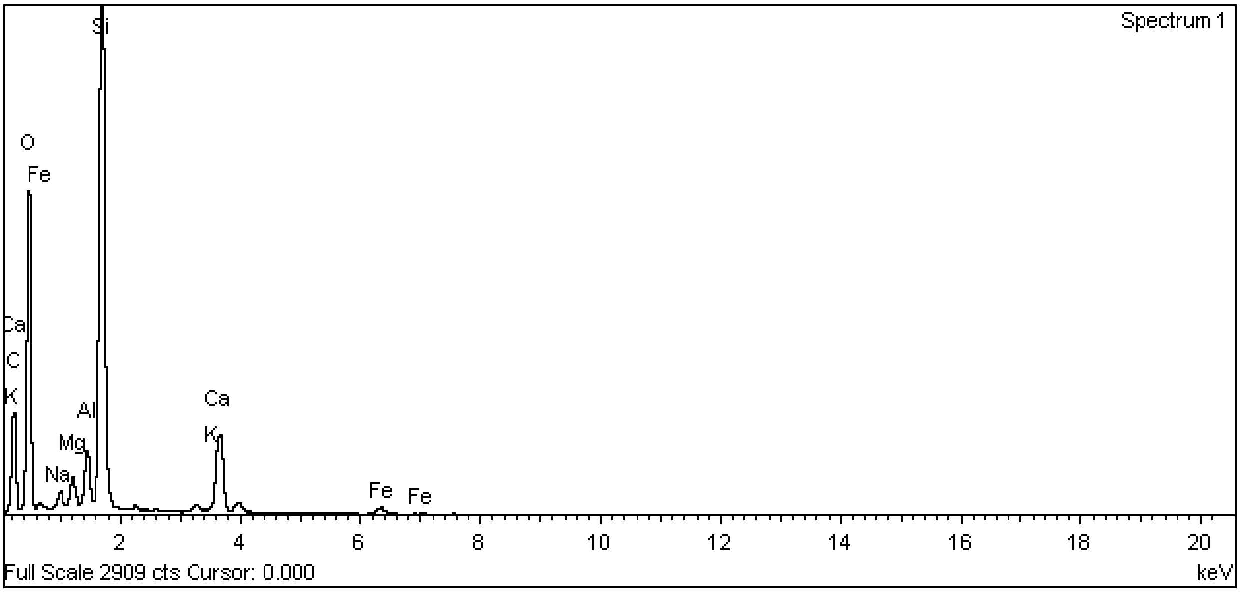


DESCRIPTION

General view of deposits within a small air void.

The deposits primarily comprised silica, with smaller quantities of iron, calcium and potassium.

SPECTRUM

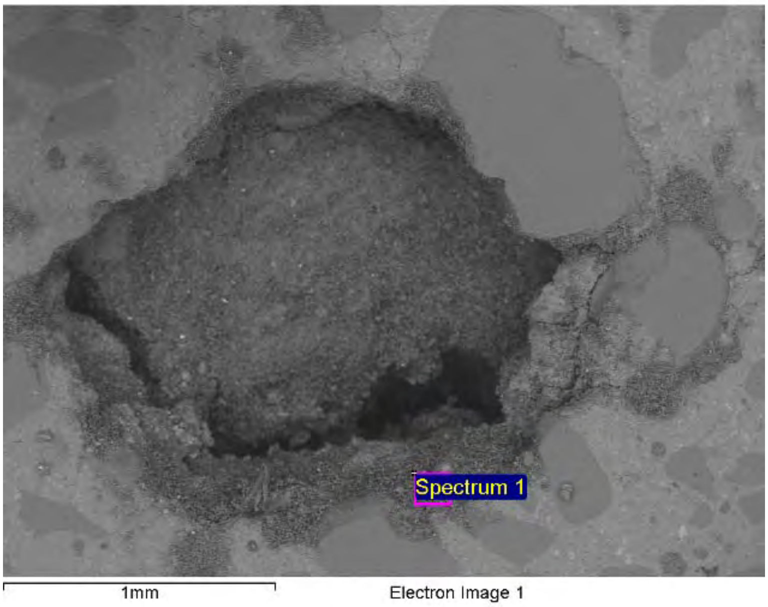


Compositional Analysis of Concrete

Scanning Electron Microscopy (SEM) / Energy Dispersive X-ray (EDX) Analysis – Results and Discussion

RSK Sample Ref.	11675/C1	**Client Sample Ref.**	#1
Analysis Location	3 (see Sheet 2)	**Figure No.**	4

BACKSCATTERED ELECTRON IMAGE

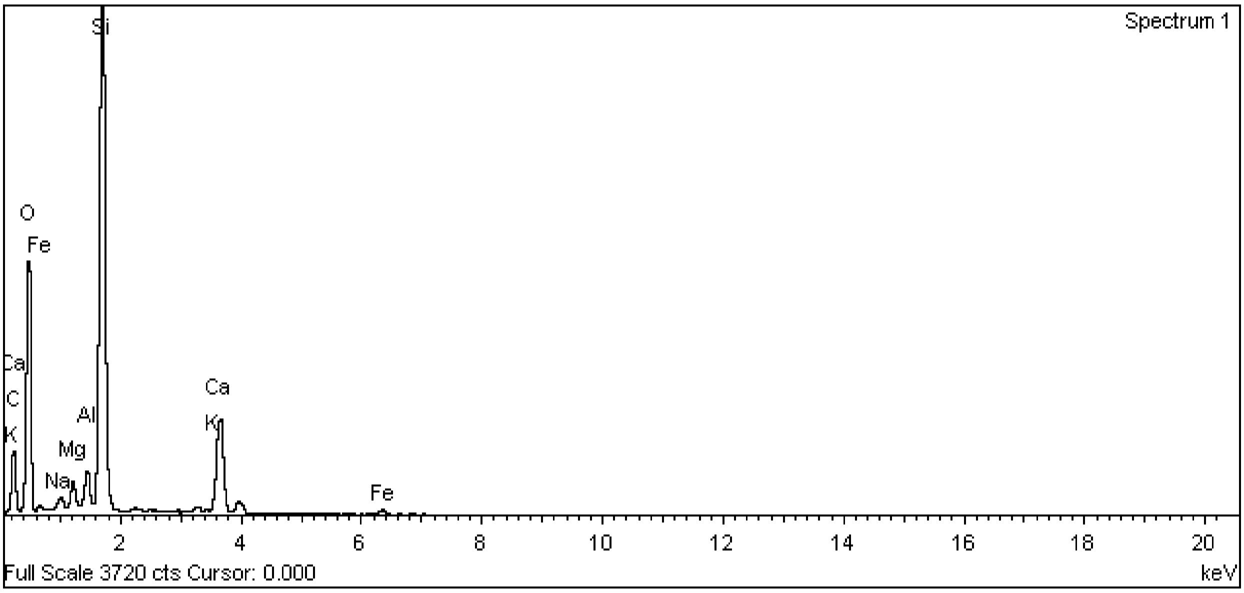


DESCRIPTION

General view of deposits within an air void.

The deposits primarily comprised silica, with smaller quantities of calcium.

SPECTRUM



Compositional Analysis of Concrete

Scanning Electron Microscopy (SEM) / Energy Dispersive X-ray (EDX) Analysis

APPENDIX

A representative cube, approximately 20mm x 20mm x 20mm sized, was sampled from the concrete core. The face of the cube that was going to be investigated was polished with progressively finer graded papers.

A JEOL 6480 LV SEM was used to image the samples in low vacuum mode. This instrument was also equipped with an Oxford Instruments INCA X-ray analysis system used for energy dispersive X-ray (EDX) analysis. EDX analyses the characteristic X-rays produced by the interaction between the primary electron beam and the sample. The technique identifies all elements present with atomic numbers of 5 and greater (boron) with a lower detection limit of approximately 0.3 weight %.

An experienced operator under the supervision of a Principal Scientist of RSK Environment Limited carried out the SEM analysis at a specialist approved sub-contract laboratory.

End of Certificate

RSK Environment Ltd
Tel: +44 (0) 1442 437500
Fax: +44 (0) 1442 437550
Email: info2@rsk.co.uk
Web: www.rsk.co.uk/stats

Materials & Structures
18 Frogmore Road
Hemel Hempstead
Hertfordshire
HP3 9RT

Compositional Analysis of Concrete

Scanning Electron Microscopy (SEM)/Energy Dispersive X-ray (EDX) Analysis

284188 – Cementaid (WA Pty. Ltd), Fimiston Plant, Kalgoorlie-Boulder, WA

Client Details			
Cementaid (WA Pty. Ltd) 200 Star Street Welshpool Western Australia, 6105 Australia			
Contact Name	Paul Mundell		
Your Reference	None advised	Order date	Not advised

Sample Details			
Sample type	Concrete, containing no Caltite admixture		
Sampled by	Client	Sampling date	Not advised
RSK Reference	11675/C3	Client Sample Reference	#3
Receipt date	05.10.11	Test date	26.01.12
RSK Ref.	**Description**		
	A representative portion of the concrete was submitted for analysis.		

Methods	
Test	A full description of the examination methods is given on the final page of this certificate.

Summary of Results

The SEM/EDX analysis determined that the majority of the deposits within air voids selected for analysis were primarily comprised of silica, with minor proportions of calcium, iron and potassium. The silica is primarily derived from quartz fine aggregate particles, whereas it is likely that the calcium, iron and potassium are derived from the cement matrix.

No alkali-silica gel deposits or sulfate deposits, such as those identified in RSK certificate 284188/39041, were encountered in the specimen selected for analysis.

The texture of the cement matrix appeared generally similar to the concrete specimen that contained Caltite (11675/C1). However, the cement matrix exhibited a high proportion of microcracks than the concrete specimen that included the Caltite admixture (284188/39147).

