

02/03/2025

SAMPLE REPORT



Sunlight House
Little Quay Street
Manchester
M3 3HP

Structures Group
132-134 Chapel Street
Leigh
Greater Manchester
WN7 2DB

PREPARED FOR :
MYCO

A. Introduction

This report provides a comprehensive overview of the restoration and cleaning works undertaken at Sunlight House, Manchester. The primary focus is to document the results of the DOFF (Integra) cleaning system, assess the suitability of stone repair materials and outline the proposed methodology for pointing and stone indents. This document aims to ensure that all restoration processes adhere to best practices and receive the necessary approvals before full implementation.

Where necessary, the report includes photographs illustrating the before and after results. These images serve to demonstrate the effectiveness of the DOFF cleaning method in removing surface contaminants while preserving the integrity of the stone. Accompanying this visual documentation is the relevant data sheets, providing the technical specifications and full details of the cleaning process.

An evaluation of the stone and repair mortars has been undertaken to identify the most appropriate match. After sampling, it has been determined that the closest match to the existing stone is 'Cotswold Gold'. Whereas 'Millstone' has been identified as the most comparable colour to the stone face, which appears to have had a previous coating applied (not sampled). Both of these form part of the Wormsley colour range and the relevant data sheets have been included for reference.

All sample works are undertaken in compliance with the Health and Safety at Work Act 1974, the Working at Height Regulations Act 2005, the Construction Design Management Regulations 2015 and the Control of Substances Hazardous to Health Regulations 1998. Strict adherence to these regulations ensures that all procedures are carried out with the highest levels of safety and legal compliance.

Figure 1 – Location & Local Environment



B. DOFF Cleaning

Methodology

Access Control: all other personnel except the operator are to be kept away from the working area.

Personal Protective Equipment (PPE): the following PPE must be worn:

- Rubber-dipped cloth gloves
- Eye protection (visor)

- Ear defenders (above 30 bar pressure)
- Waterproof clothing (skin to be covered)
- Respiratory equipment will be advisable if toxic coatings are suspected or if bird/animal droppings are to be removed.

Electrical Safety: 110V power supply to be used. All electrical equipment to be PAT tested.

Qualified Operation: the cleaning of the building surface will be carried out by a capable operator who has been instructed by Stone Health Ltd. into the proper use of the DOFF Cleaning System.

Equipment Operation:

- The DOFF will be connected to the water supply and then switched on only when in use.
- Care to be taken when handling the lance as some parts can become very hot.
- All windows etc. to be protected if required.
- Adjustment of the water volume, pressure and temperature controls should be made whilst maintaining an appropriate distance of the nozzle from the work. A balance should be achieved in order to obtain an effective cleaning result without abrading the substrate. Consideration may also be given to differing nozzle specification i.e. aperture and spray angle.

Ventilation and Equipment Storage

Equipment should be placed in a well-ventilated area out of the reach of the lance or other water spray. The exhaust must not be covered or obscured. A purpose made ventilation duct can be used if required in an enclosed area. It will reassure the Operator if the unit can be observed, if only from a distance, by himself or an assistant.

Fuel Handling

The normal fuel for the DOFF is light diesel (red) or motor vehicle diesel (white) fuel. This will be stored in suitable marked containers or drums away from heat or direct sunlight. Storage will normally be at least some metres from the DOFF heater unit. Precautions should be made to avoid accidental or malicious spillage. If adjacent to drainage or water course

Containment may be appropriate. Avoid contact with skin, soil and vegetation. Transfer of fuel to the DOFF is ideally carried out using a 20 litre Jerry-can with "clip on" spout. If storage on site is difficult transfer to the site sufficient only to maintain continuity of working

Procedures

On completion of cleaning work, all polythene protection and masking tape are to be removed. Waterproof masking tape has a high degree of adhesion; its subsequent removal can lift unsound remofilms. As the paint condition is beyond our control, remedial works are to be undertaken at the client's expense.

At the end of the working day the DOFF is taken to secure storage supplied by the P/C. At the end of the working day any particles of dirt etc. are placed into bags and taken to the P/C waste management area and correctly disposed of.

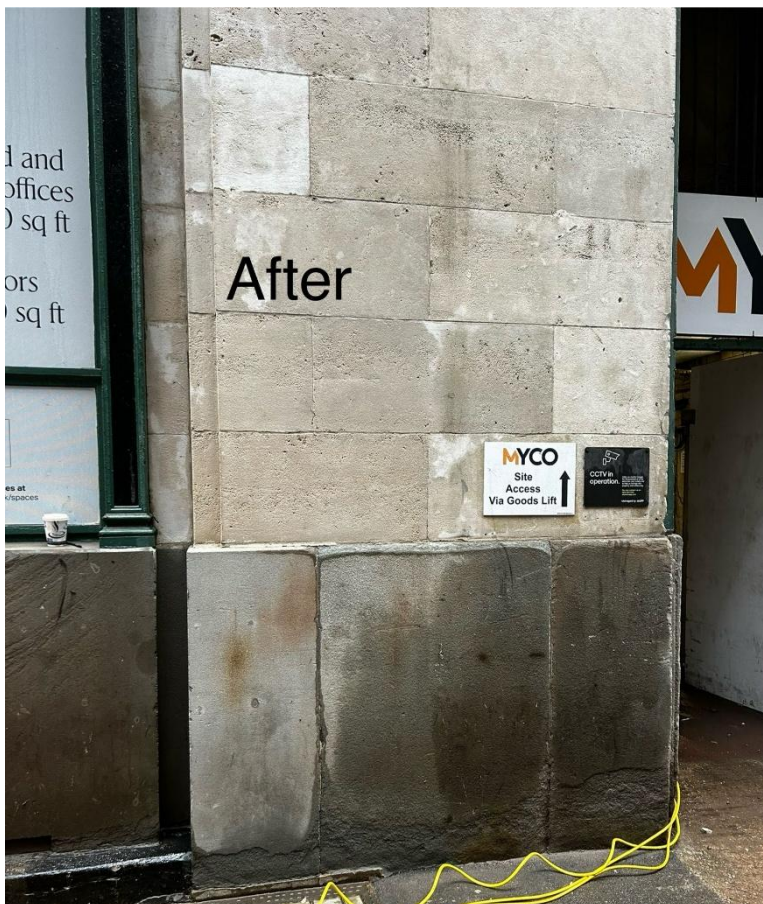
Whilst personnel working in the vicinity need not be inducted into the working of the system they should be made aware of the potential hazards – heat, ventilation, the temperature of metal/rubber components etc. Someone adjacent, other than the Operator

Outcome

Figure 2 – Stonework Before



Figure 3 – Stonework After





What is DOFF?

The DOFF Integra is a market leading, expertly engineered system that utilises a normal water supply to remove some of the more resistant forms of unwanted matter from a range of surfaces. The DOFF Integra is an advancement of the original DOFF Standard, providing greater ease of operation - eg improved manoeuvrability, quick release of modular components, digital displays and easy loading.

The water supply is fed via a pump into a hot-box where it is rapidly heated to temperatures of up to 150°C. The heated water is then fed through high temperature heat resistant hoses to the special nozzle at a rate of between 3 to 5 litres per minute.

Once cleaned, the surface dries within minutes which prevents any long-term damage as a result of trapped moisture.



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What is the DOFF most effective in removing?

Paint coatings (most oil and plastic types)
Certain types of graffiti
Bird or vermin fouling
Algae, moss, and fungi
Wax coatings
Chewing gum
Bitumen, Oil, Grease and many others, all without causing any damage or disfiguring the substrate.

What surfaces should I use the DOFF on?

We recommend the DOFF for use on surfaces such as brick, stone, concrete, tiled (glazed and encaustic), wood, faience and terracotta. It is a useful sterilisation tool for kitchens, toilets, swimming pools, hospitals and factories.

Where can I use DOFF?

DOFF can be used in Building restoration, Industry, Food production, Hygiene control, Hospitals, Factories, Transport & vehicle depots, Workshops etc.

How does DOFF work?

A normal water supply is taken through the pump into the Hotbox, where a range of temperatures of up to 150° C can be achieved. The low volume of super heated water and steam (5 litres per minute) is then fed through heat resistant hoses to special nozzles where a genuine 150° C is delivered. The surface being cleaned does not suffer any damaging pressure, thermal shock or deep saturation and dries within minutes. A range of different lances and nozzles are available.



TECHNICAL SPECIFICATION

DOFF INTEGRA

Power Supply Consumption	230 volt 50 hz 13 amp or 6.5 Kva (generator), 50 hz 30 amp or 6.5 Kva (generator), 115 volt 60 hz 30 amp or 6.5 Kva (generator), 110v 50hz 30 amp or 6.5Kva (generator)			
Water Consumption	Min 3, max 5 litres per minute. Use only clean cold water supply - if bowser or other, consult our technical team for advice			
Maximum Operating Pressure	100 bar 1450 psi			
Temperature Range	30°C to 150 °C			
Maximum Water Input temp.	30 °C			
Dry Weight kg	89 (hotbox) + 34.5 (pump) = when loaded 123.5			
Measurement mm		Length	Width	Height
	Pump	500	282	310
	Hotbox	680	630	1030
		When pump loaded length = 960		
Export Packing mm		1020	820	1150

Figure 4 – Sample Repair



The stone repair carried out demonstrates a strong match to the surrounding stone. The repair mortar used was the Wormsley's 'Cotswold Gold'. The colour and texture closely align with the existing stone, ensuring a repair that blends well with the original façade. While there are slight tonal differences, these are expected to soften over time as natural weathering takes place. The repair provides a durable and visually consistent solution.

Figure 5 – Sample Material



The closest colour match to the stone face, which appears to have had a previous coating applied, is Wormsley's 'Millstone'. Although no physical sample was carried out on site, the attached image of the sampled tray provides a clear comparison. The fragment of existing stone placed against the sample board closely aligns with the Millstone shade, suggesting that this is the most suitable option for areas where the original coating has altered the stone's appearance.



Issue 2 – March 2023

Stone and Brick Repair – Data Sheet

Product

Womersley's Stone Repair Mix is a mortar for recreating and patch repairing bricks and natural stones in a wide range of colours. The Stone repair mix can be carved, sanded, dressed and shaped like stone to give a uniquely convincing look and feel.

Manufactured on site from Lime Green Contour mortar and Colour Blaze natural pigments.

This product is not suitable for concrete repair.

Coverage

Approximately 1.7kg of dry mortar is required per litre. A 25 kg tub yields around 15 litres.

Advantages

- Quality controlled production
- Consistency of mix ratio
- Natural Elasticity to absorb minor building movements
- Breathable
- Entirely natural

Surface Preparation

The background must be assessed before work commences for the cause of decay and compatibility of the repair mix. Remove any loose or friable masonry, and any contamination. Stone or bricks which are heavily salt contaminated may not be suitable. Highly porous backgrounds should be primed the day before with a gritty brush on primer. Ensure the background is suitable for supporting the weight of the new material (10mm of Contour over 1m² weigh approx. 20kg). Brass armatures or stainless-steel lath may be required to support the mix on thicker build ups.

How to Mix

Carefully add the powder to clean water, using no more than 5 litres per 24kg tub. Mix for between 2 and 5 minutes until a workable consistency is achieved. Do not re-work. Do not use in temperatures less than 3°C or over 25°C.

How to Apply

Lightly damp the background, before applying with a hawk and trowel. Womersley's Stone Repair Mix should be used for patching or creating "blocks" of stone or brick effect. Never apply in a continuous coat as a render. Coats should be a minimum of 6mm and no more than 40mm. For multiple coats key each coat and apply green on green. For carved or cut back finishes apply the mix slight beyond the finished levels. As the mortar hardens it will become possible to cut and carve it back. A wide range of tools and techniques are suitable, and trials should be made. Our stone mix may also be run in situ for small repairs using traditional techniques.

