SANDBERG
CONSULTING ENGINEERS
INVESTIGATION INSPECTION
TESTING MATERIALS

REPORT 41378/G/3

PETROGRAPHIC EXAMINATION

OF

VARIOUS MATERIALS

WEST ELEVATION

KING'S CROSS

Reference : Instructions from Mr James Kennett of Stonewest Ltd.

1. INTRODUCTION

We were requested to undertake a petrographic examination on various materials in accordance with your instructions.

The purpose of the analysis, in the case of natural stone, was to identify the stone and provide an assessment of a potential matching source.

2. SAMPLES RECEIVED

Samples were received from Stonewest Ltd at Sandberg laboratories on 12 February 2010, as follows.

Sandberg Reference	Site Mark & Advised Location Details		Sample details
	West Elevation		
G34801		Stone cill	1 no. lump (138.7g)
G34802	#1	High level sample 1	1 no. lump (489.0g)
G34803	#2	High level sample 2	1 no. lump (50.2g)
G34804	#3	High level sample 3	1 no. lump (414.9g)
G34805	#4	High level sample 4	1 no. lump (23.9g)

3. TEST METHODS AND RESULTS

Each sample was subjected to petrographic examination in accordance with the methods described in BS 5930:1999[1], ISRM[2], BS EN 12407:2007[3] and ASTM C856-04 as appropriate to the material.

Each sample was first subjected to macroscopical and low power stereoscopic microscope examination supported by simple physical and chemical tests.

A representative portion from each sample was used to prepare a large area thin section which was examined using an Olympus BH2 and Leica DM4500P high power petrological microscopes employing plane polarised and cross polarised light at magnifications up to x1000.

The detailed petrographic examination results are given in Tables 1, 2 and 3 of this report.

Stone cill [G34801]
Off-white to faint cream, fine to medium grained OOLITIC LIMESTONE. The sample was weathered and discoloured on apparent exposed surfaces and painted in places. The stone was moderately soft and appeared microporous.

The sample could be matched to Portland Albion Stone (probable).

The matches for the submitted sample in terms of colour and appearance, along with potential sources, is detailed below.

Sandberg Ref./ Site Mark	Potential Source Material	Degree of Confidence in Match
G34801	Portland Albion Stone Guiting - Cotswold Hill Quarry Ancaster Freestone	Probable Possible Possible

The sample received was compared against archived petrographic data and thin sections. It is therefore recommended that colour matching of the stone from the suggested potential sources with the material on site is carried out.

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1 BS 5930:1999. Code of Practice for Site Investigation, Clause 44, Description and Classification of Rocks for engineering Purposes.

2 Rock Characterisation Testing and Monitoring. International Society for Rock Mechanics (ISRM) Suggested methods. Petrographic Description of Rocks p.73, 1981 Edition.

3 BS EN 12407:2007. Natural Stone Test Methods - Petrographic Examination.

We would strongly recommend that the suggested source quarries are visited by an experienced geologist and samples are examined in detail with respect to compatibility of physical characteristics, durability and comparative performance. We would welcome the opportunity to assist in this process.

Sample #1 [G34802]
Grey coloured (in hand specimen) generally good to moderate compacted RENDER / MORTAR.

Sample #2 [G34803]
Pale grey coloured (in hand specimen) generally good compacted PERLITE MORTAR.

Sample #3 [G34804]
Grey coloured (in hand specimen) generally good to moderate compacted RENDER / MORTAR.

Sample #4 [G34805]
Grey coloured (in hand specimen) generally good to moderate compacted RENDER / MORTAR.

4. REMARKS

The stone matching was based upon the sample submitted. Stone sources may be expected to exhibit considerable lateral and vertical variations in composition and character over short distances and single samples are unlikely to be reliably representative of whole source areas or specific locations within these areas during continuing exploitation.

In addition, the above suggested quarries may have stopped operating or the new stone extracted may differ considerably in colour, texture and overall composition with that originally produced.

These results and comments conclude the testing requested to date. Please do not hesitate to contact us if we can be of further assistance.

Stonewest Ltd
Lamberts Place
St. James's Road
Croydon
Surrey
CR9 2HX

For the attention of Mr James Kennett

DJE/Geoman/vb

For Sandberg LLP

D J Ellis
Partner

17 March 2010

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Stonewest Ltd
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Croydon
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This Report consists of
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For the attention of Mr James Kennett

17 March 2010

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Table/Sheet
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PETROGRAPHICAL EXAMINATION OF ROCK

BS 5930:1999, ISRM Method and BS EN 12407:2007

Date of Test / by
12.3.2010/PS

SAMPLE DETAILS			
Sample Reference	G34801	Client Reference/Site Mark	-
Sample Type, Source and Sampling Location Details:	A lump of stone advised to be ex west elevation stone cill		
Condition on Receipt:	Dry	Sample weight, g	38 approx
Methods of Preparation of Specimens and Examination Procedures:	The sample was first subjected to macroscopical and low power stereomicroscopical examination supported by simple physical and chemical tests. A representative specimen was diamond-sawn, impregnated with a low viscosity resin containing a yellow fluorescent dye and used to prepare a thin section which was then examined under a high power petrological microscopes employing magnifications up to x 1000.		
Any Other Details:	Thin section dimensions (mm): 50 x 69		

MATERIAL DESCRIPTION:	Off-white to faint cream, fine to medium grained OOLITIC LIMESTONE. The sample was weathered and discoloured on exposed surfaces and painted in places. The stone was moderately soft and appeared microporous.

MATERIAL COMPOSITION:	
COMPONENT	Volume % (estimated)
Micrite including ooids	70
Bioclasts	7
Quartz	2
Sparry calcite	1
Voids	20
TOTAL:	100

PETROGRAPHICAL DETAILS

The stone was found to be an oolitic bioclastic limestone, mainly grain supported, consisting mainly of micritic ooids, some bioclastic debris, occasional quartz grains, sparse micrite as intergranular material in places and rare sparry calcite.

Micritic ooids, commonly less than 400µm across, constituted the stone framework and exhibited a faint concentric texture.

Relict bioclastic debris was present throughout the sample generally elongate, possibly bivalve shell fragments, occasionally exhibiting the original aragonitic texture and sporadically replaced or partially replaced by sparry calcite.

Rarely sparry calcite appeared to infill intergranular voids.

Occasional irregular to elongate quartz grains less than 200µm across were mainly present within ooids.

The stone was moderately compacted with frequent irregular intergranular voids throughout the sample, mainly as intergranular spaces. The micrite was microporous, with pores beyond the resolution of a transmitted light microscope.