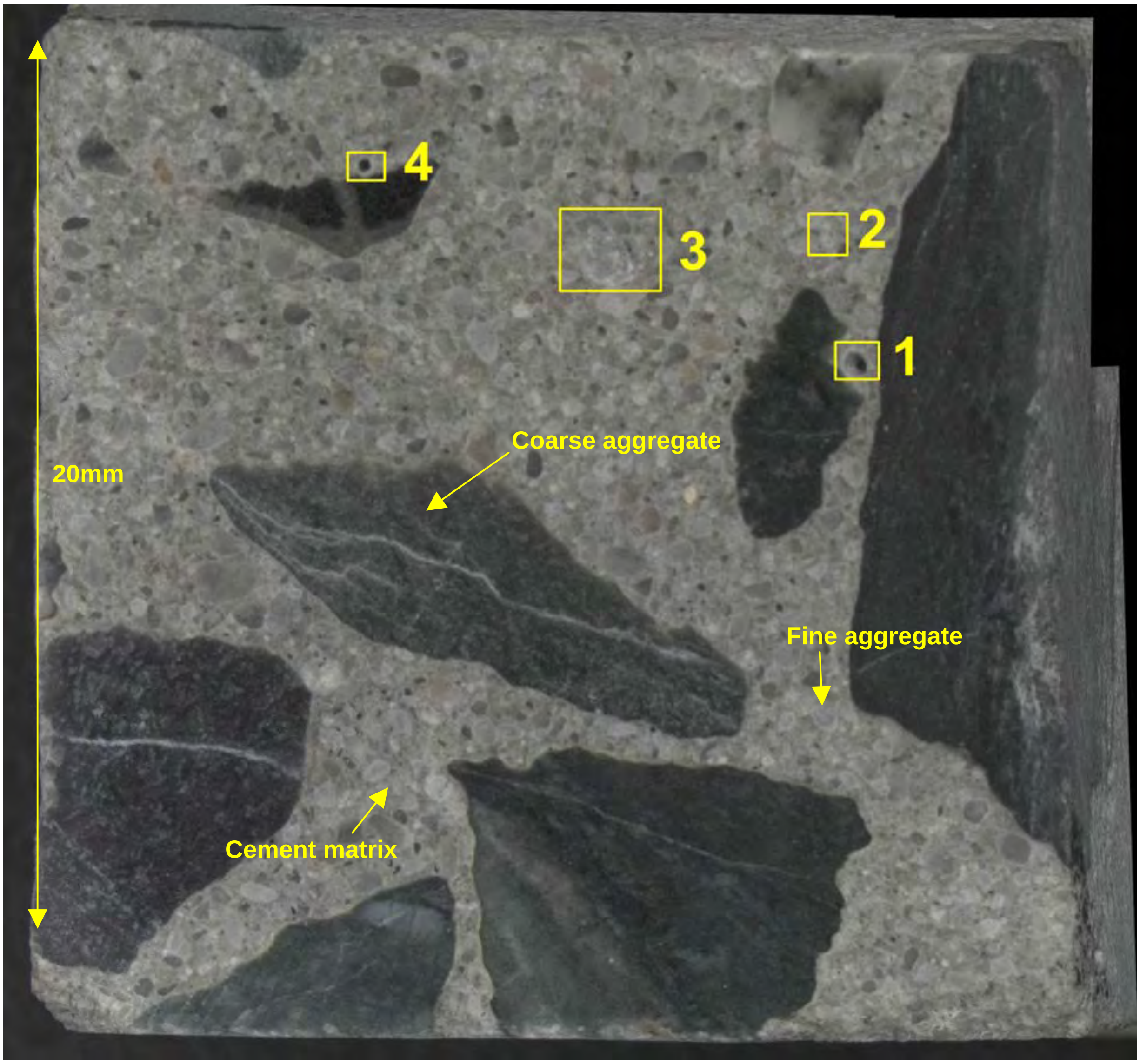
Certification			
Certificate prepared by **Paul Bennett-Hughes** Principal Scientist		Certificate reviewed by **Dr Ian Sims** Director	
Testing by	S/C Laboratory	Certificate Issue Date	26 January 2012

The results given in this certificate relate only to those samples submitted and specimens tested and to any materials properly represented by those samples and specimens.

Compositional Analysis of Concrete

Scanning Electron Microscopy (SEM) / Energy Dispersive X-ray (EDX) Analysis – Results and Discussion

RSK Sample Ref.	11675/C3	**Client Sample Ref.**	#3
Description	General view of the specimen subjected to investigation. The areas selected for analysis are shown below.		

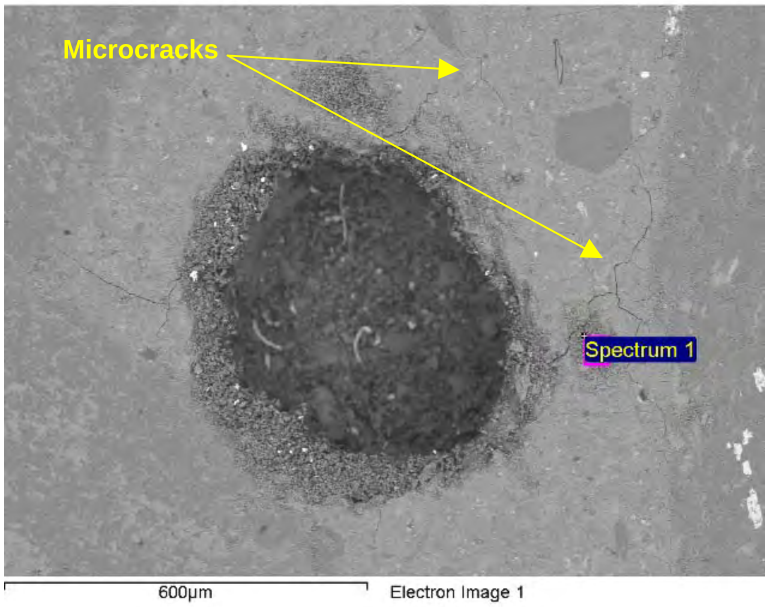


Compositional Analysis of Concrete

Scanning Electron Microscopy (SEM) / Energy Dispersive X-ray (EDX) Analysis – Results and Discussion

RSK Sample Ref.	11675/C3	**Client Sample Ref.**	#3
Analysis Location	1 (see Sheet 2)	**Figure No.**	1

BACKSCATTERED ELECTRON IMAGE



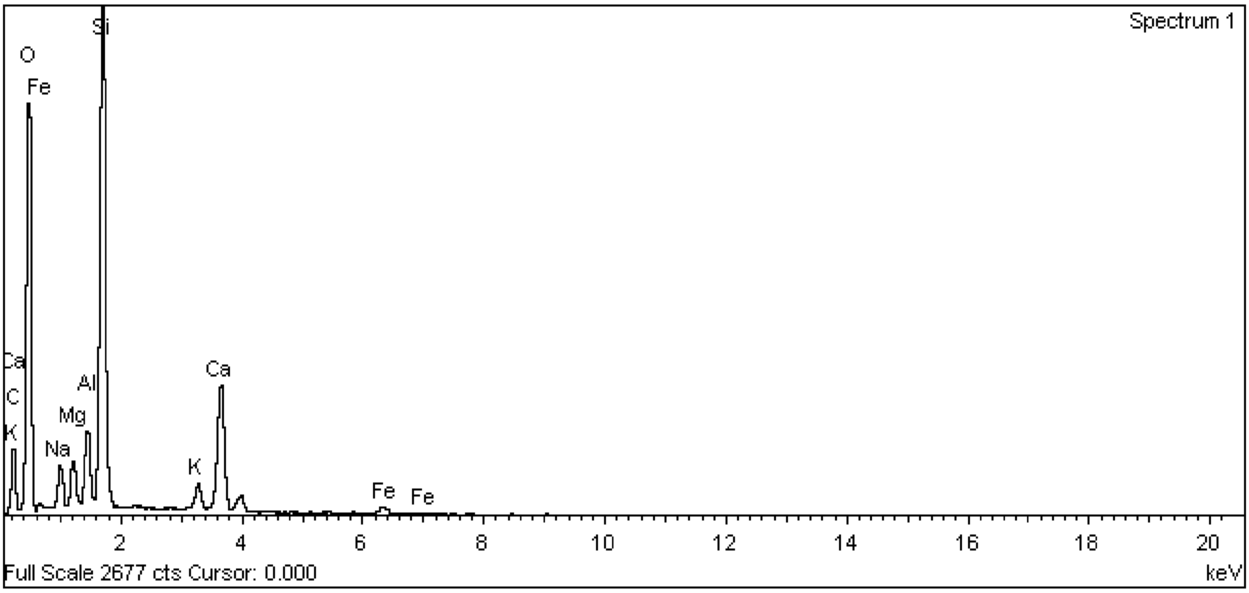
DESCRIPTION

General view of deposits within an air void.

The analysis determined the presence of silica and iron, with minor proportions of calcium, aluminium and magnesium.

Microcracks were observed running through the cement matrix.

SPECTRUM

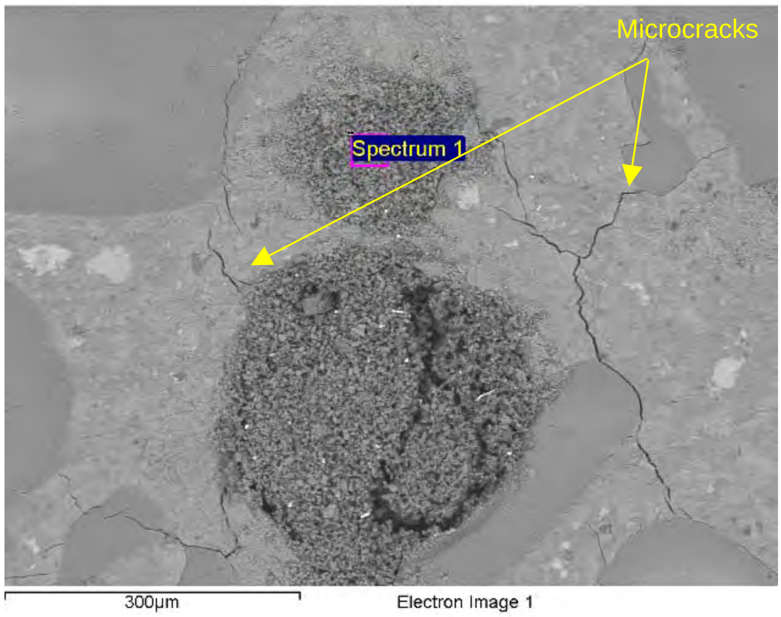


Compositional Analysis of Concrete

Scanning Electron Microscopy (SEM) / Energy Dispersive X-ray (EDX) Analysis – Results and Discussion

RSK Sample Ref.	11675/C3	**Client Sample Ref.**	#3
Analysis Location	2 (see Sheet 2)	**Figure No.**	2