Casting

Pour into a mould prepared with mould release oil, using vibration to remove air bubbles and allow to set. It is not suitable for very large cast pieces.

Womersley's Ltd

Ravensthorpe Industrial Estate, Low Mill Lane, Ravensthorpe, West Yorkshire, WF13 3LN,
Tel: 01924 400 651 Email: info@womersleys.co.uk

Curing

Prevent from drying out too rapidly, covering with hessian if necessary. Protect from frost for at least 7 days.

Fixing

Enrichments and other pieces can be fixed mechanically or adhesively to facades. If fixed at height, bond tests or pull out tests will be necessary and should be arranged at the design stage

Packaging

Available in Availability In 1 /5/10/ 24kg tubs. The plastic used is suitable for recycling.

Storage

Store in a dry place free from damp and drafts. Use within 6 months.

Performance

- Fire Class A1
- Typical Compressive strength 8 to 10N/mm²
- Adhesion To be determined after site tests.

Health and Safety

Wear suitable PPE, including gloves, dust mask and goggles. Do not breath the dust. Wash any dust or mixed materials off skin straight away with plenty of clean water. Wash tools with clean water.

Risk Phrases	Safety phrases
R36/37/38 Irritating to eyes, respiratory system and skin	S2 Keep out of reach of children
R43 Contact with wet mortar may cause irritation, dermatitis and/or burns	S26 In case contact with eyes, rinse immediately with plenty water and seek medical advice.
R 66 Repeated exposure may cause skin dryness and cracking	S24/25 Avoid contact with skin and eyes
	S36 Wear suitable protective clothing

Declaration

This product contains no cement.

All Womersley's products are manufactured under an ISO9001:2015 accredited factory production control system.

Womersley's Ltd

Ravensthorpe Industrial Estate, Low Mill Lane, Ravensthorpe, West Yorkshire, WF13 3LN,
Tel: 01924 400 651 Email: info@womersleys.co.uk

D. New Stone & Indents



The image above showcases two samples of Portland stone, which have been selected for the stone indent repairs. These samples will be used to ensure a close match to the existing stonework, both in terms of colour and texture, maintaining the architectural integrity of the building. Before any full-scale implementation, sample indents will need to be carried out at high level to assess their suitability in situ. These trial indents will be subject to review and formal approval by the planning officer before any further work proceeds. This approach will ensure that all stone replacement works are conducted in line with conservation best practices and meet the required aesthetic standards.

E. Pointing

Pointing samples are to be carried out from the scaffold to closely match the original mortar in both colour and texture. These samples will serve as benchmarks for the works and will be subject to formal approval before proceeding further. The approval process will involve sign-off from the relevant parties, ensuring that the selected mortar blend is deemed suitable.

At present, we are awaiting a mortar specification from Wormsley's / Steadfast to determine the most appropriate mix for the project. Once received, this specification will inform the pointing methodology. No pointing works shall commence until the samples have been reviewed and officially signed off.

Please see petrographic analysis below:

F. Pointing Addendums



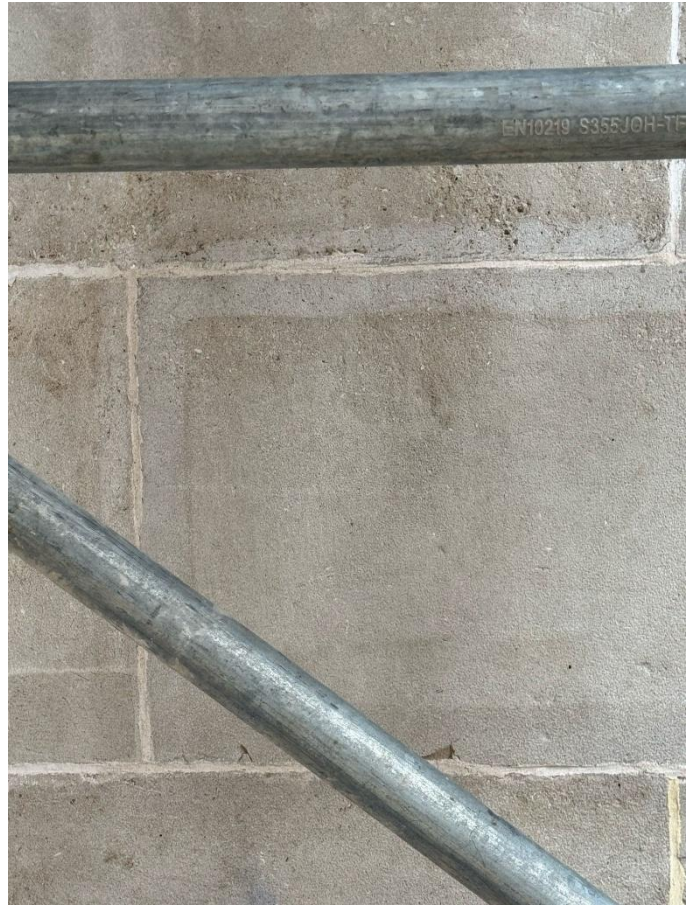
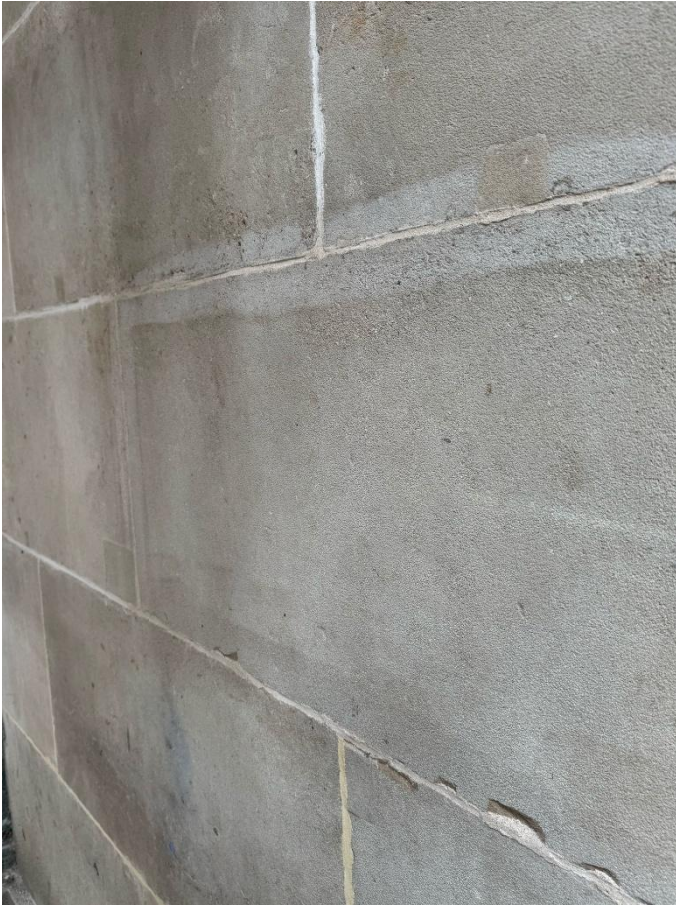
Sample 1

Womersley's Natural Lime Mortar – Colour 23.

Sample 2

Womersley's Natural Lime Mortar – Cotswold.

2.0



Sample 1

Womersley's Natural Lime Mortar – Colour 23.

1.1 Treated and brushed back

Product Data Sheet: Natural Lime Mortar

9/09/2014

Pre mixed natural hydraulic lime and sand mortar. A general purpose mortar for building or pointing stone, brick and block: available in different strengths, sand gradings and colours.

General Information

Lime Green Natural mortar is a dry pre-mixed lime mortar made with St Astier pure and natural hydraulic lime and including pigments where required.

Three different sand textures are available:

SG (approx 1mm down)
RG (approx 2mm down)
CG (approx 3mm down)

Lime Green has a wide range of colour options. Product samples may be ordered.

Packaging

Available in 25 kg bags or sealed one tonne bulk bags. All colours and textures other than off white (CG20) are made to order. Please call for lead times.

Coverage

Repointing: 20kg m² stonework; 7kg m² brickwork.

1 kg of dried product per brick, or 1.5 tonnes will produce 1 metre cubed of mortar.

Which Mortar?

Mortar Application	Natural Lime Mortar Grade
General solid brick and stone walls, parapets and lintels	Medium mortar Made with NHL3.5 lime
Above roofline, below DPC incl. copings and cappings, earth retaining walls	Strong mortar Made with NHL5 lime
The correct specification for any mortar should consider the structural requirements, the nature and condition of the background, site exposure, the time of the year and type of finish required. Less porous masonry units and harsh climates require greater mortar strength.	

Surface Preparation

Before pointing or building, clean and remove all dust and loose material from joints and masonry, and adequately dampen dry on high suction surfaces.

How to Mix

Slowly add 25 kg of Lime Green Natural mortar into a drum mixer. Add only 4 to 5 litres of clean water. Pour the water in slowly as the product mixes, using just enough to achieve the correct workability. Mix for 3 to 10 min. Lime Green mortars may be reworked up to 8hrs. Please contact us for further information.

How to Apply

Pointing and building mortars should be finished the same day or the following day in cooler periods. Lime mortars require longer curing times than cement, but the methods and principles of application are similar. When pointing or laying hard impervious masonry and / or during damp cool weather lime mortars may take a few weeks before being fully able to resist frosts. Do not use in temperatures less than 5 °C or over 30°C.





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Report - 78470/K

REPORT ON THE PETROGRAPHIC EXAMINATION OF THREE MORTAR SAMPLES
(Site: Sunlight House, Manchester; Project Ref. Project Ref 002579WJ476)



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This report comprises

Cover page

6 pages of text

Appendix A – 3 pages of petrographic descriptions

Appendix B – 3 pages of photographs illustrating the samples

Appendix C – 8 pages of photomicrographs of the thin sections

Appendix D – 5 pages of petrographic procedures and glossary

Back page

For the attention of Mr Toni Howarth

20 November 2024

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Report - 78470/K

REPORT ON THE PETROGRAPHIC EXAMINATION OF THREE MORTAR SAMPLES (Site: Sunlight House, Manchester; Project Ref. Project Ref 002579WJ476)

1 INTRODUCTION

Three small mortar samples advised to be from Sunlight House, Manchester were provided for analysis on 28 October 2024. It was requested that the samples be examined to identify their constituents and to assist in the replication of the mortars at site with modern materials. Instructions to proceed with the analysis were submitted under Purchase Order No. 002579/WJ476 23 October 2024.

2 SAMPLES

The following samples were provided for analysis:

Laboratory reference	Client / site reference	Mass, g
K19563/1	Atkinson Street - Sample 1	1.03
K19563/2	Little Quay Street - Sample 2	6.35
K19563/3	Courtyard - Sample 3	1.50

3 TEST METHODS

The petrographic testing was carried out in accordance with BS 1881-211, 2016¹. A summary of the procedures followed and a glossary of terms used in the description of the samples are given in Appendix D. In brief, the following work was carried out.

- (i) The samples were examined as received and photographed.
- (ii) A longitudinal fluorescent resin impregnated thin section was prepared from the most deteriorated inner ends of each core representing the cores between their inner surfaces and maximum depths of 67mm. Each thin section measured about 45x67mm.
- (iii) The thin sections were examined with a Zeiss petrological photomicroscope and the distribution of porosity and microcracking was assessed from an examination of the thin sections in fluorescent light using the petrological microscope.