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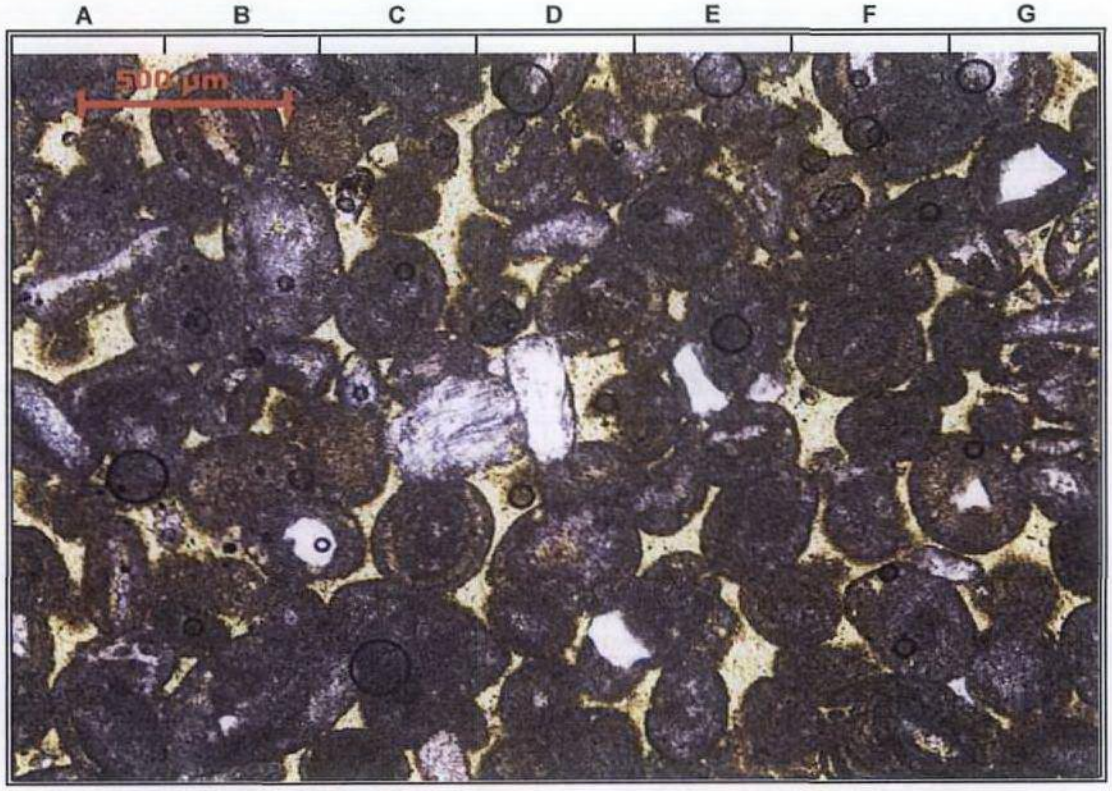
Plate 1

PETROGRAPHICAL EXAMINATION OF STONE - PHOTOMICROGRAPH



Photomicrograph Details			
Sandberg Sample Ref:	G34801	Client Ref/Site Mark:	Oolitic limestone West elevation stone cill
Microscope Light:	Plane polarised	Objective Magnification:	x5

Photomicrograph Description

General view of stone structure. Yellow colour is due to yellow impregnating resin which has infilled the intergranular spaces and micropores.

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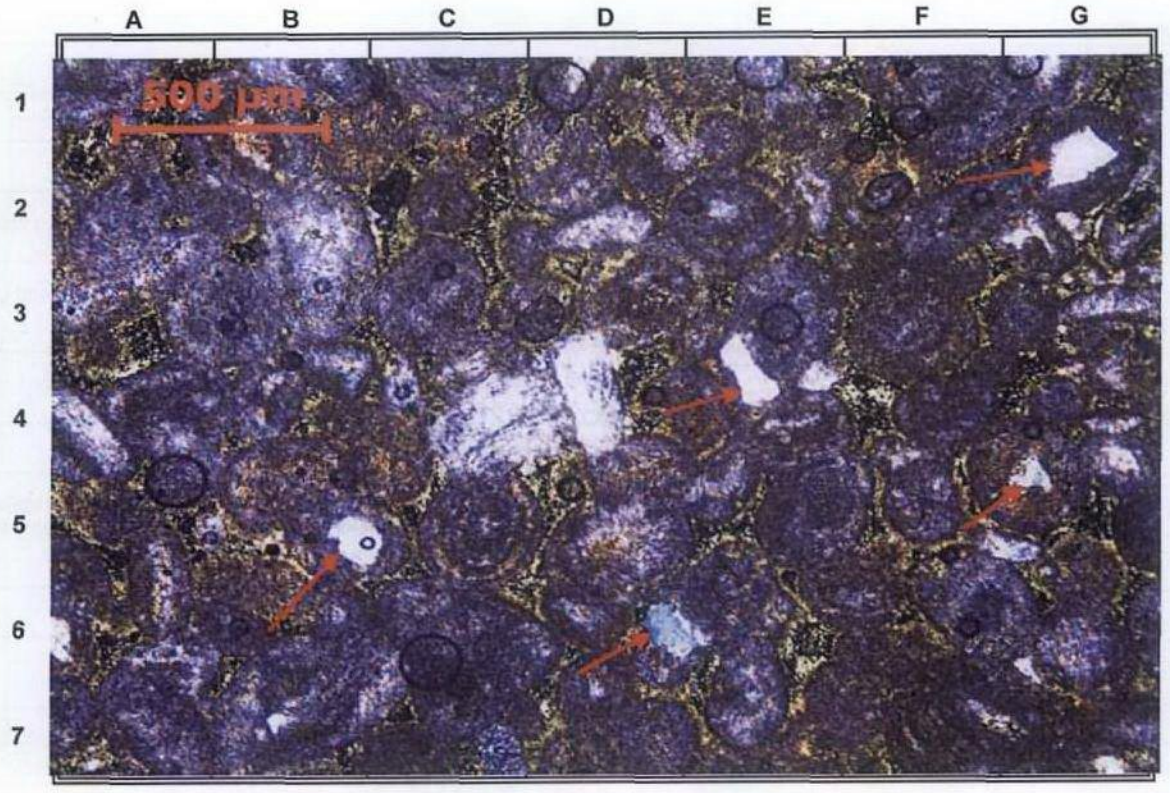
PETROGRAPHICAL EXAMINATION OF STONE - PHOTOMICROGRAPH



Photomicrograph Details			
Sandberg Sample Ref:	G34801	Client Ref/Site Mark:	Oolitic limestone West elevation stone cill
Microscope Light:	Cross polarised	Objective Magnification:	x5
Photomicrograph Description			
General view of stone structure. Yellow colour is due to yellow impregnating resin which has infilled the intergranular spaces and micropores. Red arrows point to quartz grains.			