BACKSCATTERED ELECTRON IMAGE



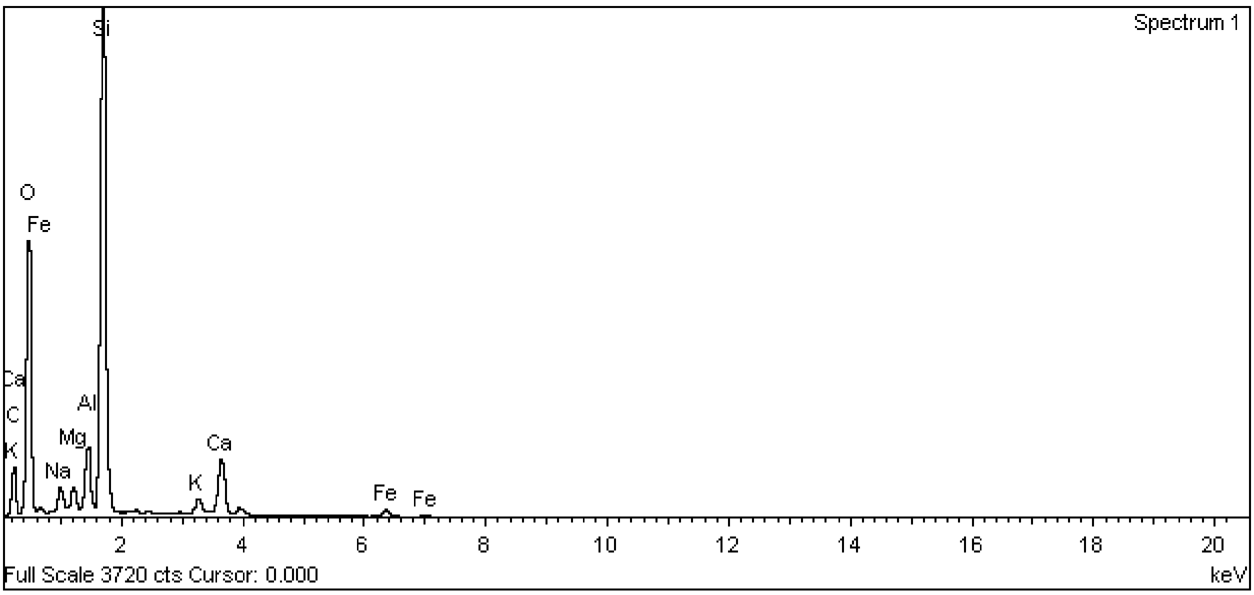
DESCRIPTION

General view of deposits within a small air void.

The deposits primarily comprised silica, with minor proportions of aluminium, calcium and magnesium.

Microcracks were observed running through the cement matrix.

SPECTRUM

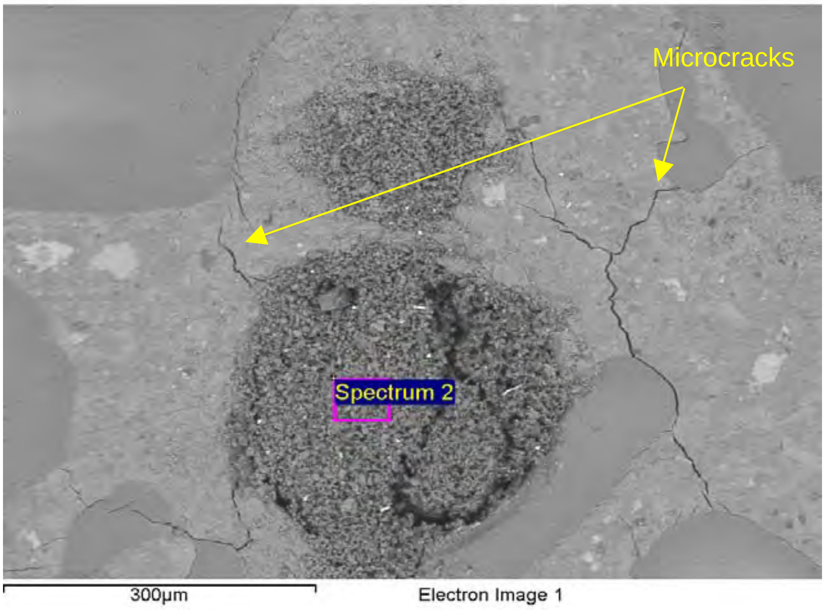


Compositional Analysis of Concrete

Scanning Electron Microscopy (SEM) / Energy Dispersive X-ray (EDX) Analysis – Results and Discussion

RSK Sample Ref.	11675/C3	**Client Sample Ref.**	#3
Analysis Location	2 (see Sheet 2)	**Figure No.**	3

BACKSCATTERED ELECTRON IMAGE



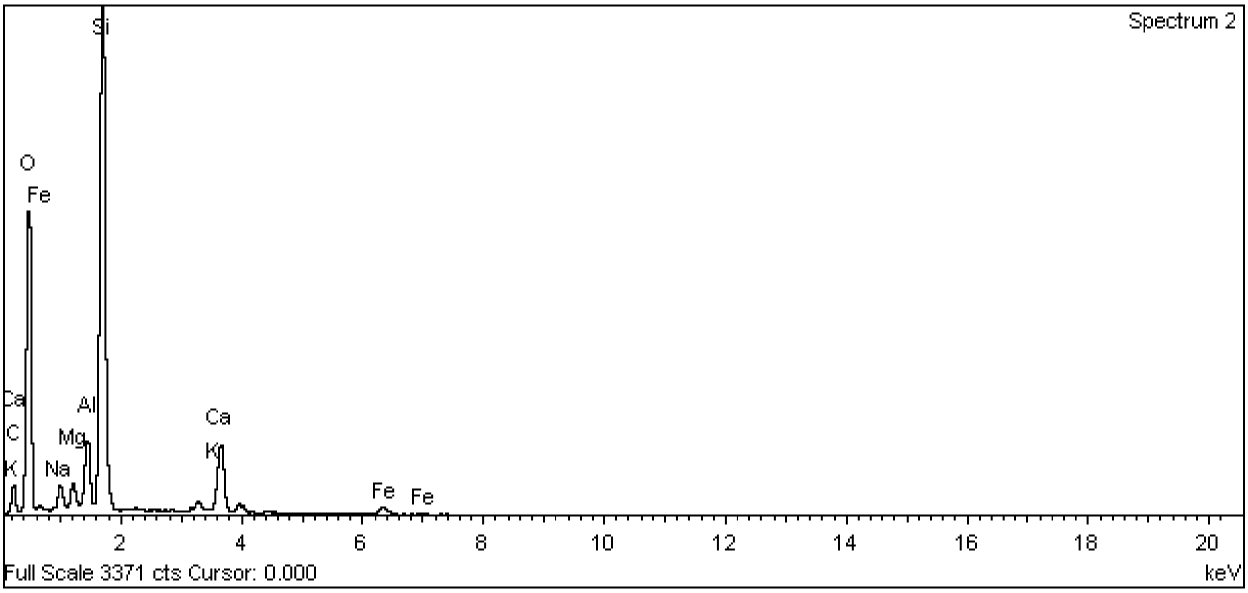
DESCRIPTION

General view of deposits within an air void.

The deposits primarily comprised silica, with smaller quantities of iron, calcium and potassium.

Microcracks were observed running through the cement matrix.

SPECTRUM

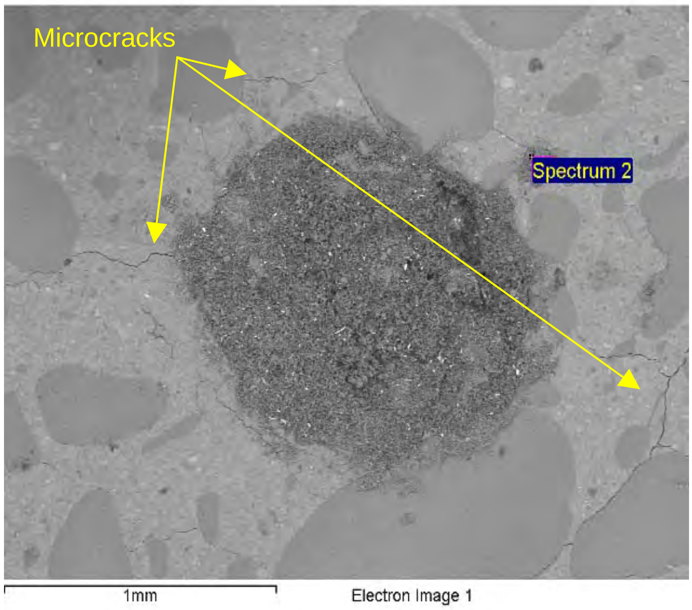


Compositional Analysis of Concrete

Scanning Electron Microscopy (SEM) / Energy Dispersive X-ray (EDX) Analysis – Results and Discussion

RSK Sample Ref.	11675/C3	**Client Sample Ref.**	#3
Analysis Location	3 (see Sheet 2)	**Figure No.**	4

BACKSCATTERED ELECTRON IMAGE



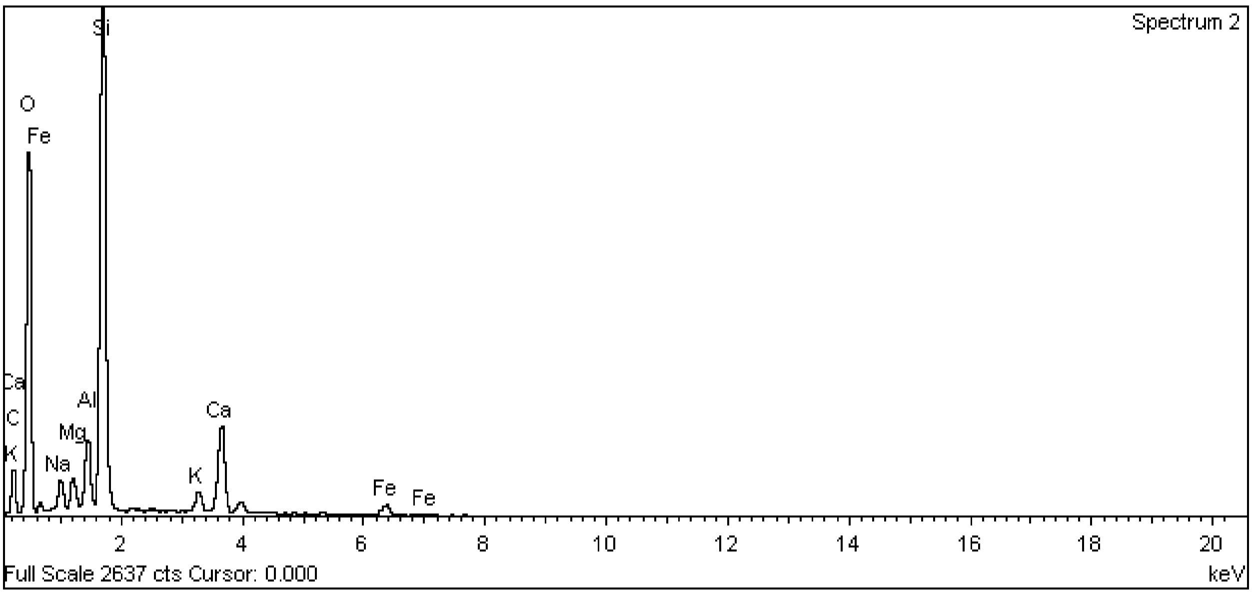
DESCRIPTION

General view of deposits within a small air void.