4 PETROGRAPHIC EXAMINATION RESULTS

4.1 Visual description of the samples

Visual descriptions of the samples as received are given in Table A1 in Appendix A and photographs illustrating the samples as received are given in Appendix B.

4.2 Petrographic description of the aggregate

A petrographic description of the aggregate in each core is given in Table A2 in Appendix A.

4.3 Petrographic description of the paste

A petrographic description of the paste in each core is given in Table A3 in Appendix A. Photomicrographs illustrating the typical appearance of the paste in the thin sections are given in Appendix C.

¹ BS 1881-211:2016 Testing concrete. Procedure and terminology for the petrographic examination of hardened concrete

5 SUMMARY - ATKINSON STREET - SAMPLE 1

5.1 Mortar types - Atkinson Street - Sample 1

The sample includes two types of lime mortar and a modern Portland cement-based mortar.

The two lime-based mortars differ mainly in terms of their aggregate contents with the Type 1 lime mortar containing only traces of aggregate and the Type 2 lime mortar containing an abundant fine sand.

The Portland cement based mortar contains fine quartz sand.

5.2 Aggregate characteristics - Atkinson Street - Sample 1

The aggregate characteristics in each mortar type are compared in the table below.

Lab. Ref.	K19563/1		
Client Ref.	Atkinson Street - Sample 1 – Aggregate characteristics		
Mortar type	<i>Type 1 lime mortar</i>	<i>Type 2 lime mortar</i>	<i>Portland cement mortar</i>
Sand type	Quartz sand (trace)	Quartz sand	Quartz sand
Estimated grading	Note 1	Fine	Fine
Nominal maximum size	0.3	0.3	0.3
Dominant particle types	Quartz	Quartz	Quartz

Note 1: Very little aggregate present.

5.3 Matrix characteristics - Atkinson Street - Sample 1

The aggregate characteristics in each mortar type are compared in the table below.

Lab. Ref.	K19563/1		
Client Ref.	Atkinson Street - Sample 1 – Matrix characteristics		
Mortar type	<i>Type 1 lime mortar</i>	<i>Type 2 lime mortar</i>	<i>Portland cement mortar</i>
Binder type	Hydraulic lime	Hydraulic lime	Portland cement resembling OPC
Calcium silicates and Portland cement	Moderate amounts calcium silicate particles composed of belite. Traces of calcium silicate particles that contain alite, possibly indicating the presence of traces of white Portland cement.	Moderate amounts calcium silicate particles composed of belite. Traces of calcium silicate particles that contain alite, possibly indicating the presence of traces of white Portland cement.	Moderate amounts of unhydrated Portland cement grains
Carbonation	Fully carbonated	Fully carbonated	Almost fully carbonated
Alteration	None seen	None seen	None seen

6 SUMMARY - LITTLE QUAY STREET - SAMPLE 2

6.1 Mortar types - Little Quay Street - Sample 2

The sample consists of a single type of mortar with a blend of fine quartz sand and crushed limestone that is probably crushed Portland stone in a hydraulic lime binder. The composition of the mortar is such that it superficially resembles Portland stone.

6.2 Aggregate characteristics - Little Quay Street - Sample 2

The aggregate characteristics are summarised in the table below.

Lab. Ref.	K19563/2
Client Ref.	Little Quay Street - Sample 2
Mortar type	<i>Hydraulic lime mortar</i>
Aggregate type	Blend of Quartz sand and crushed limestone resembling Portland stone
Estimated grading	Fine
Nominal maximum size	0.6
Dominant particle types	Quartz and Limestone

6.3 Matrix characteristics - Little Quay Street - Sample 2

The aggregate characteristics are summarised in the table below.

Lab. Ref.	K19563/2
Client Ref.	Little Quay Street - Sample 2
Mortar type	<i>Hydraulic lime mortar</i>
Binder type	Hydraulic lime
Calcium silicates and Portland cement	Traces calcium silicate particles composed of belite. Very rare calcium silicate particles that contain alite, possibly indicating the presence of traces of white Portland cement.
Carbonation	Fully carbonated
Alteration	None seen

7 SUMMARY - COURTYARD - SAMPLE 3

7.1 Mortar types - Courtyard - Sample 3

The sample consists of a single type of mortar with a blend of fine quartz sand and crushed limestone that is probably crushed Portland stone in a hydraulic lime binder. The composition of the mortar is such that it superficially resembles Portland stone.

7.2 Aggregate characteristics - Courtyard - Sample 3

The aggregate characteristics are summarised in the table below.

Lab. Ref.	K19563/3
Client Ref.	Courtyard - Sample 3
Aggregate type	Blend of Quartz sand and coal ash dust
Estimated grading	Fine
Nominal maximum size	0.3
Dominant particle types	Quartz and Ash

7.3 Matrix characteristics - Courtyard - Sample 3

The aggregate characteristics are summarised in the table below.

Lab. Ref.	K19563/3
Client Ref.	Courtyard - Sample 3
Binder type	The sample size is too small to reliably identify binder type. Traces of the outlines of particles resembling early Portland cement can occasionally be found. The mortar matrix also contains patches of microcrystalline gypsum ^{Note 1} .
Calcium silicates and Portland cement	Traces calcium silicate particles composed of belite. Very rare calcium silicate particles that contain alite, possibly indicating the presence of traces of white Portland cement. The presence of Portland cement is uncertain.
Carbonation	Uncarbonated with patchy calcite deposition
Alteration	Substantial alteration has occurred with some evidence of sulfate-related deterioration and weakening due to moisture ingress and calcite deposition.

Note 1: This may originate from historic atmospheric sulfur contamination. The possibility of calcium sulfate binder cannot however be ruled out.

8 REMARKS

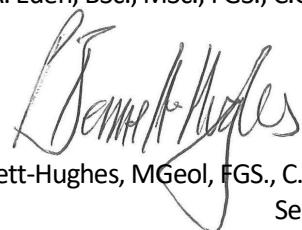
The above concludes the requested programme of testing. Please do not hesitate to contact us if we can be of any further assistance in this matter.

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For the attention of Mr Toni Howarth

for GEOMATERIALS RESEARCH SERVICES
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20 November 2024

Samples can only be retained for a period of two months from the date of issue of the report unless we are instructed otherwise. Samples can be returned or retained for a further charge.
Opinions and interpretations expressed herein are outside the scope of UKAS accreditation.

APPENDIX A – PETROGRAPHIC DESCRIPTION OF THE SAMPLES

PETROGRAPHIC EXAMINATION OF MORTAR - BS 1881-211, 2016

TABLE A1 OF 3: PETROGRAPHIC DESCRIPTION OF THE SAMPLES

Sandberg Ref.	K19563/1		
Client Ref.	Atkinson Street - Sample 1		
Condition of sample	Broken fragments ranging up to about 15mm containing three types of mortar as described below.		
Mortar type	Type 1 lime mortar	Type 2 lime mortar	Portland cement mortar
Summary of mortar constituents	Hydraulic lime with traces of chert and quartz sand particles.	Hydraulic lime with fine quartz sand	Portland cement binder with fine quartz sand
Overall colour of mortar	Yellowish white	Yellowish white	Medium greyish brown
Occurrence	Thin layer up to about 1.5mm thick consisting mainly of matrix with only traces of aggregate	The most abundant mortar type	Occurs beneath the Type 1 mortar
Aggregate			
<i>Coarse aggregate (>4mm particles)</i>	None seen	None seen	None seen
<i>Estimated BS EN 13139 sand grading classification</i>	To few sand particles present to estimate the grading. The largest sand particle measures 0.3mm	Fine 0/0.3	Fine 0/0.3
<i>Particle shape</i>	Subrounded	Subrounded	Subrounded
<i>Sand grain coatings</i>	None seen	None seen	None seen
<i>Major rock types (>20% of aggregate)</i>	Quartz	Quartz	Quartz
<i>Minor rock types (5-20% of aggregate)</i>	Feldspar	Quartzite	Quartzite
<i>Trace rock types (<5% of aggregate)</i>	-	Feldspar	Feldspar
Matrix			
<i>Binder type</i>	Hydraulic lime (high hydraulicity)	Hydraulic lime (high hydraulicity)	Portland cement – resembles OPC
<i>Undispersed lime / lime lumps</i>	Minor rounded fragments of undispersed lime	Minor rounded fragments of undispersed lime	None seen
<i>Portland cement and calcium silicates</i>	Moderate amounts calcium silicate particles composed of belite. Traces of calcium silicate particles that contain alite, possibly indicating the presence of traces of white Portland cement.	Moderate amounts calcium silicate particles composed of belite. Traces of calcium silicate particles that contain alite, possibly indicating the presence of traces of white Portland cement.	Moderate amounts of unhydrated Portland cement grains
<i>Carbonation</i>	Fully carbonated	Fully carbonated	Almost fully carbonated, other than the unhydrated cement grains
<i>Microporosity</i>	High	High	High
<i>Alteration of matrix other than carbonation</i>	None seen	None seen	None seen

PETROGRAPHIC EXAMINATION OF MORTAR - BS 1881-211, 2016
TABLE A2 OF 3: PETROGRAPHIC DESCRIPTION OF THE SAMPLES

Sandberg Ref.	K19563/2
Client Ref.	Little Quay Street - Sample 2
Condition of sample	Broken mortar fragments with a maximum dimension of about 30mm
Mortar type	Lime mortar
Summary of mortar constituents	Hydraulic lime binder with crushed Portland stone and fine quartz sand
Overall colour of mortar	Light yellow
Aggregate	
<i>Coarse aggregate (>4mm particles)</i>	None seen
<i>Estimated BS EN 13139 sand grading classification</i>	Crushed limestone 0/0.6 (fine) Sand 0/0.3 (fine)
<i>Particle shape</i>	Angular to subrounded (the sand particles are more rounded in shape than the limestone particles)
<i>Sand grain coatings</i>	None seen
<i>Major rock types (>20% of aggregate)</i>	Limestone ^{Note 1} , Quartz
<i>Minor rock types (5-20% of aggregate)</i>	Quartzite
<i>Trace rock types (<5% of aggregate)</i>	Feldspar
Matrix	
<i>Binder type</i>	Hydraulic lime
<i>Undispersed lime / lime lumps</i>	Rare rounded fragments, typically <0.1mm in diameter.
<i>Portland cement and calcium silicates</i>	Traces calcium silicate particles composed of belite. Very rare calcium silicate particles that contain alite, possibly indicating the presence of traces of white Portland cement.
<i>Carbonation</i>	Fully carbonated
<i>Microporosity</i>	High
<i>Alteration of matrix other than carbonation</i>	None seen

Note 1: Resembling Portland stone / oolitic limestone.