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MICROSCOPICAL EXAMINATION OF RENDER / MORTAR
Based on ASTM C856-04

Sandberg Sample Reference:	G34802
Client Reference/Site Mark:	Sample 1
Sample Location Details:	West elevation - High level
Date of Test/Petrographer:	15.3.2010/PS
Specimen Preparation Details: *(size, impregnation)*	A representative portion from the sample was impregnated with an epoxy resin and used to prepare a large area thin section.
Microscope Details: *(type, magnification used)*	Olympus SZ stereoscopic microscope and Olympus BH2 and Leica DM4500P high-power petrological microscope employing magnifications up to x1000
Position of Specimen: *(relationship to sample)*	Thin section was taken across the thickness of the submitted sample. Thin section dimensions, mm: 40 x 67
RENDER / MORTAR COMPOSITION AND FEATURES	
Fine Aggregate: *(incl. particle size, grading, distribution, shape and composition)*	Natural sand, with particles up to 7mm across, comprising mainly irregular particles of quartz, quartzite, chert/flint, and sporadic feldspar and glauconite.
Colour of Cement Matrix:	Grey in hand specimen and grey/brown in thin section
Cement Type: *(Portland, lime etc)*	Portland cement binder.
Unhydrated grains: *(incl. size, abundance and degree of hydration)*	Frequent unhydrated and/or partially hydrated cement grains up to 0.5mm across and commonly less than 300µm in size. The coarse grain size of the cement is indicative of an early Portland cement.
Mineral Additives:	None identified
Carbonation and Portlandite: *(incl. depth and degree of carbonation, size and distribution of $Ca(OH)_2$)*	The matrix was mainly uncarbonated with thin carbonation rims along void boundaries and partial carbonation in places next to the brick substrate. The uncarbonated matrix exhibited occasional portlandite up to 30µm across.
Compaction and Void Details: *(incl. microporosity and void types, sizes, distribution)*	Generally good to moderate compaction for a render / mortar with compaction irregular voids up to 5mm x 10mm. The microporosity of the cement paste was generally low.
Cracks and Microcracks: *(incl. sizes, abundance, distribution relationships to other features)*	Very few cracks possibly due to sampling
Secondary Deposits:	None seen
Other Information: *(incl. any evidence of deterioration, chemical attack, surface coatings, multiple layering etc.)*	No evidence of chemical attack or deterioration was identified in the specimen examined.

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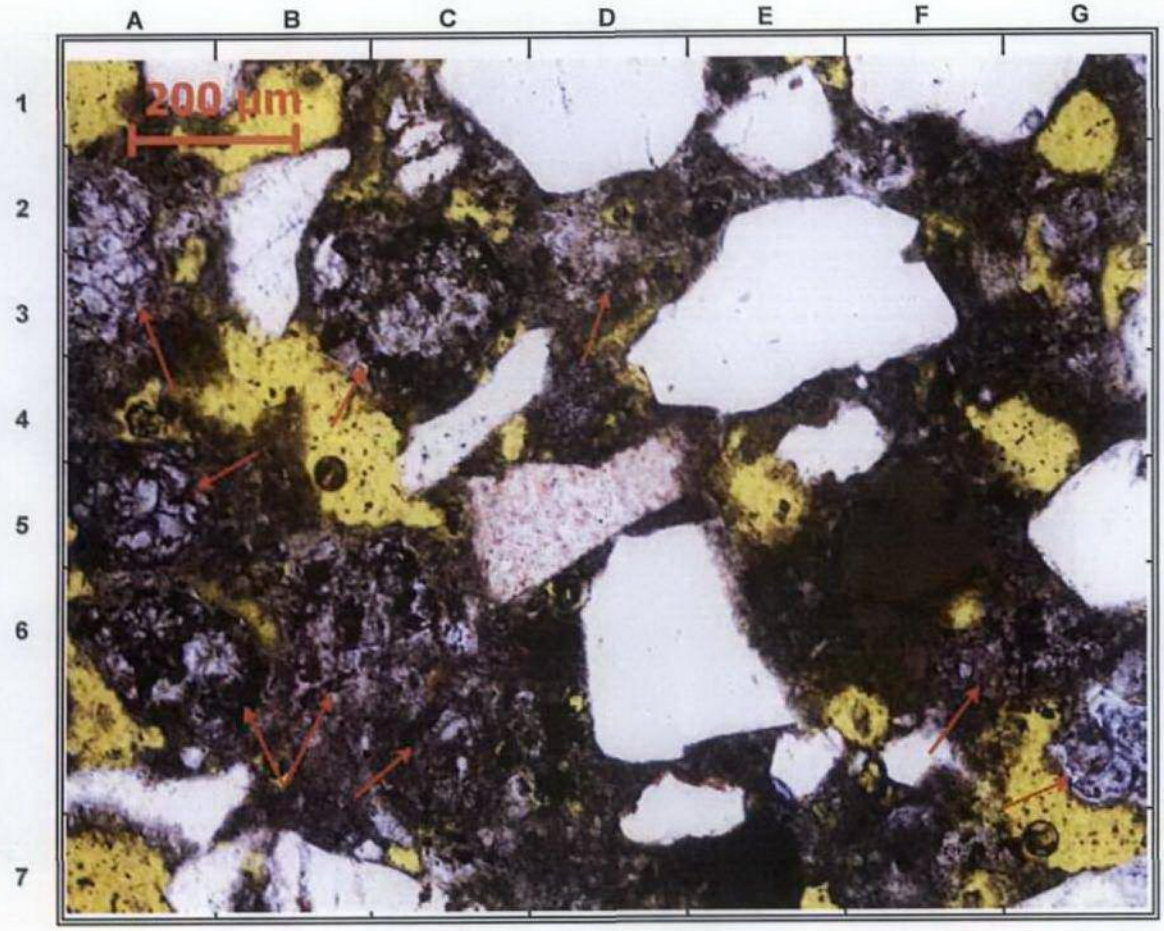
MICROSCOPICAL EXAMINATION OF HARDENED RENDER / MORTAR



Photomicrograph Details			
Sandberg Sample Ref:	G34802	Client Ref/Site Mark:	Sample 1 West elevation high level
Microscope Light:	Plane polarised	Objective Magnification:	x10

Photomicrograph Description

General view of render / mortar. Yellow colour is due to yellow impregnating resin infilling voids. Red arrows point to unhydrated cement grains. Brown grain at E-F/5-6 is a glauconite grain. White grains are quartz whilst the grain at C-D/5-6 is a chert/flint particle.