The deposits primarily comprised silica, with smaller quantities of iron, calcium and potassium.

Microcracks were observed running through the cement matrix.

SPECTRUM

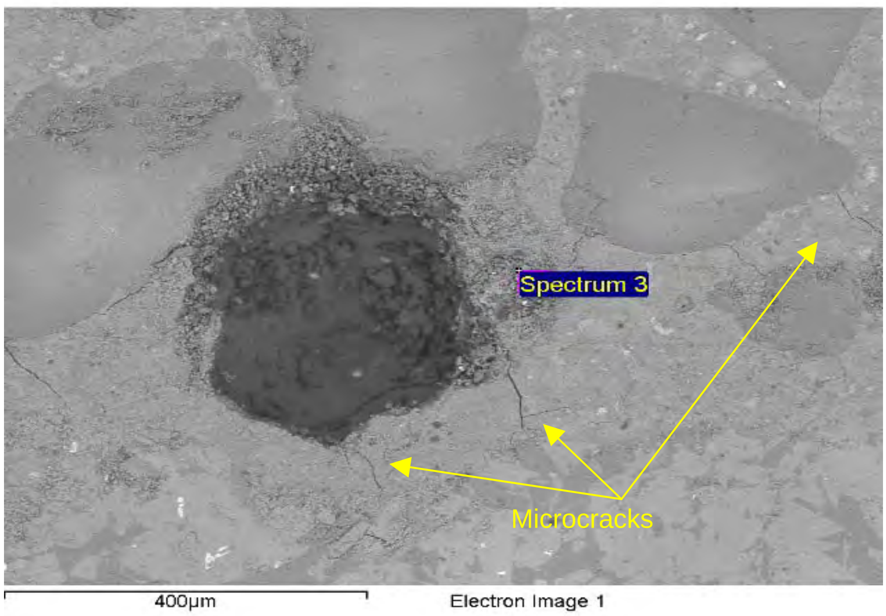


Compositional Analysis of Concrete

Scanning Electron Microscopy (SEM) / Energy Dispersive X-ray (EDX) Analysis – Results and Discussion

RSK Sample Ref.	11675/C3	**Client Sample Ref.**	#3
Analysis Location	4 (see Sheet 2)	**Figure No.**	4

BACKSCATTERED ELECTRON IMAGE



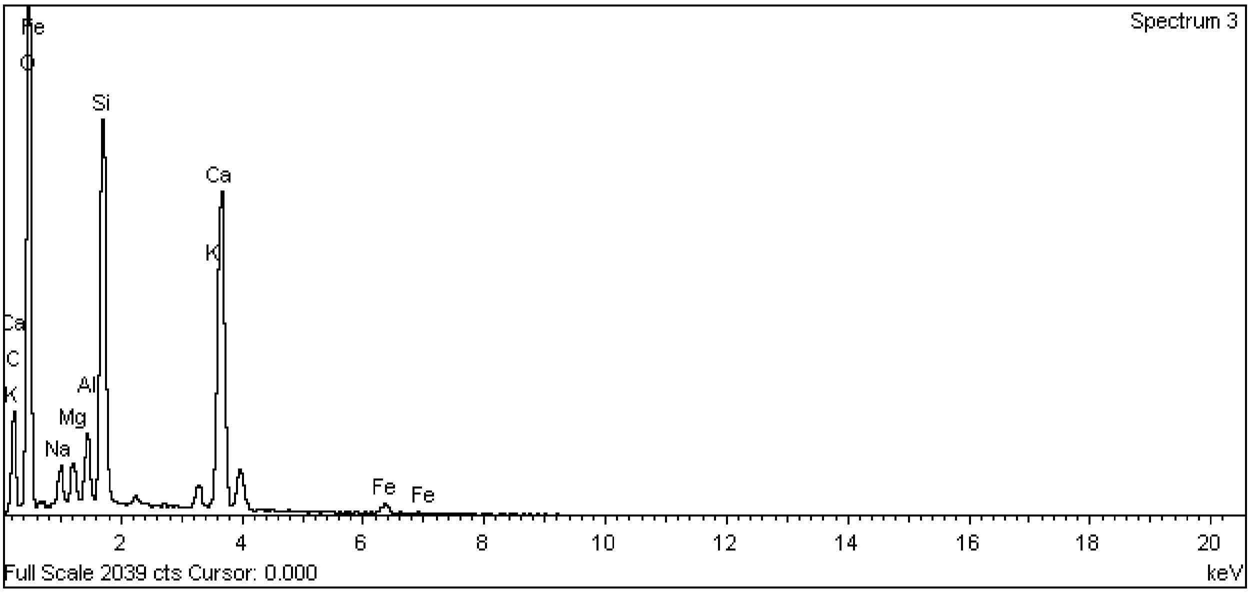
DESCRIPTION

General view of the concrete, showing an air void.

The analysis determined the presence of silica and calcium, with minor proportions of aluminium and magnesium.

Microcracks were observed running through the cement matrix.

SPECTRUM



Compositional Analysis of Concrete

Scanning Electron Microscopy (SEM) / Energy Dispersive X-ray (EDX) Analysis

APPENDIX

A representative cube, approximately 20mm x 20mm x 20mm sized, was sampled from the concrete core. The face of the cube that was going to be investigated was polished with progressively finer graded papers.

A JEOL 6480 LV SEM was used to image the samples in low vacuum mode. This instrument was also equipped with an Oxford Instruments INCA X-ray analysis system used for energy dispersive X-ray (EDX) analysis. EDX analyses the characteristic X-rays produced by the interaction between the primary electron beam and the sample. The technique identifies all elements present with atomic numbers of 5 and greater (boron) with a lower detection limit of approximately 0.3 weight %.

An experienced operator under the supervision of a Principal Scientist of RSK Environment Limited carried out the SEM analysis at a specialist approved sub-contract laboratory.

End of Certificate

APPENDIX B - CERTIFICATES OF TEST

Certificate no. 284188/39415a – Water absorption of concrete
Certificate no. 284188/39211c – Rate of absorption of water by hydraulic-cement concrete
Certificate no. 284188/39153a – Chloride content of concrete
Certificate no. 284188/39154a – Sulfate content of concrete
Certificate no. 284188/40900 – Density, absorption and voids in hardened concrete
Certificate no. 284188/41094 – Cement content
Certificate no. 284188/41095 – Original total water/cement ratio of concrete

This appendix contains 18 pages, including this one

RSK Environment Ltd
Tel: +44 (0) 1442 437500
Fax: +44 (0) 1442 437550
Email: info2@rsk.co.uk
Web: www.rsk.co.uk/stats

Materials & Structures
18 Frogmore Road
Hemel Hempstead
Hertfordshire
HP3 9RT

UKAS TESTING
0278

RSK

Water Absorption of Concrete
BS 1881-122: 1983

284188 Cementaid (WA Pty. Ltd), Fimiston Plant, Kalgoorlie-Boulder, WA

Client Details			
Cementaid (WA Pty. Ltd) 200 Star Street Welshpool Western Australia, 6105			
Contact name	Paul Mundell		
Order reference	None advised	Order date	None advised

Sample Details			
Sample type	Concrete cores		
Sampled by	Client	Casting date	Not advised
RSK batch	11675	No of samples	2
Receipt date	05/10/11	Test date	25/03/12

Methods	
Test	The test was carried out in accordance with BS 1881-122: 1983. Cores were stored and cured in 20ºC water until the day of testing. Volume was determined by air/water.
Deviations	Core diameter was 95mm (standard specifies ideally 75mm). Only one core tested, whereas the standard prefers a set of three.

Results

RSK Reference	**11675/C1**	**11675/C3**
Client Reference	1	3
Condition as received	Good	Good
Sample Orientation	Parallel to casting	Parallel to casting
Length (mm)	105.0	111.5
Diameter (mm)	95.0	95.0
Volume (mm^3)	630,000	651,673
Surface Area (mm^2)	45,491	47,430
Correction Factor	1.201	1.205
Density (kg/m^3)	2273	2399
Dry Mass (g)	1567.3	1534.5
Wet Mass, Air (g)	1572.9	1563.4
Wet Mass, Water (g)	880.8	911.8
Measured Absorption (%)	0.36	1.88
Corrected Absorption (%) #	**0.43**	**2.27**

Based on an equivalent absorption of a core having a length of 75mm and 75mm diameter

Certification			
Certificate prepared by Clive Rayner Principal Technician		Certificate reviewed by Andrew Grafton Director	
Testing by	CR	Certificate Issue Date	11/10/12

The results given in this certificate relate only to those samples submitted and specimens tested and to any materials properly represented by those samples and specimens. Any opinions and interpretations expressed herein are outside the scope of our UKAS accreditation.

End of Certificate

RSK Environment Ltd
Tel: +44 (0) 1442 437500
Fax: +44 (0) 1442 437550
Email: info2@rsk.co.uk
Web: www.rsk.co.uk/stats

Materials & Structures
18 Frogmore Road
Hemel Hempstead
Hertfordshire
HP3 9RT

Rate of Absorption of Water by Hydraulic-Cement Concretes
ASTM C1585-04

284188 Cementaid (WA Pty. Ltd), Fimiston Plant, Kalgoorlie-Boulder, WA

Client Details			
Cementaid (WA Pty. Ltd) 200 Star Street Welshpool Western Australia, 6105 Australia			
Contact name	Paul Mundell		
Order reference	None advised	Order date	None advised

Sample Details			
Sample type	Concrete cores (core diameter 95mm)		
Sampled by	Client	Casting date	Not advised
RSK batch	11675	No of samples	4
Receipt date	05/10/11	Test date	30/01 - 01/02/12

Methods	
Test	Testing was carried out in accordance with ASTM C1585-04.
Deviations	The Standard states that if the data for either the 1 minute to 6 hour or the data for 1 day and 7 day does not follow a linear relationship (a correlation coefficient, 'r^2', of less than 0.98) and does not show a systematic curvature, both the initial and secondary rate of absorption should not be calculated.