PETROGRAPHIC EXAMINATION OF MORTAR - BS 1881-211, 2016

TABLE A3 OF 3: PETROGRAPHIC DESCRIPTION OF THE SAMPLES

Sandberg Ref.	K19563/3
Client Ref.	Courtyard - Sample 3
Condition of sample	Broken mortar fragments with a maximum dimension of about 8mm and abundant loose sandy debris
Mortar type	Early Portland cement mortar
Summary of mortar constituents	Early Portland cement binder with coal ash dust and fine quartz sand. Many of the fragments contain abundant microcrystalline gypsum
Overall colour of mortar	Medium reddish brown
Aggregate	
<i>Coarse aggregate (>4mm particles)</i>	None seen
<i>Estimated BS EN 13139 sand grading classification</i>	Coal ash 0/0.1 (fine) Sand 0/0.3 (fine)
<i>Particle shape</i>	Angular to subrounded (the sand particles are more rounded in shape than the ash particles)
<i>Sand grain coatings</i>	None seen
<i>Major rock types (>20% of aggregate)</i>	Quartz, Coal ash
<i>Minor rock types (5-20% of aggregate)</i>	Quartzite
<i>Trace rock types (<5% of aggregate)</i>	Feldspar
Matrix	
<i>Binder type</i>	The sample size is too small to reliably identify binder type. Traces of the outlines of particles resembling early Portland cement can occasionally be found. The mortar matrix also contains patches of microcrystalline gypsum ^{Note 1} .
<i>Undispersed lime / lime lumps</i>	None seen
<i>Portland cement and calcium silicates</i>	The presence of Portland cement is uncertain.
<i>Carbonation</i>	Calcite deposition is occurring indicating the ingress of moisture containing dissolved CO ₂ .
<i>Microporosity</i>	High
<i>Alteration of matrix other than carbonation</i>	Substantial alteration has occurred with some evidence of sulfate-related deterioration and weakening due to moisture ingress and calcite deposition.

Note 1: This may originate from historic atmospheric sulfur contamination. The possibility of calcium sulfate binder cannot however be ruled out.

APPENDIX B – PHOTOGRAPHS ILLUSTRATING THE SAMPLES AS RECEIVED

Figure B1

Sample K19563/1

Atkinson Street - Sample 1

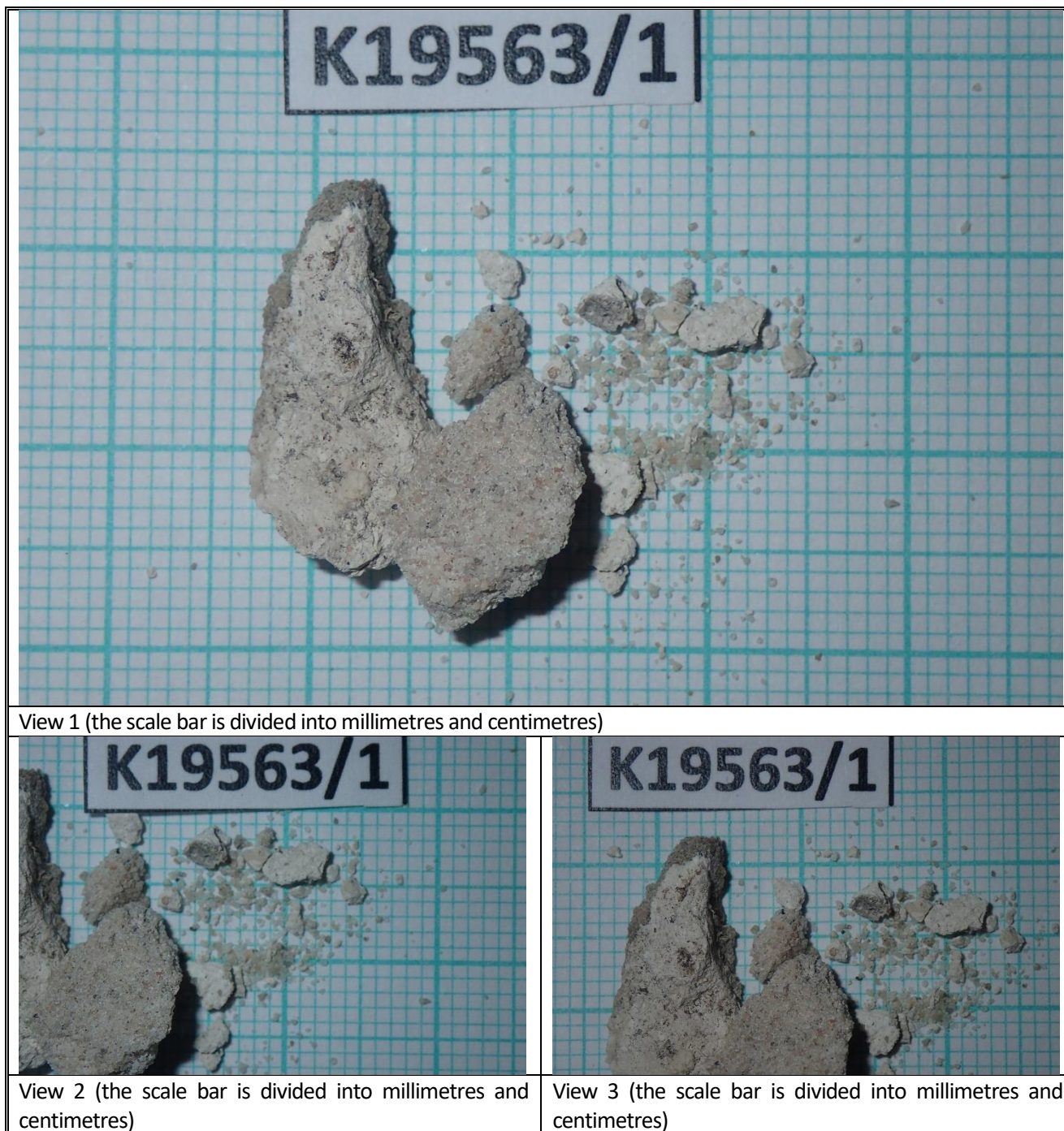


Figure B2

Sample K19563/2

Little Quay Street - Sample 2

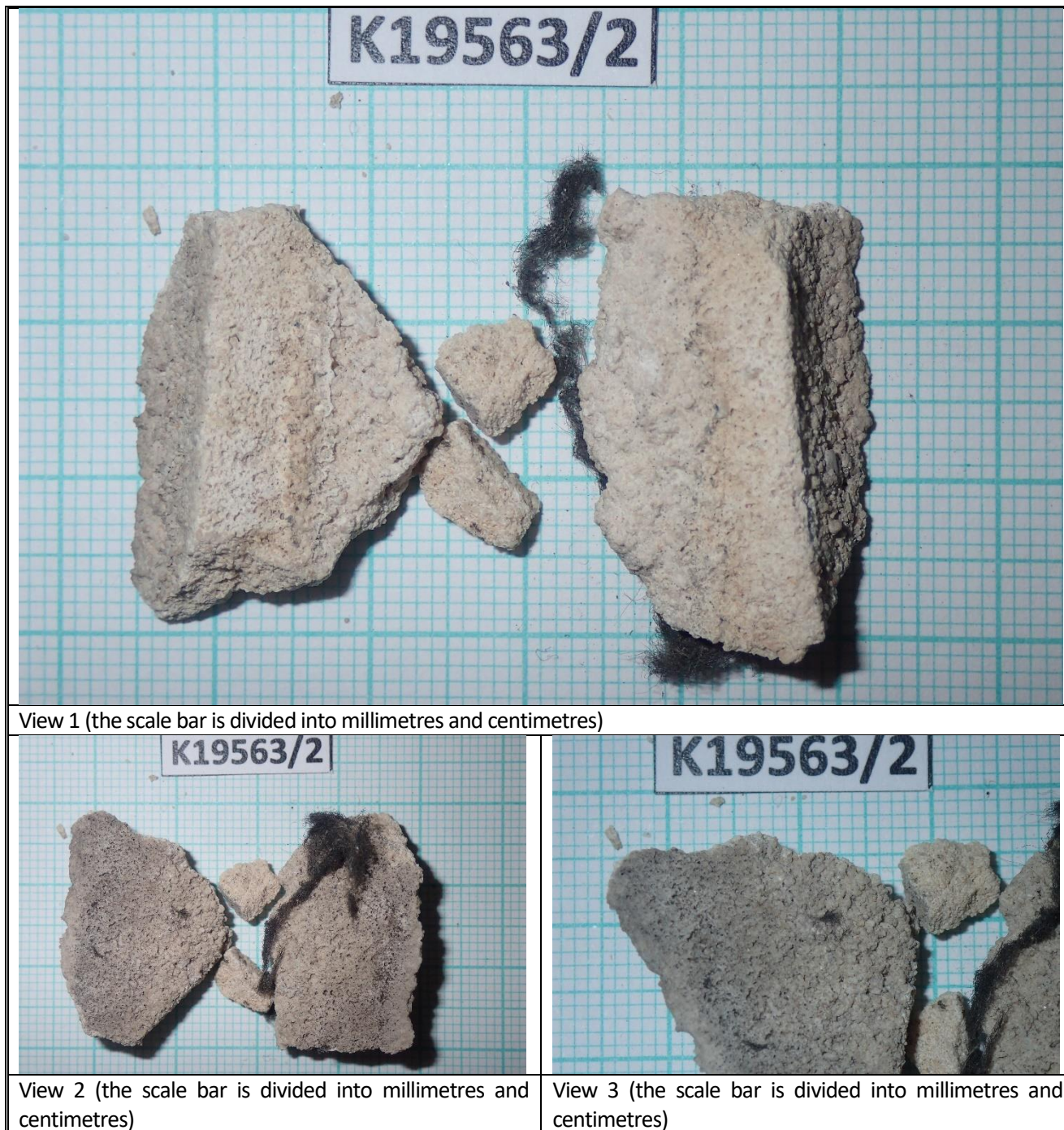
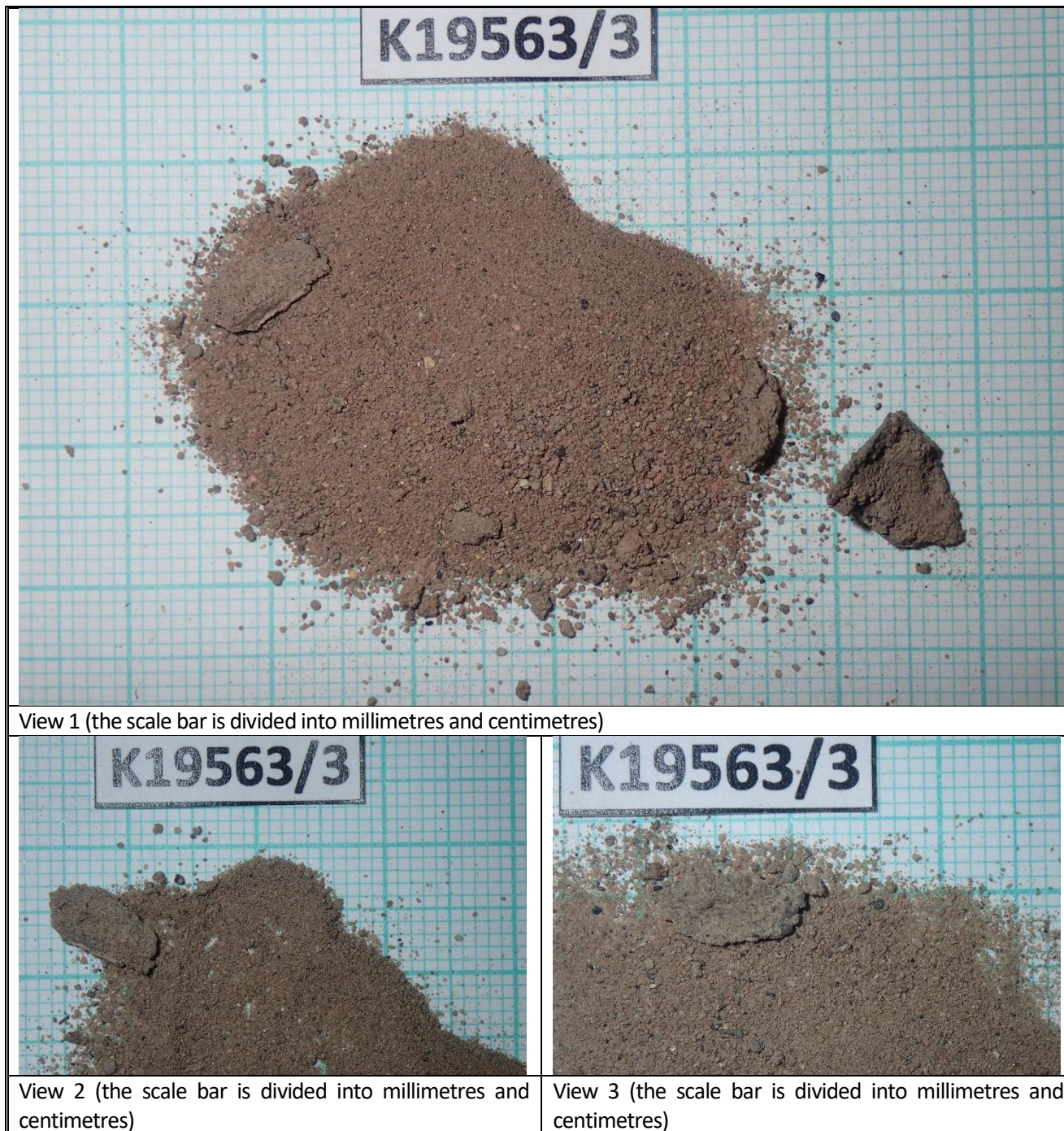