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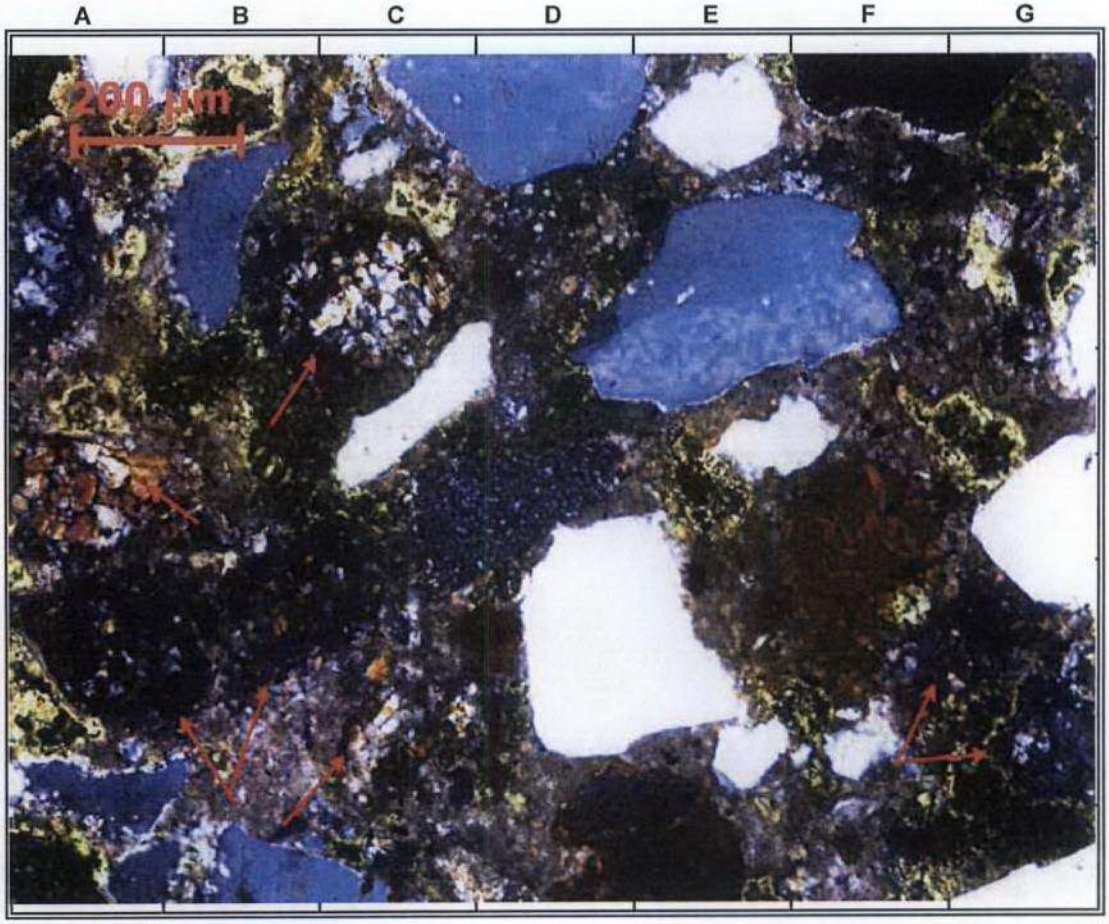
MICROSCOPICAL EXAMINATION OF HARDENED RENDER / MORTAR



Photomicrograph Details			
Sandberg Sample Ref:	G34802	Client Ref/Site Mark:	Sample 1 West elevation high level
Microscope Light:	Cross polarised	Objective Magnification:	x10

Photomicrograph Description

General view of render / mortar. Yellow colour is due to yellow impregnating resin infilling voids. Note bright fine carbonation rims along the void walls. Red arrows point to unhydrated cement grains. Brown grain at E-F/5-6 is a glauconite grain. White, blue and blue/grey grains are quartz whilst the grain at C-D/5-6 is a chert/flint particle.

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MICROSCOPICAL EXAMINATION OF RENDER / MORTAR
Based on ASTM C856-04

Sandberg Sample Reference:	G34803
Client Reference/Site Mark:	Sample 2
Sample Location Details:	West elevation - High level
Date of Test/Petrographer:	15.3.2010/PS
Specimen Preparation Details: *(size, impregnation)*	Four representative slice portions from the sample were impregnated with an epoxy resin and used to prepare a large area thin section.
Microscope Details: *(type, magnification used)*	Olympus SZ stereoscopic microscope and Olympus BH2 and Leica DM4500P high-power petrological microscope employing magnifications up to x1000
Position of Specimen: *(relationship to sample)*	The four slices were taken across the thickness of the submitted sample. Thin section dimensions, mm: 43 x 68
RENDER / MORTAR COMPOSITION AND FEATURES	
Fine Aggregate: *(incl. particle size, grading, distribution, shape and composition)*	Predominantly perlite cenospheres and sparse natural sand, with particles 600µm nominal maximum size, comprising mainly irregular particles of quartz, quartzite, chert/flint, and sporadic feldspar and tourmaline.
Colour of Cement Matrix:	Pale grey in hand specimen and grey/brown in thin section
Cement Type: *(Portland, lime etc)*	Portland cement binder.
Unhydrated grains: *(incl. size, abundance and degree of hydration)*	Occasional unhydrated and/or partially hydrated cement grains up to 100µm and commonly less than 50µm in size.
Mineral Additives:	Possible limestone dust in small proportions.
Carbonation and Portlandite: *(incl. depth and degree of carbonation, size and distribution of $Ca(OH)_2$)*	The matrix was generally uncarbonated but the presence of limestone dust masked the cement paste.
Compaction and Void Details: *(incl. microporosity and void types, sizes, distribution)*	Generally good for a perlite mortar with a few irregular to elongate compaction voids up to 2mm across and numerous voids <100µm across. The microporosity of the cement paste was moderately high to high.
Cracks and Microcracks: *(incl. sizes, abundance, distribution relationships to other features)*	Very few cracks possibly due to sampling
Secondary Deposits:	None seen
Other Information: *(incl. any evidence of deterioration, chemical attack, surface coatings, multiple layering etc.)*	No evidence of chemical attack or deterioration was identified in the specimen examined.