Results

Client Sample Ref	RSK Sample Ref	Sample Detail		Initial absorption		Secondary absorption	
				mm/√s x 10^{-4}	R^2	mm/√s x 10^{-4}	R^2
Core #2 Containing Caltite	11675/C2	Portion A -	0-50mm depth	25	0.98	11	0.99
		Portion B -	150-200mm depth	13	0.97	9	0.99
		Mean		***19***	***0.98***	***10***	***0.99***
Core #4 Not containing Caltite	11675/C4	Portion A -	0-50mm depth	64	0.99	15	0.97
		Portion B -	150-200mm depth	61	0.99	15	0.98
		Mean		***62***	***0.99***	***15***	***0.98***

Certification			
Certificate prepared by *I. Blanchard* Dr Ian Blanchard Senior Consultant		Certificate reviewed by Andrew Grafton Director	
Testing by	CR	Certificate Issue Date	01/06/12

RSK Environment Ltd
Tel: +44 (0) 1442 437500
Fax: +44 (0) 1442 437550
Email: info2@rsk.co.uk
Web: www.rsk.co.uk/stats

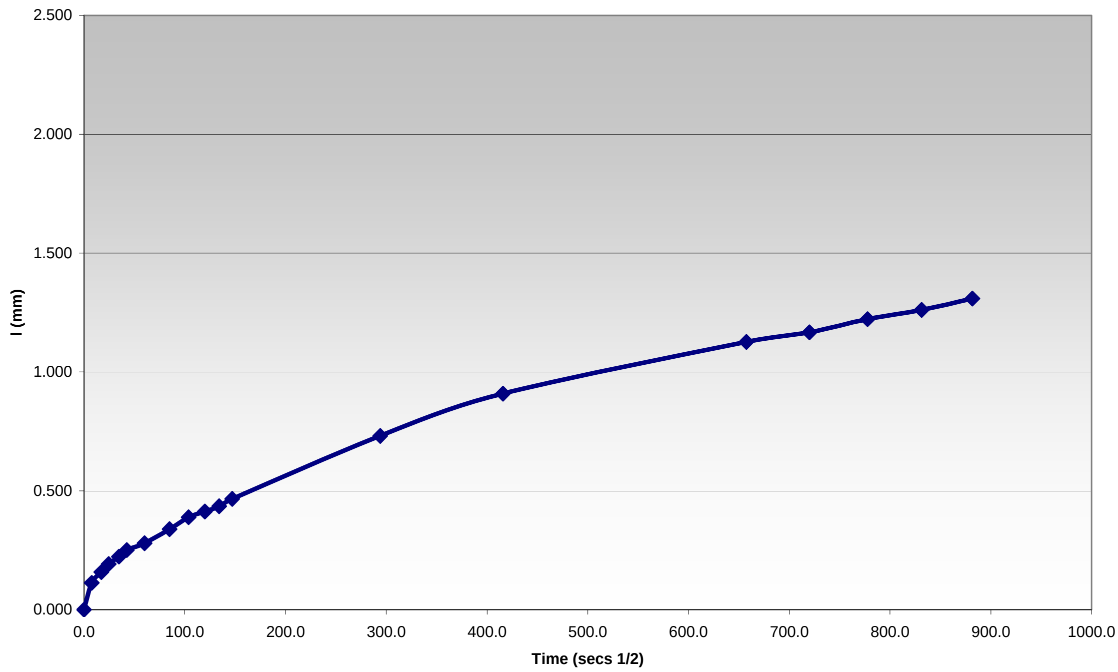
Materials & Structures
18 Frogmore Road
Hemel Hempstead
Hertfordshire
HP3 9RT

11675/C2 (Portion A)

Sample Details			
Mass of conditioned disc, g	722.3	**Cast date**	Not advised
Diameter, mm	95	**Exposed area, mm^2**	7088.2
Thickness, mm	50	**Water temp. ºC**	21

Test Data

Test time, s	Sq. root time	Mass, g	Mass difference, g	Cum. Mass, g	Mass diff/area/density = I
0	0	746.86	0.00	0.0	0.000
60	8	747.66	0.80	0.8	0.113
300	17	747.98	0.32	1.1	0.158
600	24	748.22	0.24	1.4	0.195
1200	35	748.44	0.22	1.6	0.223
1800	42	748.64	0.20	1.8	0.251
3600	60	748.84	0.20	2.0	0.279
7200	85	749.26	0.42	2.4	0.339
10800	104	749.62	0.36	2.8	0.389
14400	120	749.79	0.17	2.9	0.413
18000	134	749.94	0.15	3.1	0.435
21600	147	750.16	0.22	3.3	0.466
86400	294	752.04	1.88	5.2	0.731
172800	416	753.30	1.26	6.4	0.909
518400	720	755.13	1.54	8.3	1.167
604800	778	755.52	0.39	8.7	1.222
691200	831	755.80	0.28	8.9	1.261



RSK Environment Ltd
Tel: +44 (0) 1442 437500
Fax: +44 (0) 1442 437550
Email: info2@rsk.co.uk
Web: www.rsk.co.uk/stats

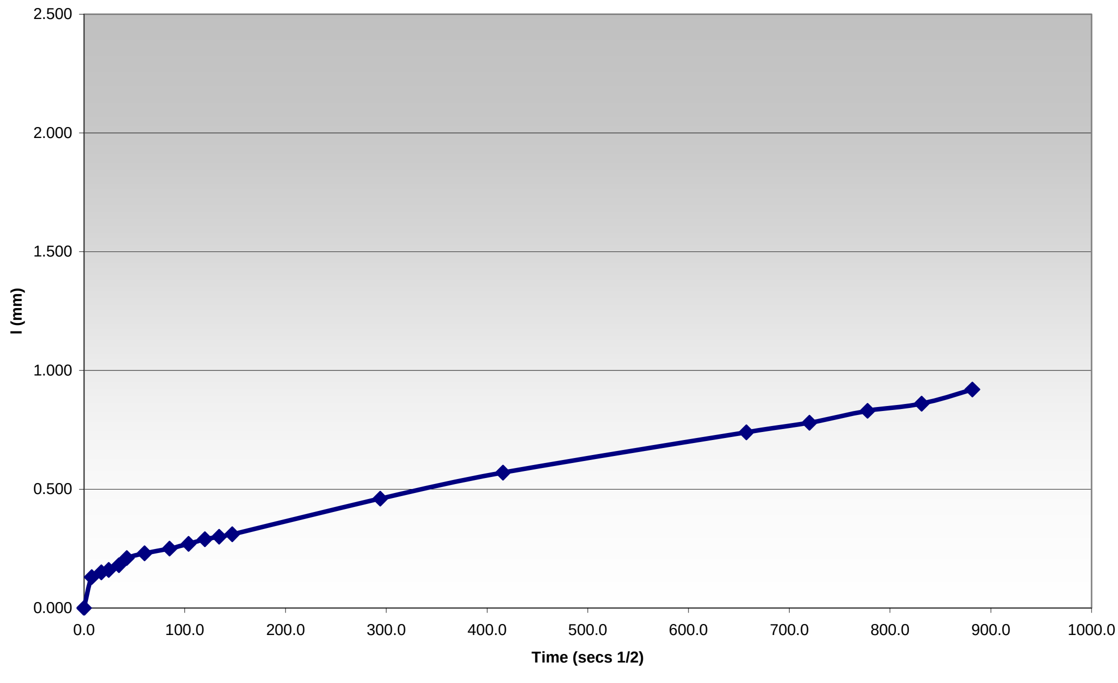
Materials & Structures
18 Frogmore Road
Hemel Hempstead
Hertfordshire
HP3 9RT

11675/C2 (Portion B)

Sample Details			
Mass of conditioned disc, g	924.9	**Cast date**	Not advised
Diameter, mm	95	**Exposed area, mm^2**	7088.2
Thickness, mm	50	**Water temp. ºC**	21

Test Data

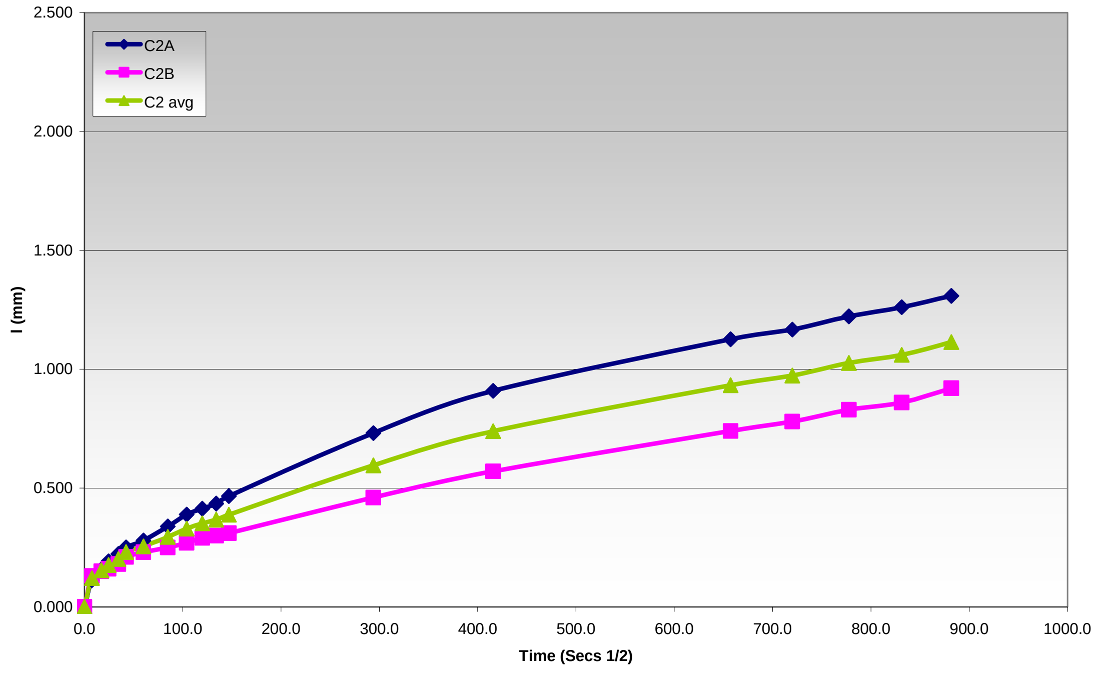
Test time, s	Sq. root time	Mass, g	Mass difference	Cum. Mass	Mass diff/area/density = I
0	0	945.04	0.00	0.00	0.000
60	8	945.95	0.91	0.91	0.130
300	17	946.10	0.15	1.06	0.150
600	24	946.20	0.10	1.16	0.160
1200	35	946.30	0.10	1.26	0.180
1800	42	946.50	0.20	1.46	0.210
3600	60	946.65	0.15	1.61	0.230
7200	85	946.80	0.15	1.76	0.250
10800	104	946.95	0.15	1.91	0.270
14400	120	947.08	0.13	2.04	0.290
18000	134	947.15	0.07	2.11	0.300
21600	147	947.25	0.10	2.21	0.310
86400	294	948.30	1.05	3.26	0.460
172800	416	949.11	0.81	4.07	0.570
518400	720	950.60	1.49	5.56	0.780
604800	778	950.90	0.30	5.86	0.830
691200	831	951.15	0.25	6.11	0.860