Figure B3

Sample K19563/3

Courtyard - Sample 3



APPENDIX C – PHOTOMICROGRAPHS ILLUSTRATING THE THIN SECTIONS

Figure C1

Sample K19563/1 Atkinson Street - Sample 1

Thin section, oblique polars: View showing the contact between the Type 1 lime mortar on the left and the Portland cement-based mortar on the right. The contact between the two mortar types is highlighted by the yellow dashed line. Unhydrated Portland cement grains (PC) and quartz (Qtz) sand particles are present in the Portland cement mortar. The Type 1 lime mortar is overwhelmingly dominated by carbonated lime matrix, visible for example in F2/3. The lime mortar contains rare calcium silicate (CS) particles.

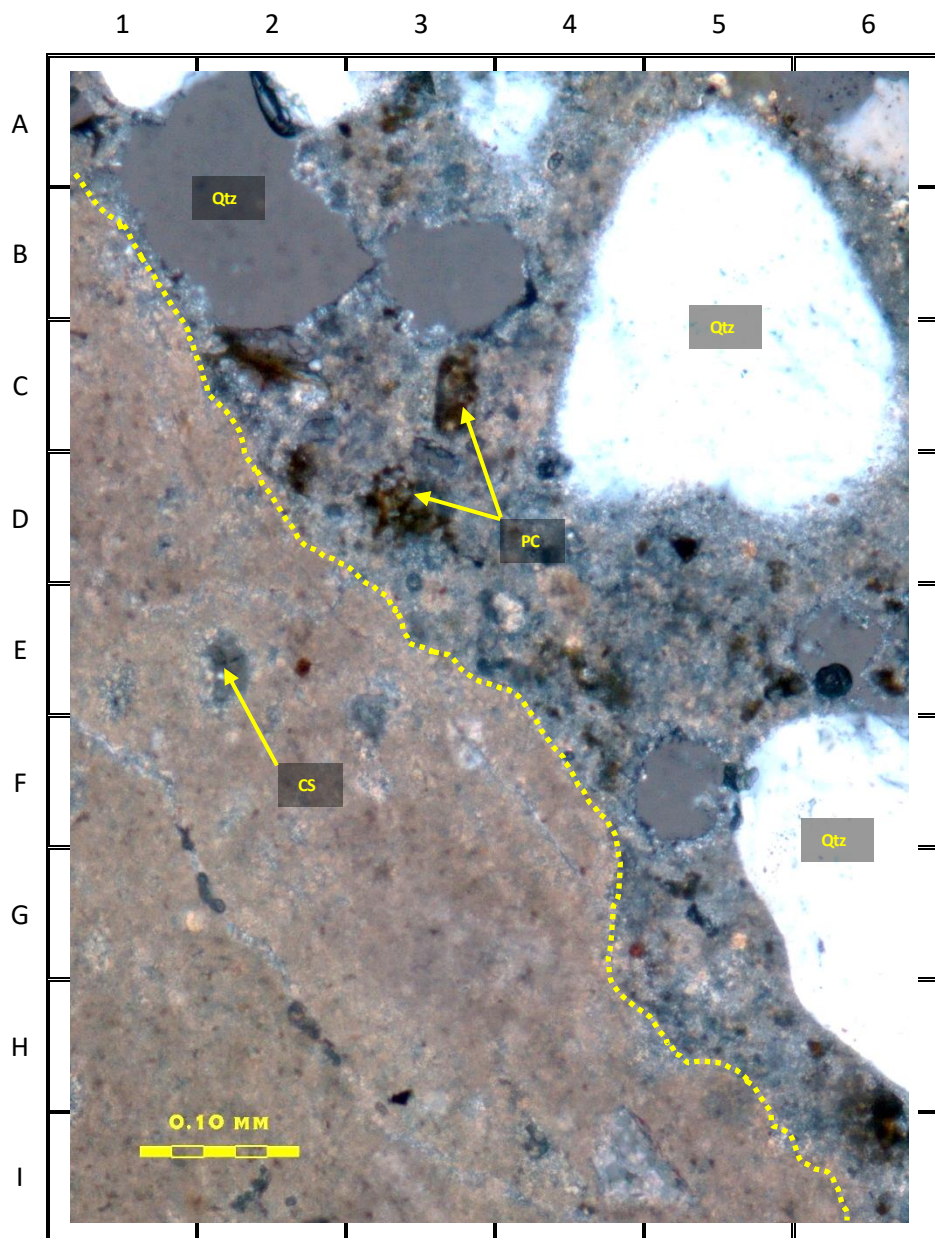


Figure C2

Sample K19563/1 Atkinson Street - Sample 1

Thin section, oblique polars: View showing the typical appearance of the Type 2 lime mortar. The field of view includes abundant quartz (Qtz) sand particles appearing various shades of grey that are surrounded by small amounts of hydraulic lime (HL) binder. Abundant voids are present throughout the field of view and can be seen for example in C2 and G3.

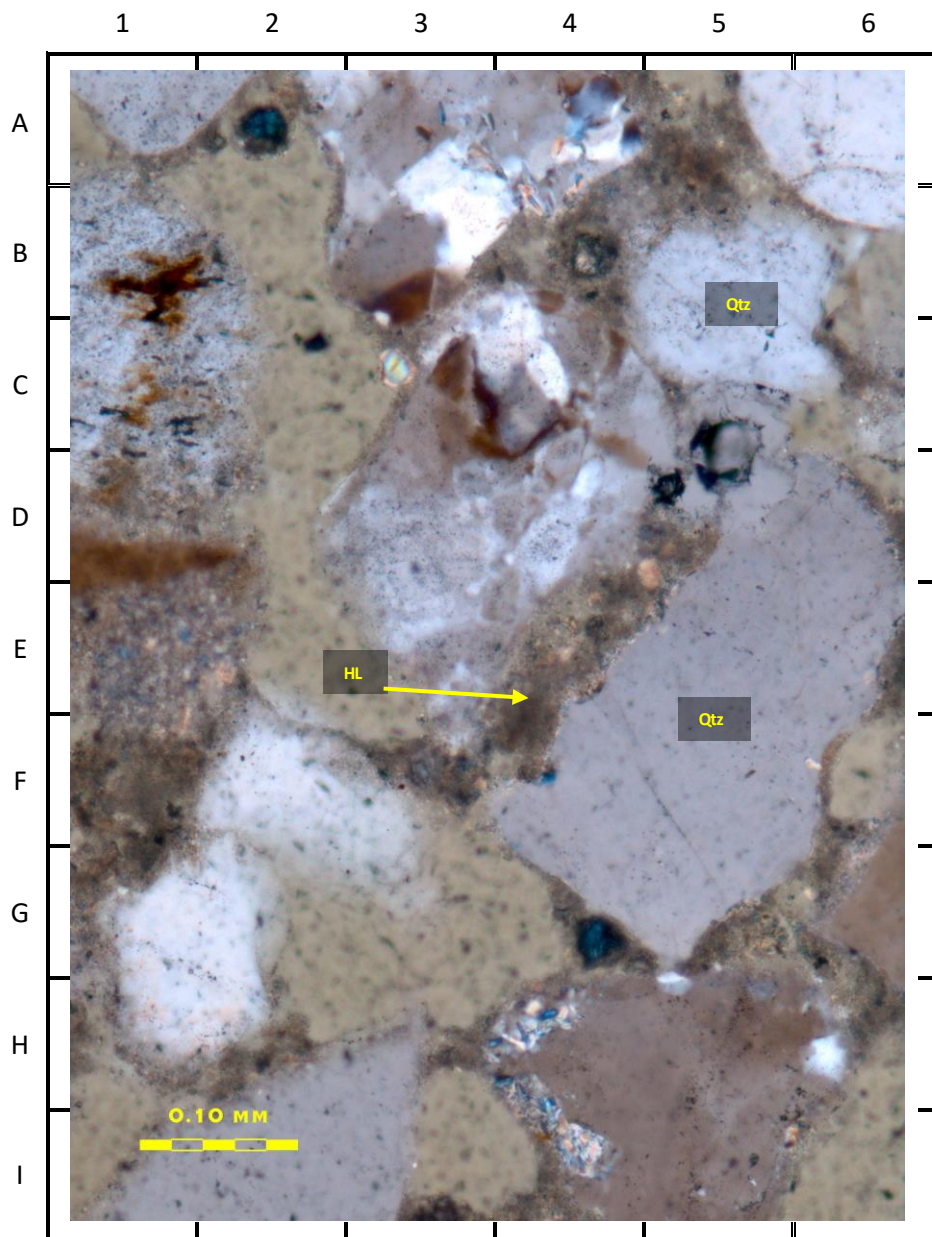


Figure C3

Sample K19563/1 Atkinson Street - Sample 1

Thin section, oblique polars: View showing an area of matrix in the Type 2 lime mortar. Note the partially hydrated calcium silicate (CS) particle that is surrounded by carbonated lime matrix, visible for example in F4. Several quartz (Qtz) sand particles are present.