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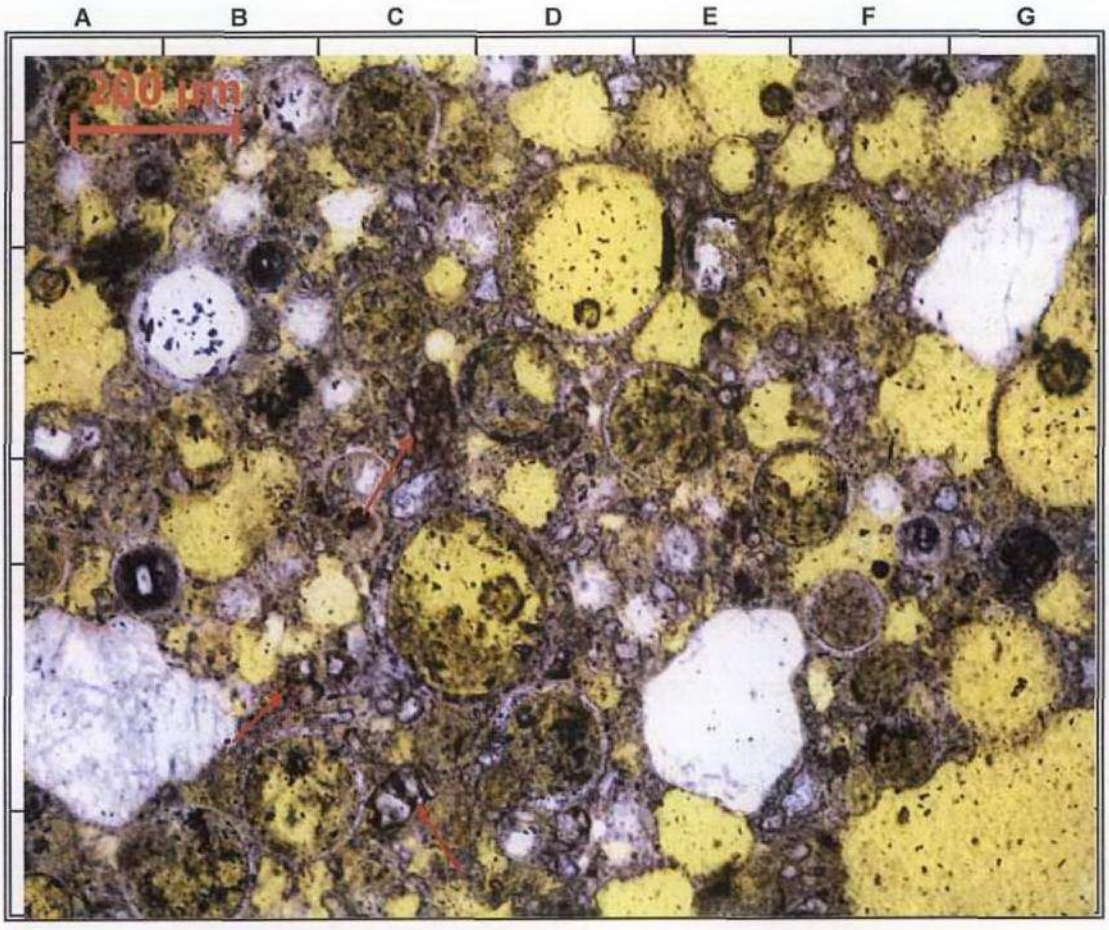
Plate 1

MICROSCOPICAL EXAMINATION OF HARDENED RENDER / MORTAR



Photomicrograph Details			
Sandberg Sample Ref:	G34803	Client Ref/Site Mark:	Sample 2 West elevation high level
Microscope Light:	Plane polarised	Objective Magnification:	x10

Photomicrograph Description

General view of perlite / mortar. Cenospheres exhibit thin glassy walls and are occasionally partially or loosely infilled with cement. Yellow colour is due to yellow impregnating resin infilling voids and cenospheres. Red arrows point to unhydrated cement grains. White grains are quartz, whilst the white sphere at A-B/3 is an empty cenosphere.

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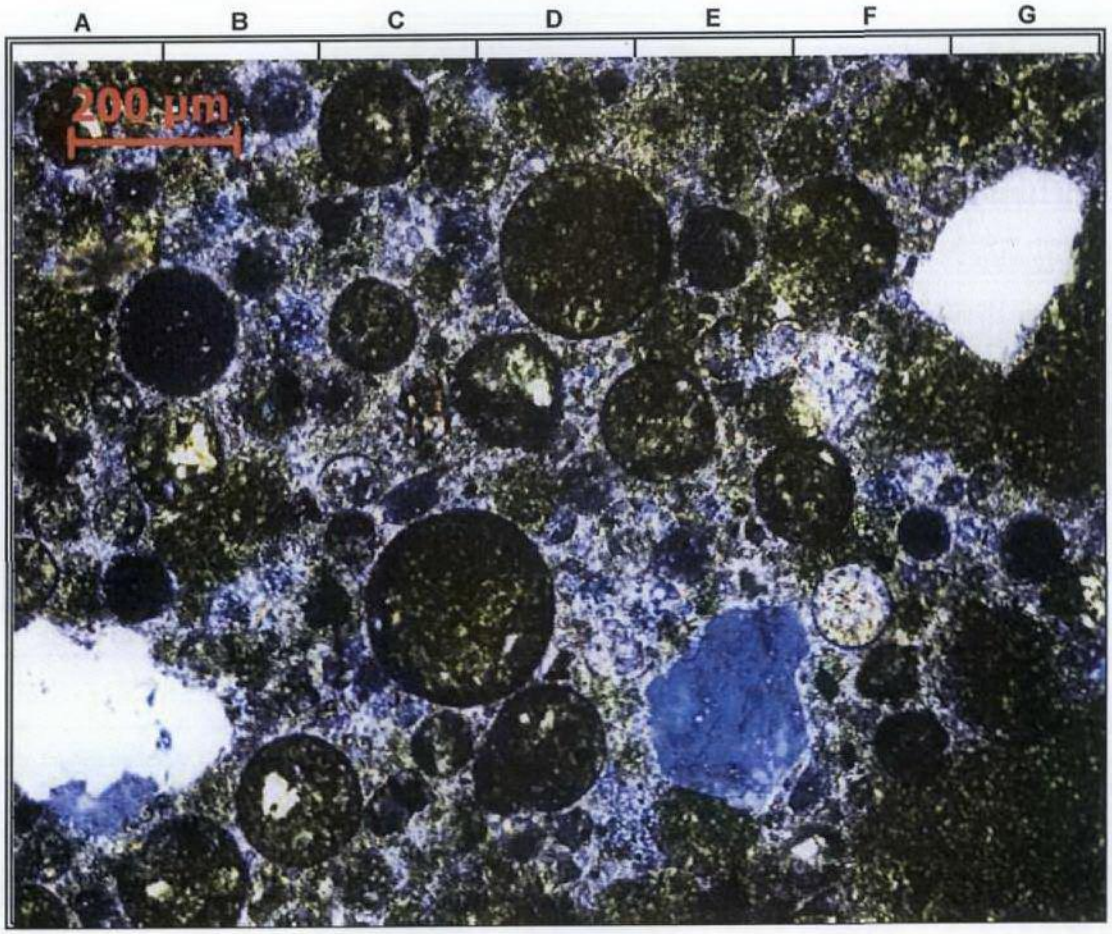
MICROSCOPICAL EXAMINATION OF HARDENED RENDER / MORTAR



Photomicrograph Details			
Sandberg Sample Ref:	G34803	Client Ref/Site Mark:	Sample 2 West elevation high level
Microscope Light:	Cross polarised	Objective Magnification:	x10

Photomicrograph Description

General view of perlite / mortar. Cenospheres exhibit thin glassy walls (which are in this image in extinction) and are occasionally partially or loosely infilled with cement. Yellow colour is due to yellow impregnating resin infilling voids and cenospheres. White and blue grains are quartz, whilst the dark/black sphere at A-B/3 is an empty cenosphere.