RSK Environment Ltd
Tel: +44 (0) 1442 437500
Fax: +44 (0) 1442 437550
Email: info2@rsk.co.uk
Web: www.rsk.co.uk/stats

Materials & Structures
18 Frogmore Road
Hemel Hempstead
Hertfordshire
HP3 9RT

11675/C2 - Summary



RSK Environment Ltd
Tel: +44 (0) 1442 437500
Fax: +44 (0) 1442 437550
Email: info2@rsk.co.uk
Web: www.rsk.co.uk/stats

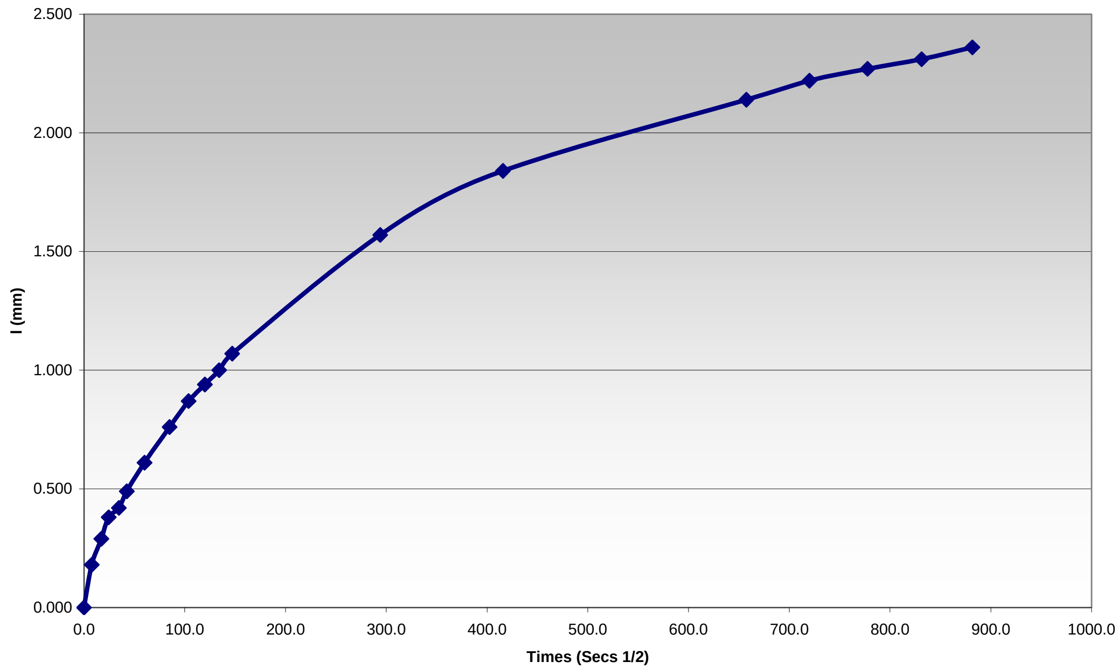
Materials & Structures
18 Frogmore Road
Hemel Hempstead
Hertfordshire
HP3 9RT

11675/C4 (Portion A)

Sample Details			
Mass of conditioned disc, g	809.1	**Cast date**	Not advised
Diameter, mm	95	**Exposed area, mm^2**	7088.2
Thickness, mm	50	**Water temp. ºC**	21

Test Data

Test time, s	Sq. root time	Mass, g	Mass difference	Cum. Mass	Mass diff/area/density = I
0	0	824.45	0.00	0.00	0.000
60	8	825.70	1.25	1.25	0.180
300	17	826.50	0.80	1.25	0.290
600	24	827.15	0.65	2.70	0.380
1200	35	827.45	0.30	3.00	0.420
1800	42	827.95	0.50	3.50	0.490
3600	60	828.75	0.80	4.30	0.610
7200	85	829.85	1.10	5.40	0.760
10800	104	830.60	0.75	6.15	0.870
14400	120	831.14	0.54	6.69	0.940
18000	134	831.55	0.41	7.10	1.000
21600	147	832.00	0.45	7.55	1.070
86400	294	835.55	3.55	11.10	1.570
172800	416	837.51	1.96	13.06	1.840
518400	720	840.16	2.65	15.71	2.220
604800	778	840.55	0.39	16.10	2.270
691200	831	840.80	0.25	16.35	2.310



RSK Environment Ltd
Tel: +44 (0) 1442 437500
Fax: +44 (0) 1442 437550
Email: info2@rsk.co.uk
Web: www.rsk.co.uk/stats

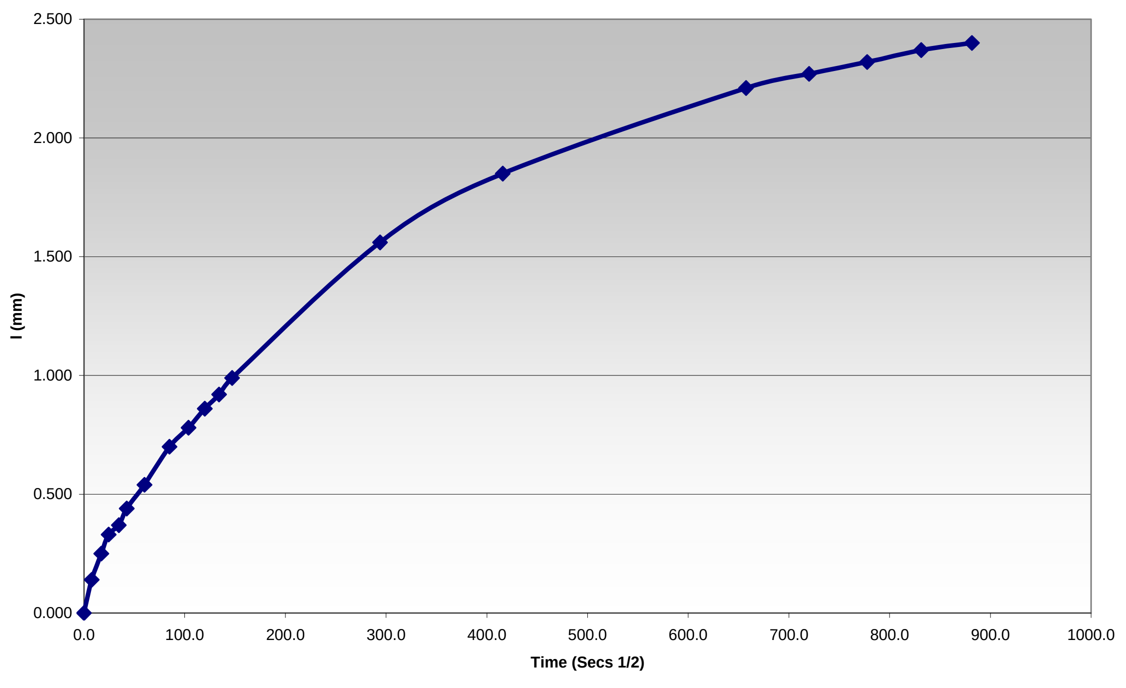
Materials & Structures
18 Frogmore Road
Hemel Hempstead
Hertfordshire
HP3 9RT

11675/C4 (Portion B)

Sample Details			
Mass of conditioned disc, g	821.85	**Cast date**	Not advised
Diameter, mm	95	**Exposed area, mm^2**	7088.2
Thickness, mm	50	**Water temp. ºC**	21

Test Data

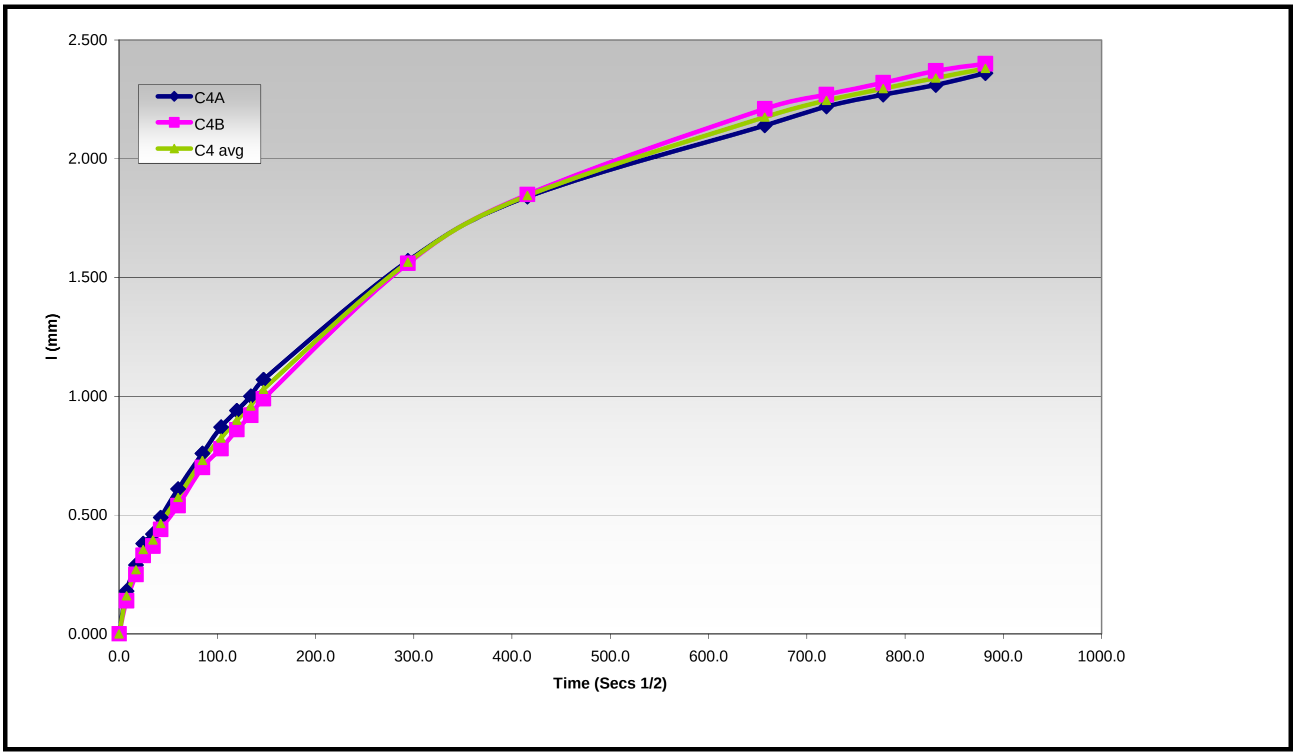
Test time, s	Sq. root time	Mass, g	Mass difference	Cum. Mass	Mass diff/area/density = I
0	0	834.40	0.00	0.00	0.00
60	8	835.40	1.00	1.00	0.140
300	17	836.15	0.75	1.75	0.250
600	24	836.76	0.55	2.30	0.330
1200	35	837.00	0.30	2.60	0.370
1800	42	837.50	0.50	3.10	0.440
3600	60	838.20	0.70	3.80	0.540
7200	85	839.35	1.15	4.95	0.700
10800	104	839.95	0.00	4.95	0.780
14400	120	840.48	0.60	5.55	0.860
18000	134	840.95	0.53	6.08	0.920
21600	147	841.45	0.47	6.55	0.990
86400	294	845.45	0.50	7.05	1.560
172800	416	847.50	6.05	13.10	1.850
518400	720	850.51	3.01	16.11	2.270
604800	778	850.88	0.37	16.48	2.320
691200	831	851.20	0.32	16.80	2.370