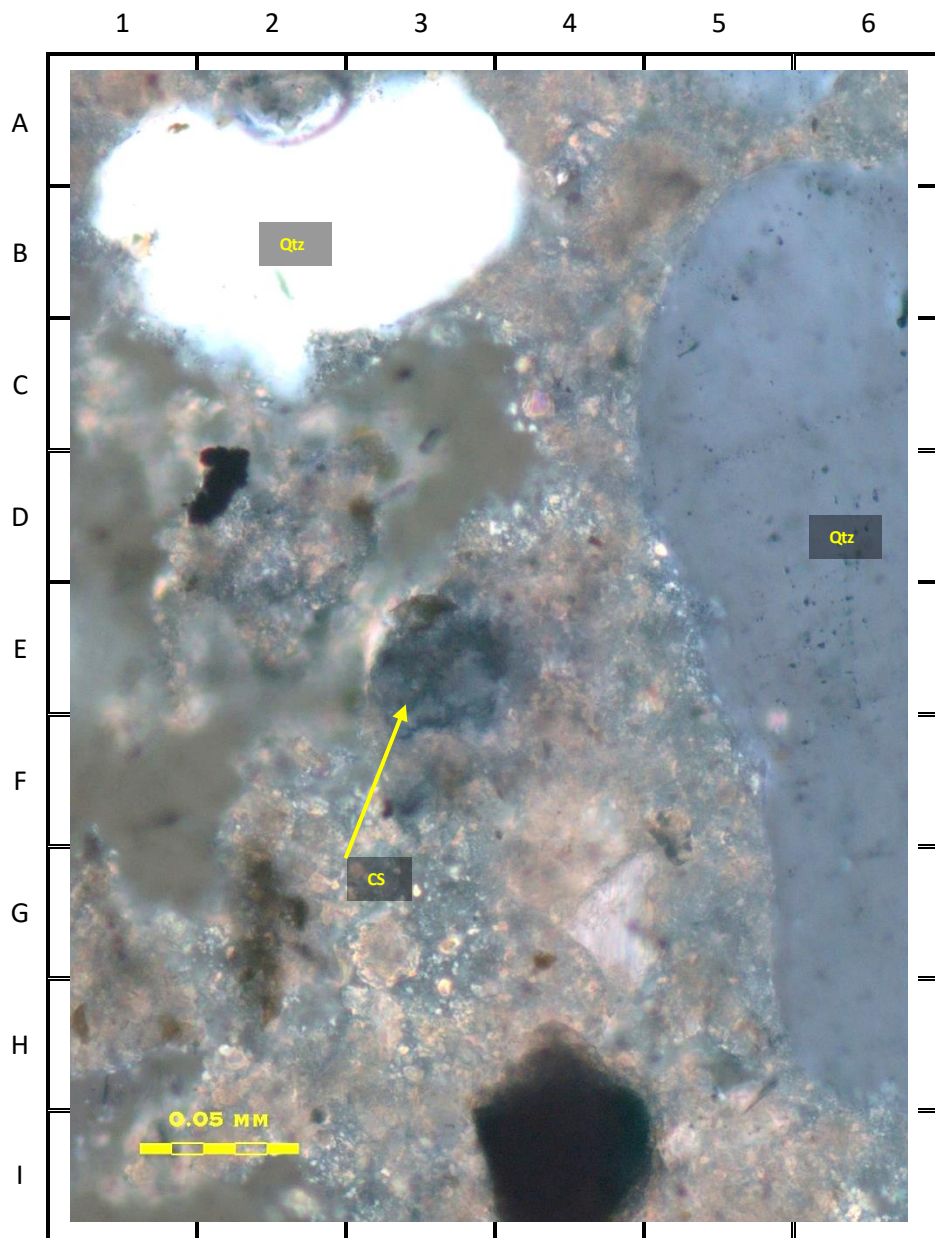


Figure C4

Sample K19563/2 Little Quay Street - Sample 2

Thin section, oblique polars: Low magnification view of the thin section showing abundant quartz sand particles appearing various shades of grey to white and crushed limestone particles, visible for example in F4 and C2 that are surrounded by an abundant carbonated hydraulic lime matrix.

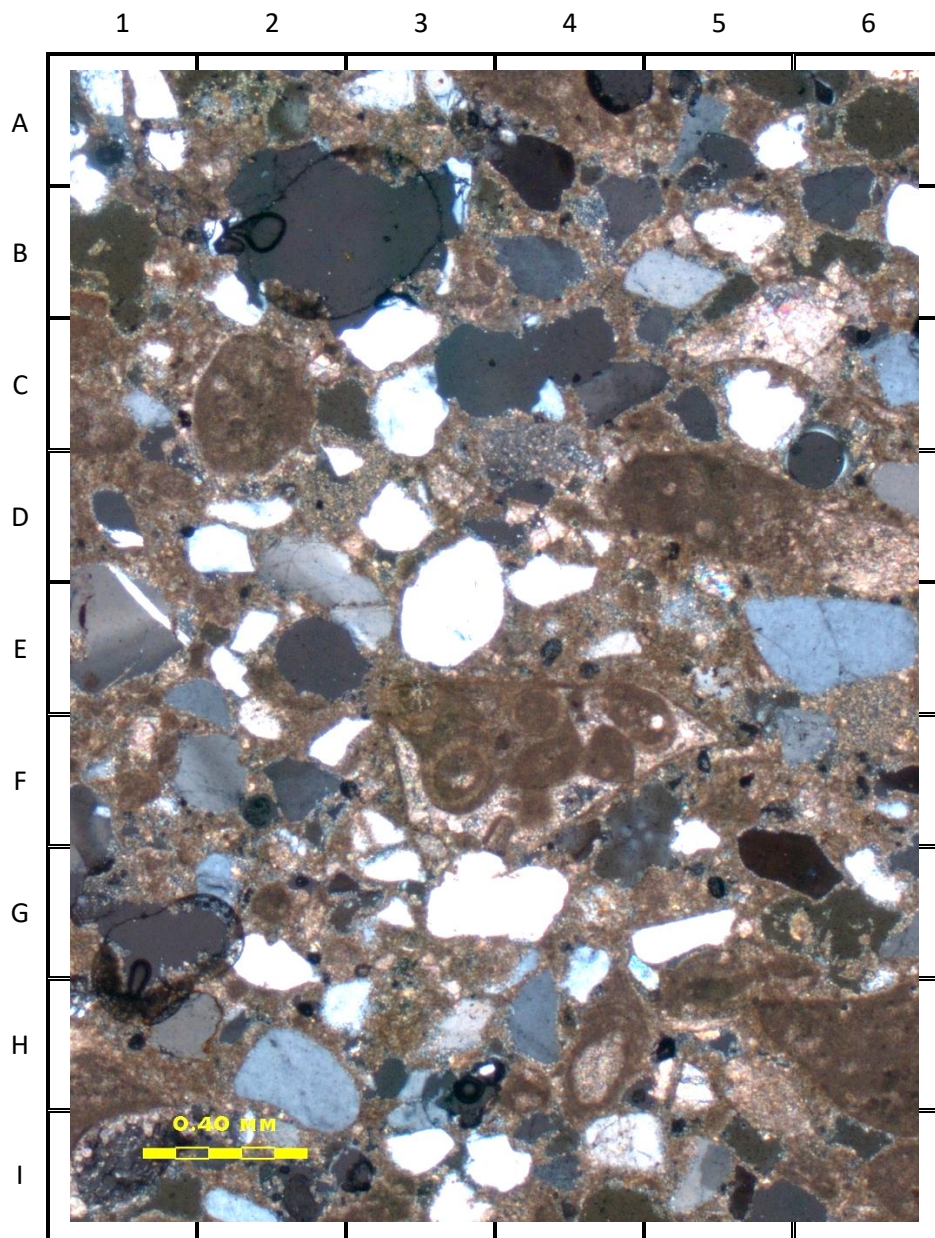


Figure C5

Sample K19563/2 Little Quay Street - Sample 2

Thin section, oblique polars: View showing an area of matrix with an unhydrated calcium silicate (CS) particle occurring in carbonated lime matrix and partially surrounds quartz sand particles appearing various shades of grey. An ironstone particle occurs in H6.

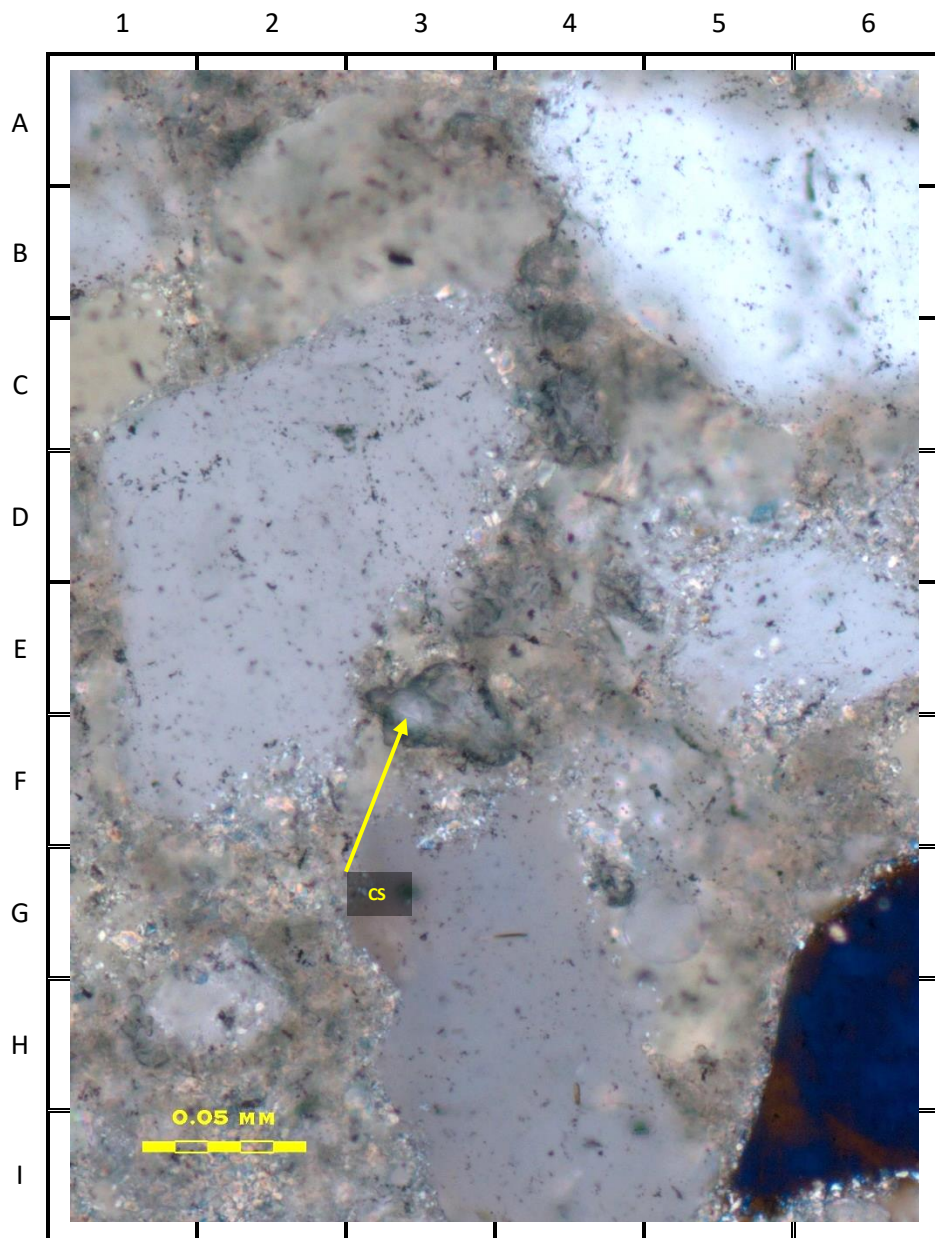


Figure C6

Sample K19563/3 Courtyard - Sample 3

Thin section, oblique polars: View showing an area of matrix with black coal ash particles visible for example around C4/5, and quartz sand particles visible for example in B/C2 and H3. Calcite crystals are growing within the matrix around F4 and I4/5.

