

SANDBERG

CONSULTING ENGINEERS

INVESTIGATION INSPECTION
MATERIALS TESTING

Sandberg LLP
5 Carpenters Place
London SW4 7TD
Tel: 020 7565 7000
Fax: 020 7565 7101
email: clapham@sandberg.co.uk
web: www.sandberg.co.uk

REPORT 41378/G/2

PETROGRAPHIC EXAMINATION

OF

VARIOUS MATERIALS

WESTERN RANGE, CENTRAL BLOCK,
LEVEL 8 CORNICE
KING'S CROSS

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

For the attention of Mr G. Earl

This Report consists of
3 pages of text
Table 1 of 3 sheets
Table 2 of 3 sheets
Table 3 of 3 sheets

24 February 2010

Partners: N C D Sandberg S M Pringle S C Clarke D J Ellis P Tate A A Willmott R A Rogerson J M Caldon M A Eden
Senior Associates: J D French Dr R M Harris R A Lilly C Morgan G S Mayers
Associates: R H Gostomski D Hunt P Sotiropoulos R D Easthope I M Hudson I McLean J Williamson S R P Morris M I Ingle
Consultants: T Carbray Prof F M Burdekin J L Pickering

Sandberg established in 1860 is a member firm of the Association for Consultancy and Engineering
Sandberg LLP (Reg No OC304229) is registered in England and Wales Registered Office 40 Grosvenor Gardens London SW1W 0EB

SANDBERG
CONSULTING ENGINEERS
INVESTIGATION INSPECTION
TESTING MATERIALS

REPORT 41378/G/2
PETROGRAPHIC EXAMINATION
OF
VARIOUS MATERIALS
WESTERN RANGE, CENTRAL BLOCK
LEVEL 8 CORNICE
KING'S CROSS

Reference : Instructions from Mr G. Earl 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

The sample was received from Stonewest Ltd at Sandberg laboratories on 20 January 2010, as follows.

Sandberg Reference	Site Mark & Advised Location Details	Sample details
	Western range, Central Block, level 8 cornice	
G34759	#1	1 no. lump
G34760	#2	1 no. lump
G34761	#5	1 no. lump

3. TEST METHODS AND RESULTS

Each sample was subjected to petrographic examination in accordance with the methods

described in BS 5930:1999¹, ISRM², BS EN 12407:2007³ 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.

Sample #1

Buff to beige, fine to medium grained SANDSTONE/GRITSTONE. The stone exhibited faint bedding planes (lines) running parallel to two parallel surfaces of the lump sample. The stone was moderately hard to moderately soft (subjective scratch test).

The sample could be matched to Moorside, Ladycross, Shipley, Elland Edge Flagrock and Yorkstone Watson quarry.

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
G34759	Moorside [Grid reference: SJ 951` 798]	Possible
	or	
	Ladycross [Grid reference: NY 945 555]	Possible
	or	
	Shipley [Grid reference: NY 015 209]	Possible
	or	
	Elland Edge Flagrock [Grid reference: SE 122 236]	Possible
	or	
	Yorkstone Watson Quarry [Grid reference: SE 125 235]	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.

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 #2

Roman cement MORTAR.

No evidence of chemical attack or deterioration was identified in the specimen examined.

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.

Sample #3

Air entrained RESIN REPAIR MORTAR.

The sample exhibited two layers with a good bond. The top layer was up to 15mm and the lower layer up to 30mm in thickness. The top layer comprised mainly resin and sparse very fine crushed quartz and sand grains, whilst the lower layer contained mainly quartz sand and sparse quartz crushed fines. Both layers of the mortar were hard to very hard (subjective scratch test). The lower layer exhibited copper rod and a chicken wire type reinforcement.

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 Sandberg LLP

For the attention of Mr G. Earl

D J Ellis
Partner

DJE/Geoman/vb

24 February 2010

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

Tests reported on sheets not bearing the UKAS logo in this report/certificate are not included in the UKAS accreditation schedule for this laboratory.