RSK Environment Ltd
Tel: +44 (0) 1442 437500
Fax: +44 (0) 1442 437550
Email: info2@rsk.co.uk
Web: www.rsk.co.uk/stats

Materials & Structures
18 Frogmore Road
Hemel Hempstead
Hertfordshire
HP3 9RT

11675/C4 - Summary



RSK Environment Ltd
Tel: +44 (0) 1442 437500
Fax: +44 (0) 1442 437550
Email: info2@rsk.co.uk
Web: www.rsk.co.uk/stats

Materials & Structures
18 Frogmore Road
Hemel Hempstead
Hertfordshire
HP3 9RT

UKAS TESTING
0278

Chloride Content of Concrete
BS 1881-124: 1988

284188 Cementaid (WA Pty. Ltd), Fimiston Plant, Kalgoorlie-Boulder, WA

Client Details			
Cementaid (WA Pty. Ltd) 200 Star Street Welshpool Western Australia, 6105 Australia			
Contact name	Paul Mundell		
Order reference	None advised	Order date	None advised

Sample Details			
Sample type	Concrete		
Sampled by	Client	Sampling date	Not advised
RSK batch	11674	No. of samples	2
Receipt date	05/10/11	Test date/period	20/10/12

Methods	
Test	Two concrete core samples were received at RSK's laboratory and incremental dust samples were obtained by drilling. The chloride content of the dust samples was determined in accordance with BS 1881-124:1988. Titration was carried out potentiometrically using a silver/silver chloride electrode. Cement contents of 18% were advised by the Client.
Deviations	None.

Results
The results are reported on page 2 of this certificate.

Certification			
Certificate prepared by Dr David Crofts Principal Scientist		Certificate reviewed by Paul Bennett-Hughes Principal Scientist	
Testing by	BJS	Certificate issue date	15/10/12

The results given in this certificate relate only to those samples submitted and specimens tested and to any materials properly represented by those samples and specimens. Any opinions and interpretations expressed herein are outside the scope of our UKAS accreditation.

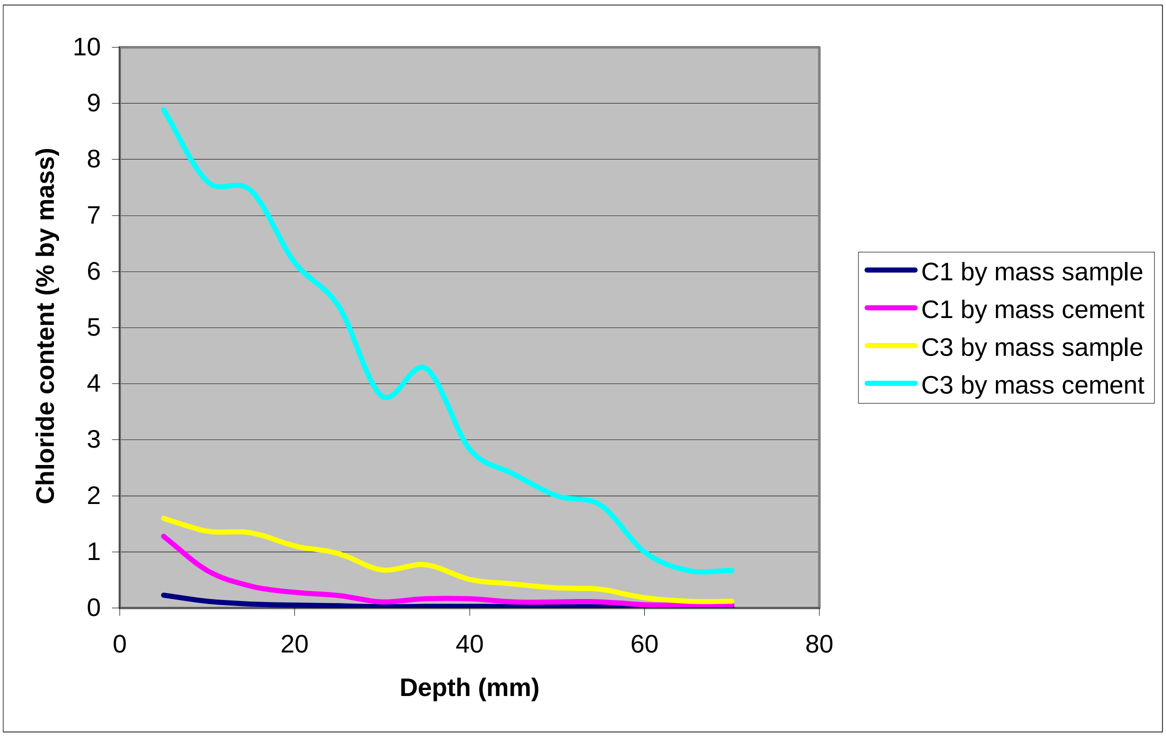
RSK Environment Ltd
Tel: +44 (0) 1442 437500
Fax: +44 (0) 1442 437550
Email: info2@rsk.co.uk
Web: www.rsk.co.uk/stats

Materials & Structures
18 Frogmore Road
Hemel Hempstead
Hertfordshire
HP3 9RT

UKAS TESTING
0278

Results				
Depth (mm):	**Chloride (as Cl ion)**			
	11675/C1 (containing Caltite)		**11675/C3 (not containing Caltite)**	
	% by mass sample	**% by mass cement**	**% by mass sample**	**% by mass cement**
0-5	0.23	1.28	1.60	8.89
5-10	0.12	0.67	1.37	7.61
10-15	0.07	0.39	1.34	7.44
15-20	0.05	0.28	1.11	6.17
20-25	0.04	0.22	0.97	5.39
25-30	0.02	0.11	0.68	3.78
30-35	0.03	0.17	0.77	4.28
35-40	0.03	0.17	0.51	2.83
40-45	0.02	0.11	0.43	2.39
45-50	0.02	0.11	0.36	2.00
50-55	0.02	0.11	0.33	1.83
55-60	0.01	0.06	0.18	1.00
60-65	0.01	0.06	0.12	0.67
65-70	0.01	0.06	0.12	0.67
Inner surface	0.01	0.06	0.48	2.67

Graph of depth from outer surface against determined chloride content



End of Certificate

RSK Environment Ltd
Tel: +44 (0) 1442 437500
Fax: +44 (0) 1442 437550
Email: info2@rsk.co.uk
Web: www.rsk.co.uk/stats

Materials & Structures
18 Frogmore Road
Hemel Hempstead
Hertfordshire
HP3 9RT

UKAS TESTING
0278

Sulfate Content of Concrete
BS 1881-124: 1988

284188 Cementaid (WA Pty. Ltd), Fimiston Plant, Kalgoorlie-Boulder, WA

Client Details			
Cementaid (WA Pty. Ltd) 200 Star Street Welshpool Western Australia, 6105 Australia			
Contact name	Paul Mundell		
Order reference	None advised	Order date	None advised

Sample Details			
Sample type	Concrete		
Sampled by	Client	Sampling date	Not advised
RSK batch	11674	No. of samples	2
Receipt date	05/10/11	Test date/period	20/10/12

Methods	
Test	Two concrete core samples were received at RSK's laboratory and incremental dust samples were obtained by drilling. The sulfate content of the dust samples was determined in accordance with BS 1881-124:1988.
Deviations	None.

Results
The results are reported on page 2 of this certificate.

Certification			
Certificate prepared by Dr David Crofts Principal Scientist		Certificate reviewed by Paul Bennett-Hughes Principal Scientist	
Testing by	BJS	Certificate issue date	15/10/12

The results given in this certificate relate only to those samples submitted and specimens tested and to any materials properly represented by those samples and specimens. Any opinions and interpretations expressed herein are outside the scope of our UKAS accreditation.