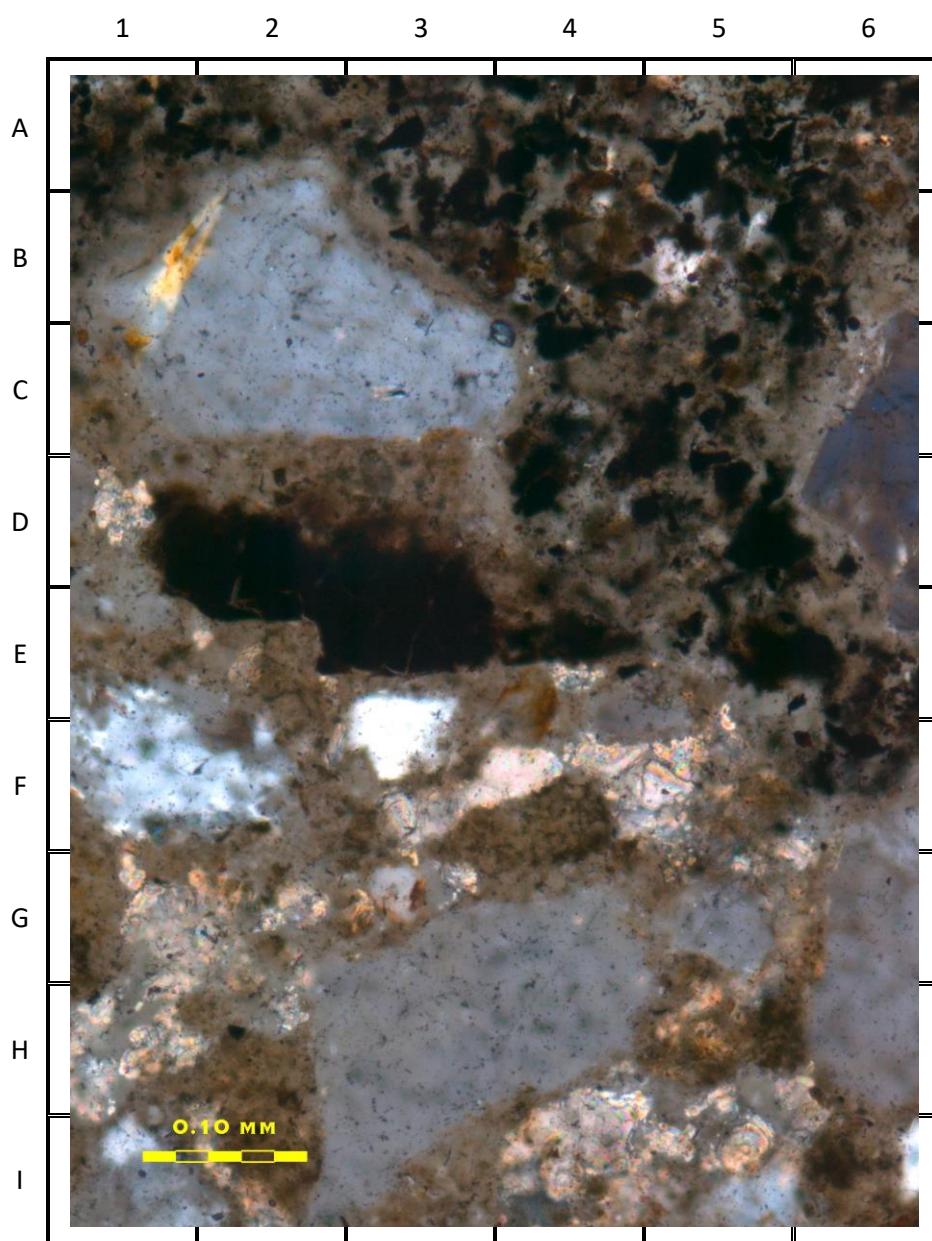


Figure C7

Sample K19563/3 Courtyard - Sample 3

Thin section, oblique polars: View showing an area of matrix that is composed of microcrystalline gypsum in E/F3. Quartz sand particles occur for example in B3/4 and F6.

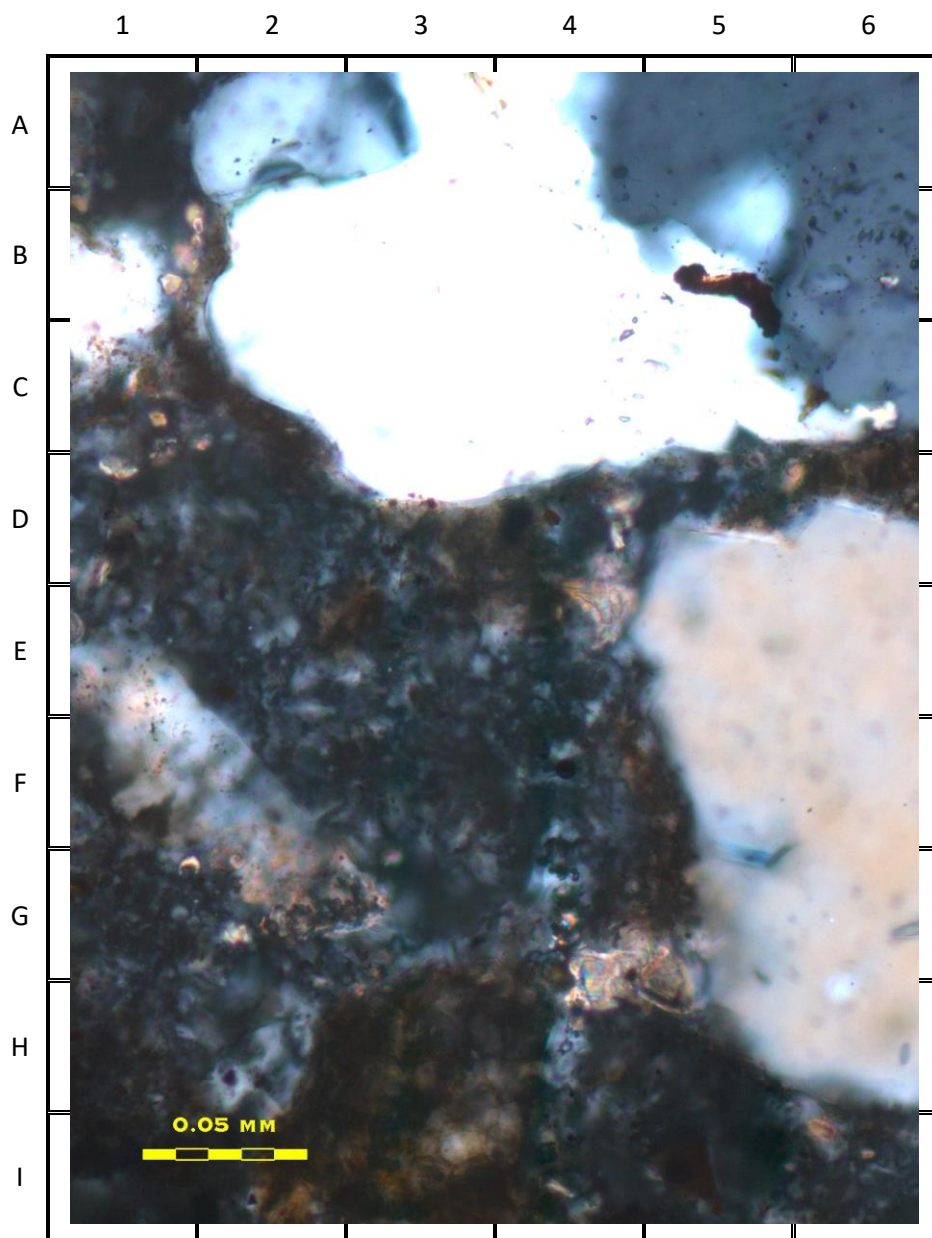
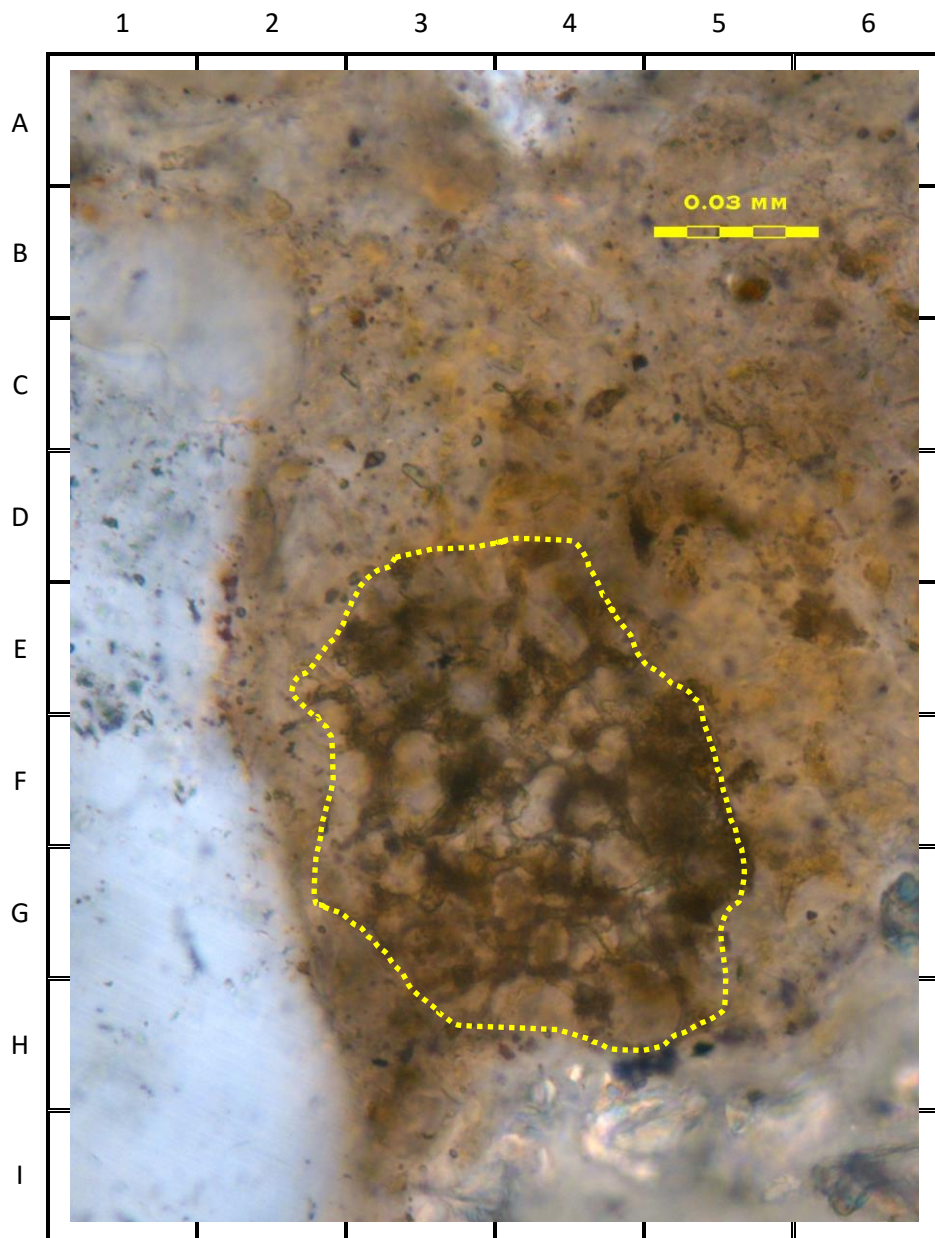


Figure C8

Sample K19563/3 Courtyard - Sample 3

Thin section, oblique polars: View showing an area of substantially hydrated matrix with a Portland cement grain-like structure outlined in yellow. Leached matrix with iron staining dominates the field of view and can be seen for example in C4/5. A quartz particle occurs in F1.



APPENDIX D – PETROGRAPHIC PROCEDURES AND GLOSSARY

1. Preliminary examination:

The samples are examined with the binocular microscope as received and their dimensions and main features are recorded. The features observed include the following.

- (a) The presence and position of reinforcement.
- (b) The extent to which reinforcement is corroded.
- (c) The nature of the external surfaces of the concrete.
- (d) The features and distribution of macro and fine cracks.
- (e) The distribution and size range and type of the aggregate.
- (f) The type and condition of the cement paste.
- (g) Any superficial evidence of deleterious processes affecting the concrete.