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

SANDBERG

CONSULTING, INSPECTING
AND TESTING ENGINEERS



41378/G/2

Table/Sheet

1/1

Date of Test / by

23.2.2010/PS

PETROGRAPHICAL EXAMINATION OF ROCK

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

SAMPLE DETAILS			
Sample Reference	G34759	Client Reference/Site Mark	Lump 1
Sample Type, Source and Sampling Location Details:	Stone lump ex. western range - Central block, Level 8, Cornice		
Condition on Receipt:	Dry	Sample weight, g:	230
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 slice specimen from the sample was diamond-sawn and used to prepare a large area thin section which was then examined under a high power petrological microscope.		
Any Other Details:	The lump sample exhibited two parallel formed surfaces (i.e. exposed and underside). Thin section taken across the 50mm thickness of the sample. Thin section dimensions 45mm (thickness) x 65mm (length)		

MATERIAL DESCRIPTION:	Buff to beige, fine to medium grained SANDSTONE/GRITSTONE. The stone exhibited faint bedding planes (lines) running parallel to two parallel surfaces of the lump sample. The stone was moderately hard to moderately soft (subjective scratch test).
-----------------------	---

MATERIAL COMPOSITION:		PETROGRAPHICAL DETAILS ⁿ
COMPONENT	Volume % (estimated)	<p>The stone was found to be a grain supported sandstone comprising predominantly irregular/angular to elongate grains of quartz, occasional chlorite and feldspar, sporadic mica and rare zircon.</p> <p>The clastic components were quartz and feldspar ranging in size from 50µm to 300µm with the most common size range between 100µm to 200µm and therefore fine to medium grained. The clasts (i.e. quartz and feldspar) were angular to sub-angular and occasionally elongate, with medium to low sphericity and were the main structural constituents of the stone.</p> <p>Quartz appeared occasionally strained with embayed boundaries, angular to subangular, irregular to elongate with medium to low sphericity. Feldspar included plagioclase and possibly microcline, both of which exhibited alteration to chlorite and mica.</p> <p>Intergranular chlorite was microporous and frequently exhibited staining by iron or manganese oxide. Chlorite was also associated with altered feldspar. The buff to beige colour of the stone was due to the stained chlorite.</p> <p>Intergranular mica was sporadically present as muscovite (white) and occasional biotite (brown) mica and was occasionally seen to be aligned along bedding lines.</p> <p>Iron and/or manganese oxide granules were mainly associated with chlorite and mica both of which exhibited brown/orange staining.</p> <p>The stone was moderately to well compacted with occasional voids up to 200µm across and commonly less than 100µm in size infilled or partially infilled with chlorite. The presence of microporous chlorite and altered feldspar however may contribute to the overall porosity of the stone.</p>
Quartz	75	
Feldspar	7	
Chlorite	13	
Mica	5	
Others	<1	
TOTAL:	100	

UE = Undulatory Extinction. ND = Not Determined. NA = Not Applicable. NS = Not Supplied.
ⁿ Details mainly relate to components or features of possible engineering significance.