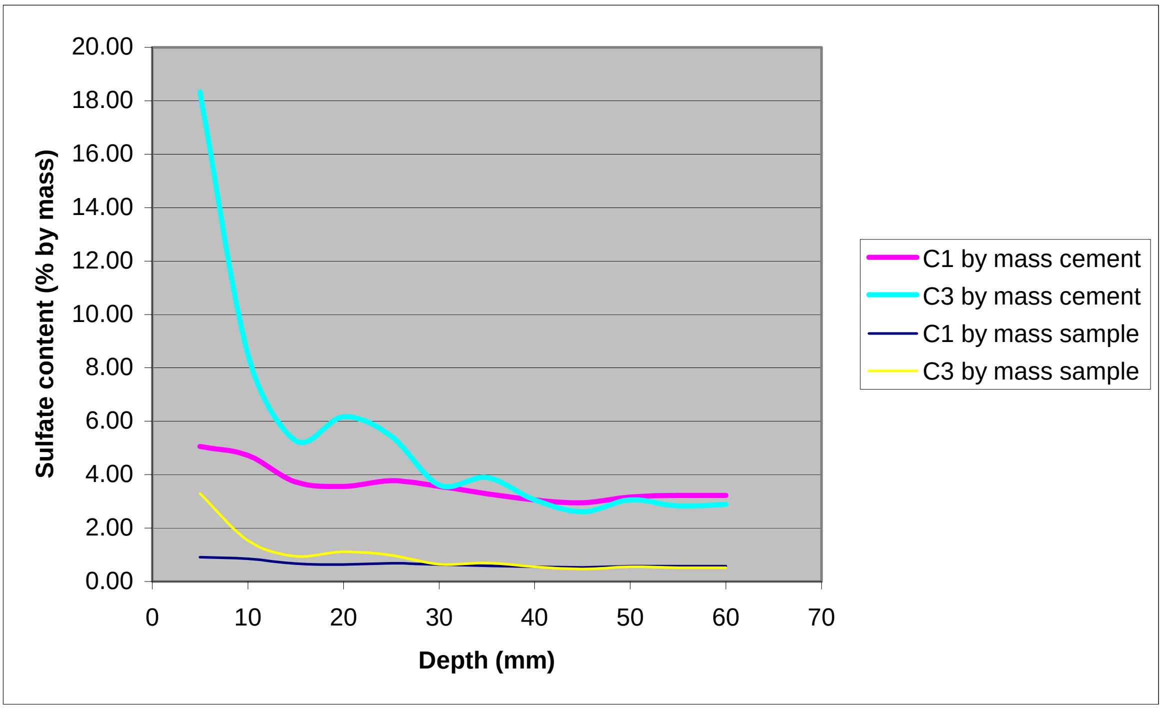
RSK Environment Ltd
Tel: +44 (0) 1442 437500
Fax: +44 (0) 1442 437550
Email: info2@rsk.co.uk
Web: www.rsk.co.uk/stats

Materials & Structures
18 Frogmore Road
Hemel Hempstead
Hertfordshire
HP3 9RT

UKAS TESTING
0278

Results				
Depth (mm):	**Sulfate (as SO_3)**			
	11675/C1 (containing Caltite)		**11675/C3 (not containing Caltite)**	
	% by mass sample	**% by mass cement**	**% by mass sample**	**% by mass cement**
0-5	0.91	5.06	3.3	18.33
5-10	0.85	4.72	1.53	8.50
10-15	0.67	3.72	0.95	5.28
15-20	0.64	3.56	1.11	6.17
20-25	0.68	3.78	0.98	5.44
25-30	0.64	3.56	0.65	3.61
30-35	0.59	3.28	0.7	3.89
35-40	0.55	3.06	0.55	3.06
40-45	0.53	2.94	0.47	2.61
45-50	0.57	3.17	0.55	3.06
50-55	0.58	3.22	0.51	2.83
55-60	0.58	3.22	0.52	2.89
Inner surface	0.49	2.72	0.61	3.39

Graph of depth from outer surface against determined sulfate content



End of Certificate

RSK Environment Ltd
Tel: +44 (0) 1442 437500
Fax: +44 (0) 1442 437550
Email: info2@rsk.co.uk
Web: www.rsk.co.uk/stats

Materials & Structures
18 Frogmore Road
Hemel Hempstead
Hertfordshire
HP3 9RT

Density, Absorption & Voids in Hardened Concrete
ASTM C642-06

284188 Cementaid (WA Pty. Ltd), Fimiston Plant, Kalgoorlie-Boulder, WA

Client Details			
Cementaid (WA Pty. Ltd) 200 Star Street Welshpool Western Australia, 6105 Australia			
Contact name	Paul Mundell		
Order reference	None advised	Order date	None advised

Sample Details			
Sample type	Concrete cores (95mm diameter)		
Sampled by	Client	Casting date	Not advised
RSK batch	11675	No of samples	6
Receipt date	05/10/12	Test date	15/10 – 19/10/12

Methods	
Test	Testing was carried out in accordance with ASTM C642-06.
Deviations	Individual test portions were derived from incremental depth slices from a single core. The individual portions were less than 350cm^3 in volume.

Results
The results are reported on page 2 of this certificate.

Certification			
Certificate prepared by Clive Rayner Principal Technician		Certificate reviewed by Andrew Grafton Director	
Testing by	CR	Certificate Issue Date	24/10/12

RSK Environment Ltd
Tel: +44 (0) 1442 437500
Fax: +44 (0) 1442 437550
Email: info2@rsk.co.uk
Web: www.rsk.co.uk/stats

Materials & Structures
18 Frogmore Road
Hemel Hempstead
Hertfordshire
HP3 9RT

Sample Details		
RSK reference	**Depth from outer surface, mm**	**Client reference / Location**
11675/C2-1	50-80	Core 2 – Concrete containing Caltite
11675/C2-2	80-110	
11675/C2-3	110-150	
11675/C4-1	50-80	Core 4 – Concrete without Caltite
11675/C4-2	80-110	
11675/C4-3	110-150	

Results								
RSK reference	C2-1	C2-2	C2-3	**C2**	C4-1	C4-2	C4-3	**C4**
Depth from outer surface, mm	50-80	80-110	110-150	**– Mean**	50-80	80-110	110-150	**– Mean**
Absorption after immersion (%)	2.54	1.27	0.84	**1.55**	5.22	4.94	4.44	**4.86**
Absorption after immersion and boiling (%)	5.51	4.16	3.87	**4.51**	5.45	5.27	4.63	**5.12**
Bulk density dry (Mg/m^3)	2.24	2.29	2.25	**2.26**	2.33	2.35	2.39	**2.36**
Bulk density after immersion (Mg/m^3)	2.30	2.31	2.27	**2.29**	2.45	2.47	2.50	**2.47**
Bulk density after immersion and boiling (Mg/m^3)	2.36	2.38	2.34	**2.36**	2.45	2.47	2.50	**2.47**
Apparent Density (Mg/m^3)	2.55	2.53	2.47	**2.52**	2.66	2.68	2.69	**2.68**
Volume of permeable pore space (voids) (%)	12.3	9.5	8.7	**10.2**	12.7	12.2	11.1	**12.0**

The results given in this certificate relate only to those samples submitted and specimens tested and to any materials properly represented by those samples and specimens.

End of Certificate

RSK Environment Ltd
Tel: +44 (0) 1442 437500
Fax: +44 (0) 1442 437550
Email: info2@rsk.co.uk
Web: www.rsk.co.uk/stats

Materials & Structures
18 Frogmore Road
Hemel Hempstead
Hertfordshire
HP3 9RT

UKAS TESTING
0278

Cement Content of Concrete
BS 1881-124:1988

284188 Cementaid (WA Pty. Ltd), Fimiston Plant, Kalgoorlie-Boulder, WA

Client Details			
Cementaid (WA Pty. Ltd) 200 Star Street Welshpool Western Australia, 6105 Australia			
Contact name	Paul Mundell		
Order reference	None advised	Order date	None advised

Sample Details			
Sample type	Concrete		
Sampled by	Client	Sampling date	Not advised
RSK batch no.	11675	No. of samples	2
Receipt date	05/10/11	Test date	29/11/12

Methods	
Test	The analyses for insoluble residue, soluble silica and calcium oxide were carried out in accordance with BS 1881-124:1988, Clause 5.
Precision	BS 1881-124:1988 suggests the following precision values for the determination of the cement content: Repeatability = 40kg/m^3, Reproducibility = 60kg/m^3
Deviations	None.

Summary of Results*		
RSK sample reference	11675/C2	11675/C4
Cement content, kg/m^3:	**446**	**423**

*A full table of results is included on page 2 of this certificate.

Certification			
Certificate prepared by Ben Stainton Senior Chemistry Technician		Certificate reviewed by Dr David B Crofts Principal Scientist	
Testing by	BJS	Certificate issue date	29/11/12

The results given in this certificate relate only to those samples submitted and specimens tested and to any materials properly represented by those samples and specimens. Any opinions and interpretations expressed herein are outside the scope of our UKAS accreditation.

RSK Environment Ltd
Tel: +44 (0) 1442 437500
Fax: +44 (0) 1442 437550
Email: info2@rsk.co.uk
Web: www.rsk.co.uk/stats

Materials & Structures
18 Frogmore Road
Hemel Hempstead
Hertfordshire
HP3 9RT

UKAS TESTING
0278

Sample Details	
RSK sample reference	Client sample reference
11675/C2	2
11675/C4	4

Results		
RSK sample reference	11675/C2	11675/C4
Determined values (% by mass)		
Insoluble residue	67.3	66.9
Soluble silica	4.3	4.1
Calcium oxide	15.2	15.1
Calculated values (% by mass)		
Portland cement ex silica	19.8	18.8
Portland cement ex lime	23.6	23.4
Preferred cement content value	19.8	18.8
Aggregate content	75.7	76.9
Mix proportions (ratio by mass)		
Aggregate/cement ratio	3.8	4.1
Cement content (kg/m^3)	**446**	**423**
Assumptions		
Soluble silica in cement (% by mass)	20.2	
Calcium oxide in cement (% by mass)	64.5	
Soluble silica in aggregate (% by mass)	0.4	
Calcium oxide in aggregate (% by mass)	0.0	
Dry density of concrete (kg/m^3)	2250	
Water of hydration of concrete (% by mass)	23	

End of Certificate

RSK Environment Ltd
Tel: +44 (0) 1442 437500
Fax: +44 (0) 1442 437550
Email: info2@rsk.co.uk
Web: www.rsk.co.uk/stats

Materials & Structures
18 Frogmore Road
Hemel Hempstead
Hertfordshire
HP3 9RT

Original Total Water/Cement Ratio of Concrete
BS 1881-124: 1988

284188 Cementaid (WA Pty. Ltd), Fimiston Plant, Kalgoorlie-Boulder, WA

Client Details			
Cementaid (WA Pty. Ltd) 200 Star Street Welshpool Western Australia, 6105 Australia			
Contact name	Paul Mundell		
Order reference	None advised	Order date	None advised

Sample Details			
Sample type	Concrete		
Sampled by	Client	Sampling date	Not advised
RSK batch	11675	No. of samples	2
Receipt date	05/10/11	Test date/period	20/10/12

Methods	
Test	The analysis was carried out in accordance with BS 1881-124: 1988 clause 7.2.
Remarks	The cement contents of the samples were determined (see certificate 284188/41094).
Deviations	The solvent used was tetrachloroethene.

Results

RSK sample reference	Client sample reference	Capillary porosity (% by mass)	Cement content (% by mass)	Water/cement ratio
11675/C2	2	6.3	19.8	0.5
11675/C4	4	4.2	18.8	0.5

Certification			
Certificate prepared by Ben Stainton Senior Chemistry Technician		Certificate reviewed by Dr David B Crofts Principal Scientist	
Testing by	BJS	Certificate issue date	29/11/12

The results given in this certificate relate only to those samples submitted and specimens tested and to any materials properly represented by those samples and specimens.

End of Certificate