2. Polished surfaces:

A plate is cut, where possible, from each sample. This is typically about 20 mm thick and usually provides as large a section of the sample as is possible and typically has a polished surface area of $>100\text{cm}^2$. The plate is polished to give a high quality surface that can be examined with a high quality binocular microscope or even with the petrological microscope if necessary. The polished plate is used to assess the following.

- (a) The size, shape and distribution of coarse and fine aggregate.
- (b) The coherence, colour, and porosity of the cement paste.
- (c) The distribution, size, shape, and content of voids.
- (d) The composition of the concrete in terms of the volume proportions of coarse aggregate, fine aggregate, paste and void.
- (e) The distribution of fine cracks and microcracks. Often the surface is stained with a penetrative dye, so that these cracks can be seen. Microcrack frequency is measured along lines of traverse across the surface.
- (f) The relative abundance of rock types in the coarse aggregate is assessed.

3. Thin sections:

A thin section is prepared for each sample as appropriate. The section is usually made from a plate cut at right angles to the external surface of the concrete, so that the outer 70 mm or so of the concrete are included in the section. Sometimes it is more appropriate to make the section from inner parts of the concrete. This might be appropriate where specific problems are being investigated for example. The section normally measures about 50 x 70 mm.

In manufacturing the thin section a plate some 10 mm thick is cut from the sample. This is impregnated with a penetrative resin containing a yellow fluorescent dye. The resin penetrates into cracks, microcracks, and capillary pores in the sample. One side of the impregnated plate is then polished and the plate is mounted on to a glass slide. The surplus sample is then removed and the plate is ground and polished to give a final thickness of between 20 and 30 micrometres. At all stages the cutting and grinding is carried out using an oil based coolant in order to prevent further hydration of the cement and excessive heating of the section. The thin section is covered and then examined with a high quality Zeiss petrological photomicroscope.

The thin section supplies the following types of information:

- (a) Details of the rock types present in the coarse and fine aggregate and in particular structures seen within those rocks.
- (b) Details of the aggregate properties are measured such as the degree of strain in quartz.
- (c) The size, distribution and abundance of phases in the cement paste are assessed including, for example, the occurrence of calcium hydroxide and the amount of residual unhydrated clinker.
- (d) The presence of cement replacement phases such as slag or PFA can usually be recognised (though the amount of these phases cannot be judged accurately). The presence of high alumina cement can be detected and the type of cement clinker can often be assessed.
- (e) Any products of processes of deterioration of either the cement paste or the aggregate can be recognised.

4. Broken surfaces:

After the specially prepared surfaces and sections are completed, the remainder of the core is examined with the binocular microscope. In particular, the pieces are broken to produce fresh surfaces. These surfaces allow the contents of voids to be studied and the nature of aggregate surfaces or crack surfaces to be investigated.

5. Composition:

Where the size of the sample is appropriate the composition of the sample can be measured using either the polished slice or the thin section, depending on the size of the sample and on details of the aggregate type and paste. The thin section is preferable, for example where large quantities of dust are present. The volume proportions are found by the method of point counting using a mechanical stage. The amount of coarse aggregate can also be assessed by this method if a distinction can be made between coarse and fine aggregate. The results obtained usually represent the sample reasonably, but may not represent the concrete.

6. Water/cement ratio:

The hydration processes of cement paste vary significantly with the original water/cement ratio. Concretes with a low water/cement ratio tend to leave substantial quantities of unhydrated cement clinker and to develop only limited amounts of coarsely crystalline calcium hydroxide. In particular, the extent to which calcium hydroxide is separated into layers on aggregate surfaces and occurs in voids and on void surfaces varies with the original water/cement ratio. The number and proportion of unhydrated cement clinker particles varies inversely with the original water/cement ratio. Comparison with standard concretes made with known water/cement ratios visually, and by measurement allows the water/cement ratio of the cement paste to be assessed directly. The standard error attached to the estimation of water/cement ratio by this means is considered to be approximately ± 0.1 for unaltered concrete of similar type that in the Sandberg Reference Concrete Collection. It should be noted that aggregate dust, the presence of admixtures and additives all contribute to uncertainty in the petrographic measurement of the water/cement ratio of the concrete.

7. Glossary:

The following is a short list of technical terms in common use in the petrographic examination of concrete².

Alkali-aggregate reaction (AAR): This is a broad term encompassing both alkali carbonate reaction (ACR) and alkali silicate reaction and alkali-silica reaction (ASR). It refers to reactions between alkalies in usually derived from the cement in the cement paste and aggregate particles. Some forms of alkali-aggregate reaction such as ASR result in the formation of an alkali-silicate gel that is readily detectable in thin sections. Other forms of alkali-carbonate reaction such as ACR may not result gel formation.

Alkali carbonate reaction (ACR): This form of reaction is very rare in the UK and there is some debate over the precise mechanism of this reaction. Most documented cases of ACR involve argillaceous, dolomitic limestone. The reaction which is expansive is rarely associated with the formation of obvious gel deposits.

Alkali-silicate/silica reaction (ASR): This is by far the most common form of AAR and generally results from reactions between either microcrystalline, cryptocrystalline, or substantially strained quartz and associated microcrystalline quartz at grain margins and alkalies in cement paste. On rare occasions, ASR may result from the presence of highly reactive opaline silica in aggregate. Petrographic examination is the definitive method for the detection of this form of concrete deterioration. The reaction commonly results in the development of cracking that originates within reactive aggregate particles and continues into the surrounding paste and gel deposits are commonly associated with the occurrence of ASR.

Calcium aluminate cement (CAC): This is a general term that encompasses high alumina cement (HAC) as well as some of the more modern aluminate cements used in rapid setting concrete repair materials or some types of sprayed concretes and grouts.

Carbonation: Carbonation most commonly results from the exposure of concrete to atmospheric carbon dioxide and results in the conversion of portlandite to calcium carbonate and also affects some of the cement hydrate phases forming complex calcium silicate hydrate carbonate compounds. In damp conditions or in concrete exposed to moisture containing dissolved carbon dioxide, coarse-textured carbonation may develop and coarse crystals of calcium carbonate may develop within the cement paste. "Popcorn" calcite deposition (PCD) is one form of this type of carbonation.

Cracking: Cracks are classified using the following terms:

- **Macroscopic cracks:** These cracks are visible in the hand specimen or with the aid of a stereo binocular microscope and are typically >0.01mm wide.
- **Macrocrack:** These are cracks that are readily visible to the naked eye without the aid of a stereo binocular microscope and are typically >0.1mm wide.
- **Fine crack:** These are cracks that are only readily visible with a stereo binocular microscope or in thin section. Cracks of this type are typically between 0.01 and 0.10mm wide.
- **Microcracking:** These cracks cannot be detected with a stereo binocular microscope. They are typically <0.01mm wide and are most easily seen in petrographic thin sections containing fluorescent dye and by using fluorescent illumination.

Delayed ettringite formation (DEF): This term describes deleterious ettringite formation in concrete that has been cured at elevated temperatures, typically >65°C. Ettringite formation resulting from this process can be readily detected using thin sections and the ettringite tends to form in peripheral cracks around aggregate surfaces and sometimes within microcracks in the paste.

² Applied Petrography Group. A code of practice for the petrographic examination of concrete (Author M A Eden), SR2, The Geological Society of London, London, 2010 (Available for download from <http://www.appliedpetrographygroup.com>).

Drying shrinkage cracking: Drying shrinkage microcracks tend to develop radially around the surfaces of fine aggregate particles in concrete. Fine cracks and macrocracks caused by drying shrinkage tend to be parallel-sided cracks and orientated perpendicular to concrete surfaces.

Ettringite: This is a very common calcium-alumino-sulphate mineral. It occurs in most concretes where moisture ingress has occurred. Ettringite formation may be deleterious in the case of DEF or sulphate attack where it can give rise to a deleterious expansion and distinctive forms of cracking but in most cases secondary ettringite formation is non-deleterious.

Fly ash (also known as PFA / pulverised fly ash): This material is a by-product of coal burning power stations and can be readily recognised in thin sections, where it is visible as spherical glass particles, some of which may be hollow. Hollow PFA particles may be referred to as cenospheres. PFA is also commonly associated with small quantities of graphite particles that appear black in thin section.

Fine crack: See section on cracking.

GGBS: Ground, granulated blast furnace slag. This material is commonly employed as a cement replacement material in concrete and can be easily recognised in thin section. The GGBS particles are typically angular and are composed almost entirely of glass.

High alumina cement (HAC): This is a form of cement manufactured from the fusion of limestone and bauxite. It is readily distinguishable in thin section from most other types of cement. Petrographic examination is the definitive method for the detection of carbonation in concrete containing HAC.

Macrocrack: See section on cracking.

Macroscopic: This is a general term referring to features that are visible to the naked eye or with the aid of a stereo microscope.

Microcrack: See section on cracking.

Microsilica: Well dispersed microsilica cannot be directly observed in thin sections. However, distinctive clots of undispersed microsilica are commonly present in concrete containing microsilica – even where most of the microsilica is well dispersed. Microsilica clots are isotropic, and tend to be spherical and are sometimes concentrically layered. They are typically <100µm in diameter.

PFA: See section on fly ash

Plastic shrinkage cracking: This form of cracking occurs in concrete prior to its hardening. It can be distinguished from many other forms of cracking in that it results in cracks that are generally restricted to the cement paste and are non-parallel sided. Cracks of this type typically appear on the concrete surface and commonly diminish in width rapidly with depth and the paste surrounding cracks of this type is commonly of locally high porosity reflecting the migration of moisture towards the cracks during the drying out of the concrete surfaces.

Porosity: This term is distinct from void content. It refers to microscopic pores within cement hydrates. Porosity is directly related to water/cement ratio, but is also strongly influenced by curing and many forms of concrete deterioration. Porosity is sometimes used as an indicator of water/cement ratio in hardened concrete.

Portland cement: Portland cement is the most common form of binder used in concrete and is manufactured from the burning of limestone and an alumino-silicate rock (clay or shale) at temperatures of up to 1500°C. There are many forms of Portland cement and it is commonly possible to distinguish sulphate-resisting and white Portland cement and ordinary Portland cement using petrographic thin sections.

Portlandite: Portlandite is calcium hydroxide and is one of the products formed during cement hydration. Portlandite is readily recognisable in thin sections and has a distinctively high birefringence that contrasts with the much lower birefringence of the hydrated cement phases.

Sulphate attack: This is a general term encompassing both conventional sulphate attack resulting in gypsum and ettringite formation, but also includes sulphate attack associated with thaumasite formation. Sulphate attack can be readily recognised in thin sections and commonly results in the development of surface-parallel cracks infilled with ettringite or thaumasite.

Thaumasite: This is a carbonate-sulphate calcium hydrate mineral with a complex composition. It is a common reaction product in concrete exposed to moisture containing both carbonate and sulphate ions. Thaumasite is most commonly encountered in concrete exposed to temperatures of $<4^{\circ}\text{C}$. Some forms of thaumasite can be readily distinguished from ettringite and have a high birefringence. However, some forms of thaumasite have a much lower birefringence and can be difficult to distinguish from ettringite without recourse to SEM micro-analysis.

Void: This describes empty spaces present in concrete that are typically greater than about 5 micrometres in diameter. It encompasses both entrained air voids (spherical voids typically $<1\text{mm}$ in diameter) as well as much larger entrapped air voids. It should be noted that it is possible for concrete to have a low porosity, but a high void content.

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Materials, samples and test specimens are retained for a period of 2 months from the issue of the final report.

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