SANDBERG

CONSULTING, INSPECTING
AND TESTING ENGINEERS

41378/G/2

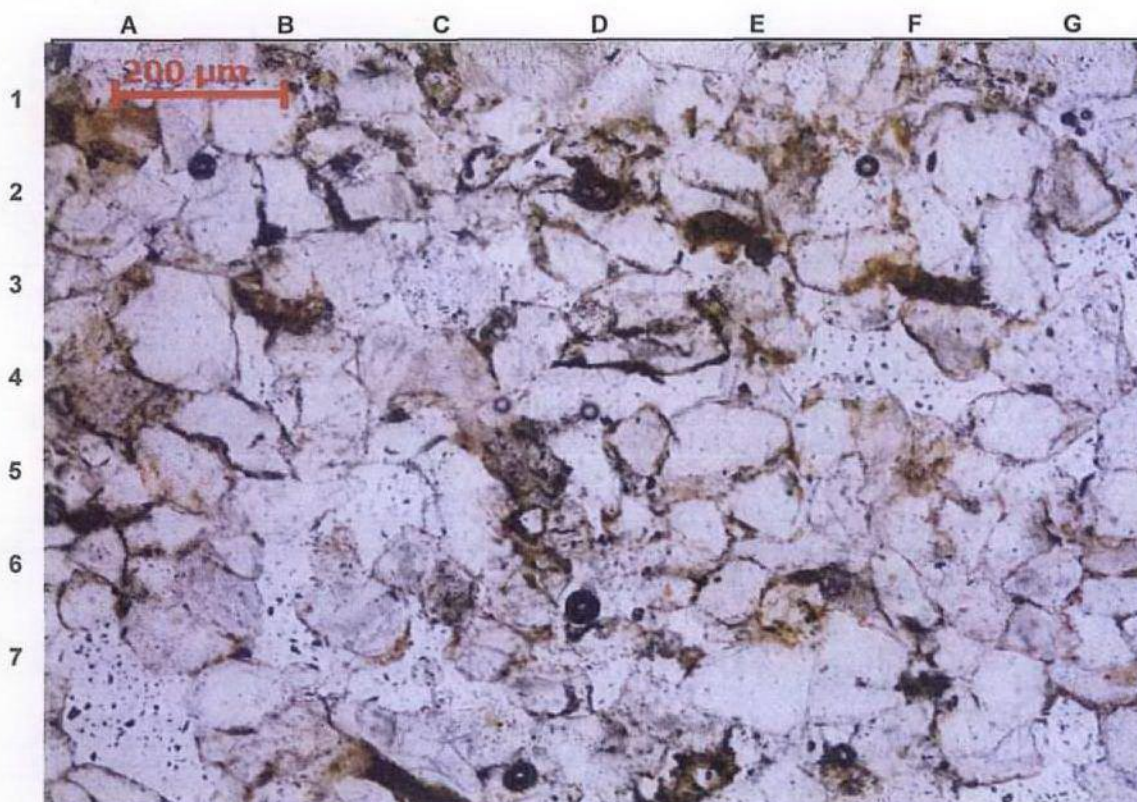
Table/Sheet

1/2

Plate

1

PETROGRAPHICAL EXAMINATION OF STONE - PHOTOMICROGRAPH



Sandberg Sample Ref:	G34759	Client Ref/Site Mark:	Lump 1 Sandstone (bedded)
Microscope Light:	Plane polarised	Objective Magnification:	x10
Photomicrograph Description			
General view of stone structure. White grains are quartz. Intergranular material is mainly chlorite which is microporous. Brown to dark brown interstitial material is iron or manganese oxide stained chlorite.			