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MICROSCOPICAL EXAMINATION OF RENDER / MORTAR
Based on ASTM C856-04

Sandberg Sample Reference:	G34804
Client Reference/Site Mark:	Sample 3
Sample Location Details:	West elevation - High level
Date of Test/Petrographer:	15.3.2010/PS
Specimen Preparation Details: *(size, impregnation)*	Three representative slice portions from the sample were impregnated with an epoxy resin and used to prepare a large area thin section.
Microscope Details: *(type, magnification used)*	Olympus SZ stereoscopic microscope and Olympus BH2 and Leica DM4500P high-power petrological microscope employing magnifications up to x1000
Position of Specimen: *(relationship to sample)*	The three slices were taken across the thickness of the submitted sample. Thin section dimensions, mm: 45 x 75
RENDER / MORTAR COMPOSITION AND FEATURES	
Fine Aggregate: *(incl. particle size, grading, distribution, shape and composition)*	Natural sand, with particles up to 7mm across, comprising mainly irregular particles of quartz, quartzite, chert/flint, and sporadic feldspar and glauconite.
Colour of Cement Matrix:	Grey in hand specimen and grey/brown in thin section
Cement Type: *(Portland, lime etc)*	Portland cement binder.
Unhydrated grains: *(incl. size, abundance and degree of hydration)*	Frequent unhydrated and/or partially hydrated cement grains up to 0.8mm across and commonly less than 500µm in size. The coarse grain size of the cement is indicative of an early Portland cement.
Mineral Additives:	None identified
Carbonation and Portlandite: *(incl. depth and degree of carbonation, size and distribution of $Ca(OH)_2$)*	The matrix was carbonated along the top surface up to 6mm depth. The remainder of the cement paste was mainly uncarbonated with thin carbonation rims along void boundaries and partial carbonation in places next to the brick substrate. The uncarbonated matrix exhibited occasional portlandite up to 30µm across.
Compaction and Void Details: *(incl. microporosity and void types, sizes, distribution)*	Generally good to moderate compaction for a render / mortar with compaction irregular voids up to 2mm x 3mm. The microporosity of the cement paste was generally low.
Cracks and Microcracks: *(incl. sizes, abundance, distribution relationships to other features)*	Very few cracks possibly due to sampling
Secondary Deposits:	None seen
Other Information: *(incl. any evidence of deterioration, chemical attack, surface coatings, multiple layering etc.)*	No evidence of chemical attack or deterioration was identified in the specimen examined. The top surface was coated with approximately nine layers of paint.

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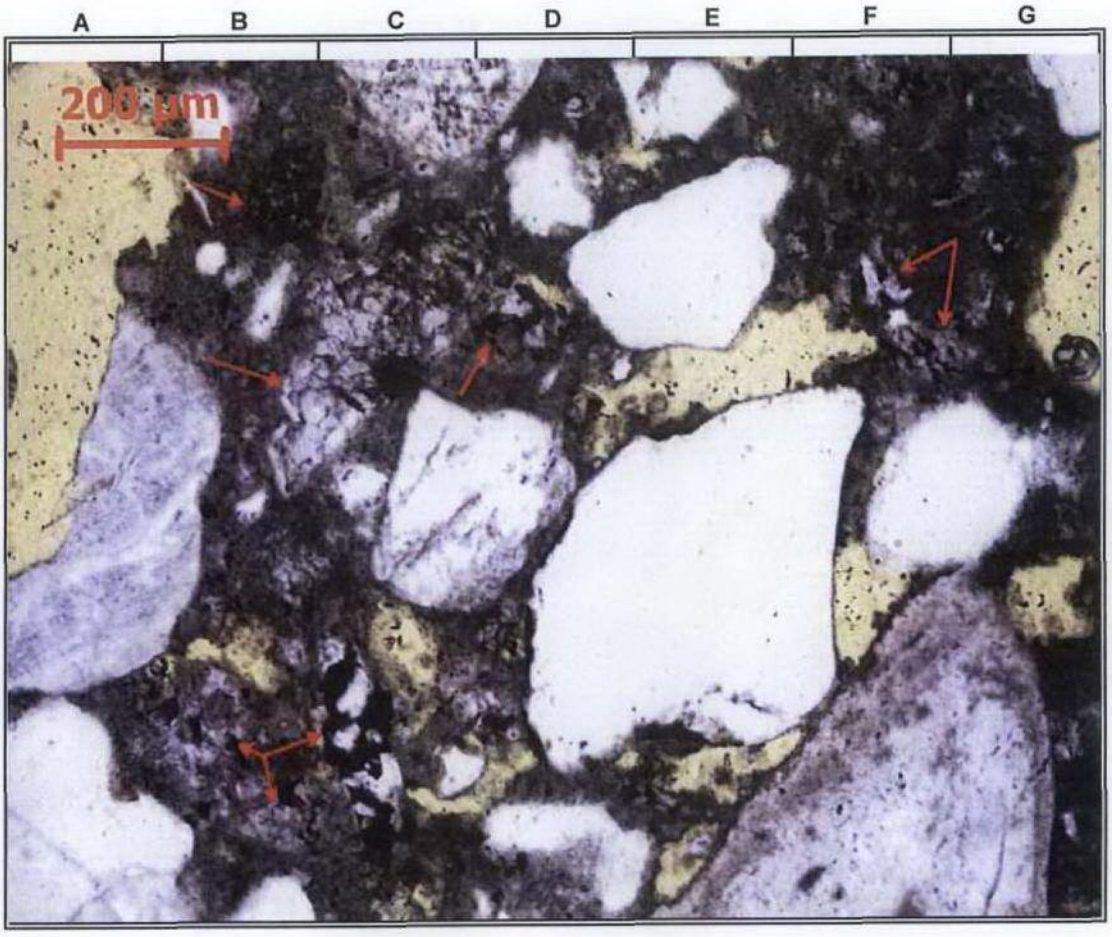
Plate 1

MICROSCOPICAL EXAMINATION OF HARDENED RENDER / MORTAR



Photomicrograph Details			
Sandberg Sample Ref:	G34804	Client Ref/Site Mark:	Sample 3 West elevation high level
Microscope Light:	Plane polarised	Objective Magnification:	x10

Photomicrograph Description

General view of render / mortar. Yellow colour is due to yellow impregnating resin infilling voids. Red arrows point to unhydrated cement grains. White and pale blue grains are quartz except the particle at E-G/6-7 which is a chert/flint particle.

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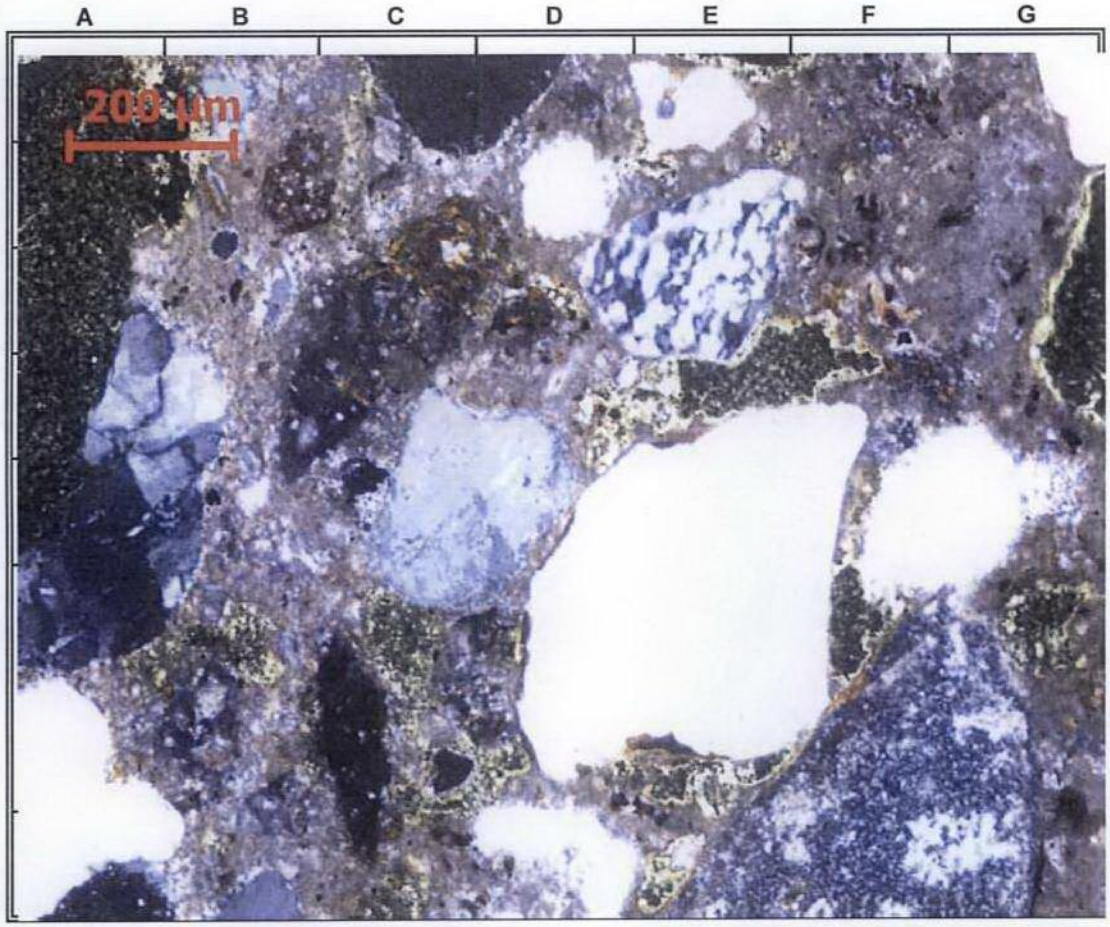
Plate 2

MICROSCOPICAL EXAMINATION OF HARDENED RENDER / MORTAR



Photomicrograph Details			
Sandberg Sample Ref:	G34804	Client Ref/Site Mark:	Sample 3 West elevation high level
Microscope Light:	Cross polarised	Objective Magnification:	x10

Photomicrograph Description

General view of render / mortar. Yellow colour is due to yellow impregnating resin infilling voids. White and blue/grey grains are quartz except the particle at E-G/6-7 which is a chert/flint particle. Note the thin carbonation rims along the void walls.

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MICROSCOPICAL EXAMINATION OF RENDER / MORTAR
Based on ASTM C856-04

Sandberg Sample Reference:	G34805
Client Reference/Site Mark:	Sample 4
Sample Location Details:	West elevation - High level
Date of Test/Petrographer:	15.3.2010/PS
Specimen Preparation Details: *(size, impregnation)*	Three representative slice portions from the sample were impregnated with an epoxy resin and used to prepare a large area thin section.
Microscope Details: *(type, magnification used)*	Olympus SZ stereoscopic microscope and Olympus BH2 and Leica DM4500P high-power petrological microscope employing magnifications up to x1000
Position of Specimen: *(relationship to sample)*	The three slices were taken across the thickness of the submitted sample. Thin section dimensions, mm: 45 x 60
RENDER / MORTAR COMPOSITION AND FEATURES	
Fine Aggregate: *(incl. particle size, grading, distribution, shape and composition)*	Natural sand, with particles up to 7mm across, comprising mainly irregular particles of quartz, quartzite, chert/flint, and sporadic feldspar and glauconite.
Colour of Cement Matrix:	Grey in hand specimen and grey/brown in thin section
Cement Type: *(Portland, lime etc)*	Portland cement binder.
Unhydrated grains: *(incl. size, abundance and degree of hydration)*	Frequent unhydrated and/or partially hydrated cement grains up to 0.5mm across and commonly less than 300µm in size. The coarse grain size of the cement is indicative of an early Portland cement.
Mineral Additives:	None identified
Carbonation and Portlandite: *(incl. depth and degree of carbonation, size and distribution of $Ca(OH)_2$)*	The matrix was carbonated along the top surface up to 5mm depth. The remainder of the cement paste was mainly uncarbonated with thin carbonation rims along void boundaries and partial carbonation in places next to the brick substrate. The uncarbonated matrix exhibited occasional portlandite up to 30µm across.
Compaction and Void Details: *(incl. microporosity and void types, sizes, distribution)*	The sample was very small for a reliable assessment. Generally good to moderate compaction for a render / mortar with compaction irregular voids up to 2mm x 3mm. The microporosity of the cement paste was generally low.
Cracks and Microcracks: *(incl. sizes, abundance, distribution relationships to other features)*	Very few cracks possibly due to sampling
Secondary Deposits:	None seen
Other Information: *(incl. any evidence of deterioration, chemical attack, surface coatings, multiple layering etc.)*	No evidence of chemical attack or deterioration was identified in the specimen examined. The top surface was coated with layers of paint.

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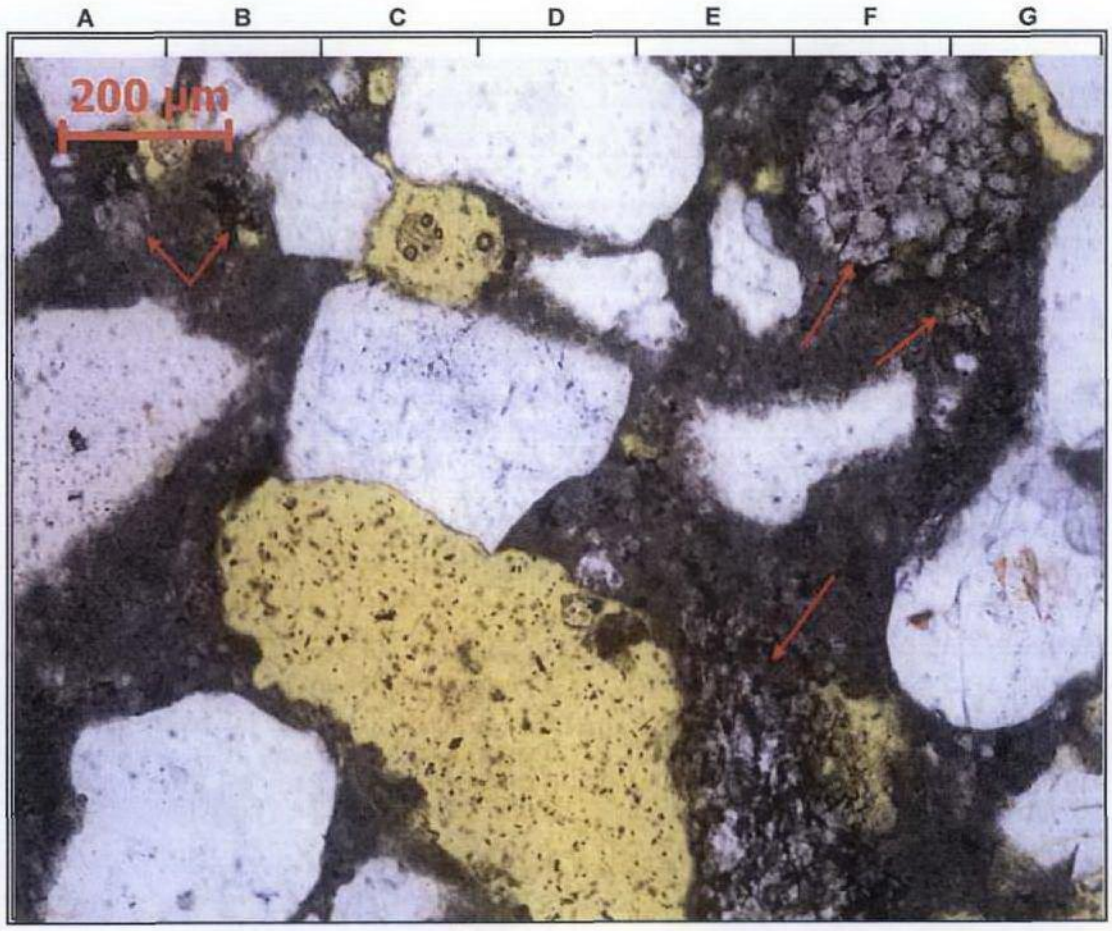
Plate 1

MICROSCOPICAL EXAMINATION OF HARDENED RENDER / MORTAR



Photomicrograph Details			
Sandberg Sample Ref:	G34805	Client Ref/Site Mark:	Sample 4 West elevation high level
Microscope Light:	Plane polarised	Objective Magnification:	x10

Photomicrograph Description

General view of render / mortar. Yellow colour is due to yellow impregnating resin infilling voids. Red arrows point to unhydrated cement grains. White and pale blue grains are quartz except the particle at A-B/3-5 which is a chert/flint particle.

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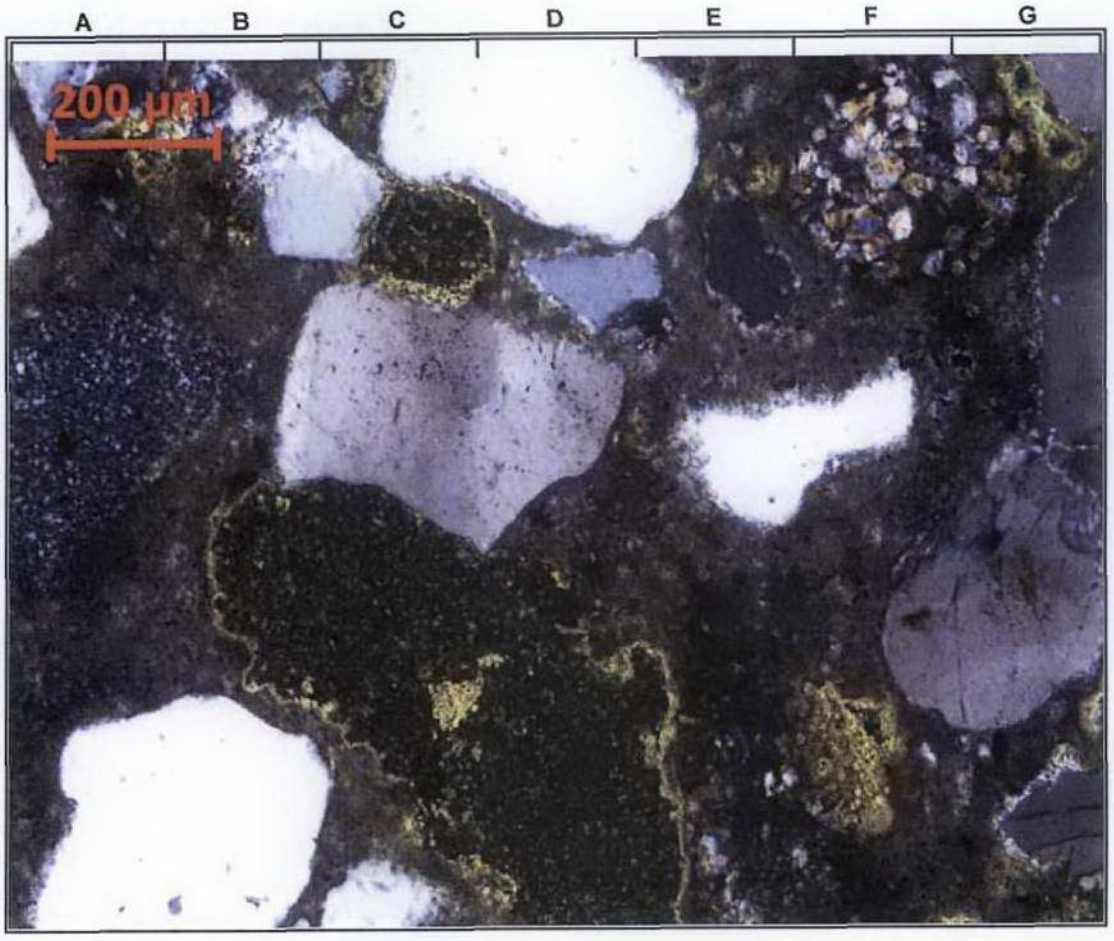
Plate 2

MICROSCOPICAL EXAMINATION OF HARDENED RENDER / MORTAR



Photomicrograph Details			
Sandberg Sample Ref:	G34805	Client Ref/Site Mark:	Sample 4 West elevation high level
Microscope Light:	Cross polarised	Objective Magnification:	x10

Photomicrograph Description

General view of render / mortar. Yellow colour is due to yellow impregnating resin infilling voids. White and blue/grey grains are quartz except the particle at A-B/3-5 which is a chert/flint particle. Note the thin carbonation rims along the void walls. A large cement grain is present at F-G/1-2.