SANDBERG

CONSULTING, INSPECTING
AND TESTING ENGINEERS

41378/G/2

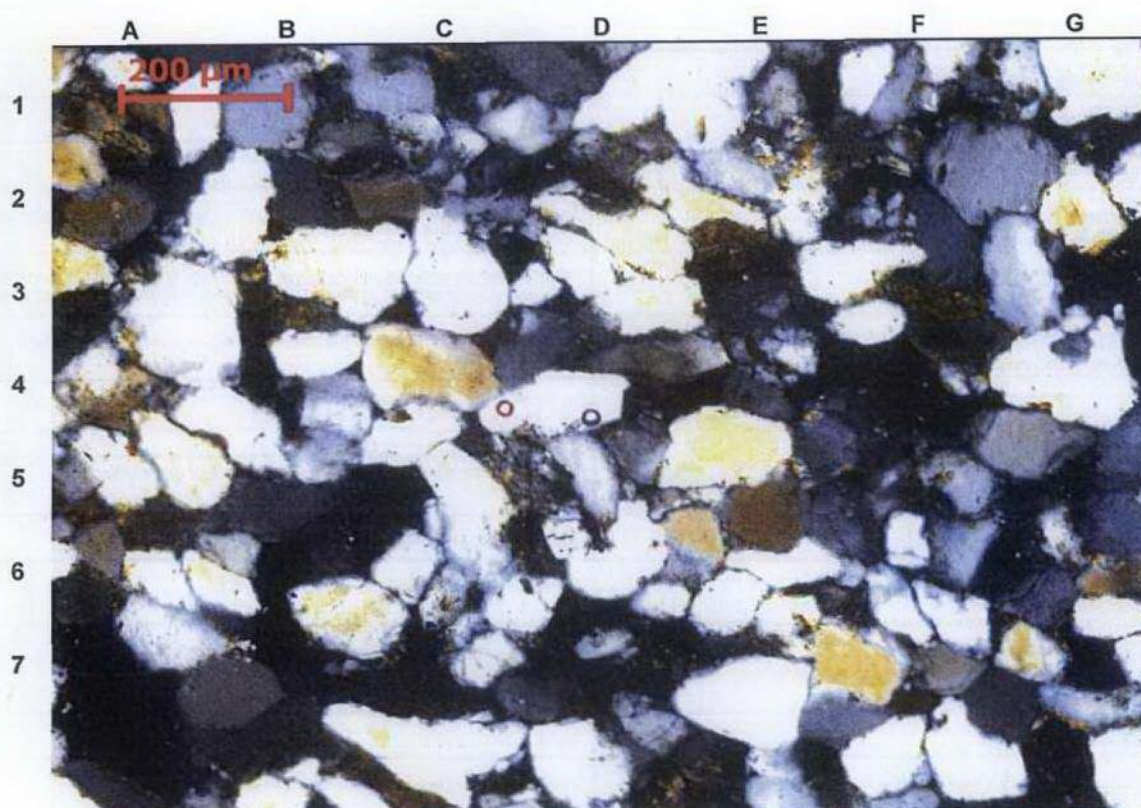
Table/Sheet

1/3

Plate

2

PETROGRAPHICAL EXAMINATION OF STONE - PHOTOMICROGRAPH

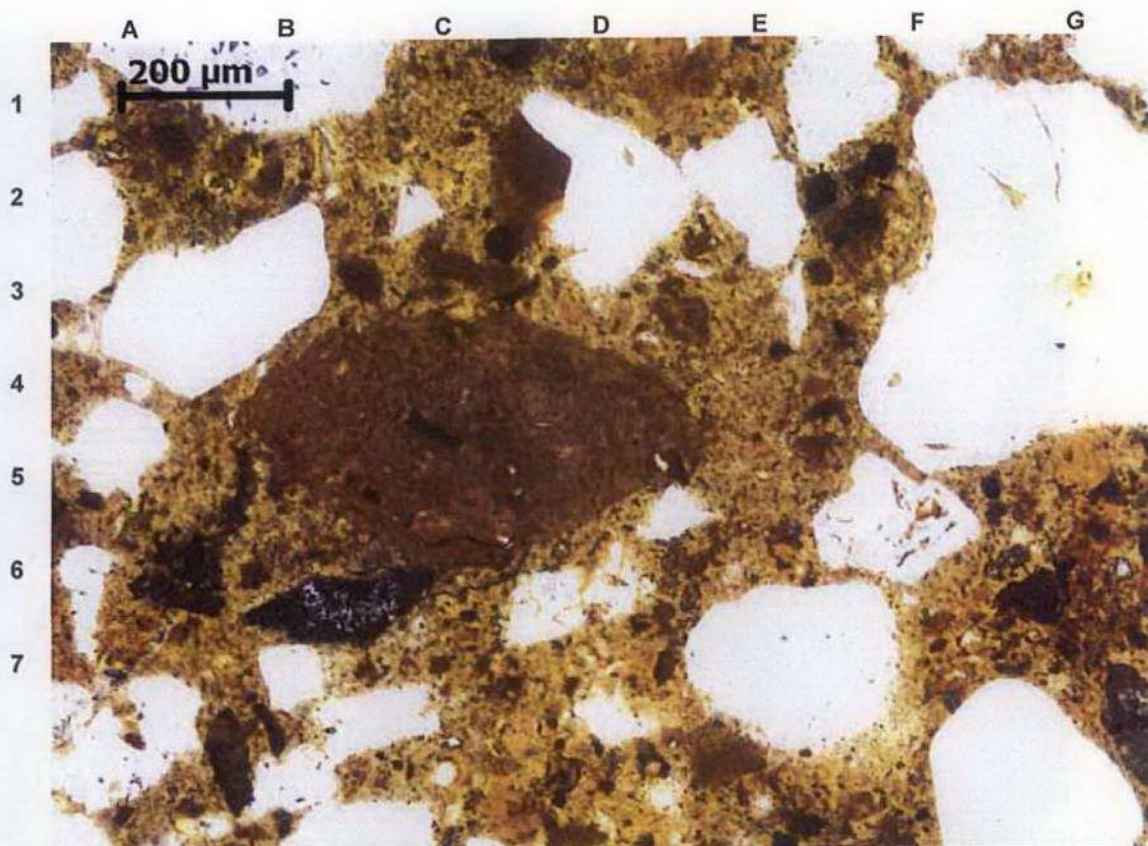


Sandberg Sample Ref:	G34759	Client Ref/Site Mark:	Lump 1 Sandstone (bedded)
Microscope Light:	Cross polarised	Objective Magnification:	x10
Photomicrograph Description			
General view of stone structure. White, blue/grey and yellow grains are quartz. Intergranular material is mainly chlorite which is microporous. Brown to dark brown interstitial material is iron or manganese oxide stained chlorite.			

MICROSCOPICAL EXAMINATION OF HARDENED MORTAR Based on ASTM C856- 04

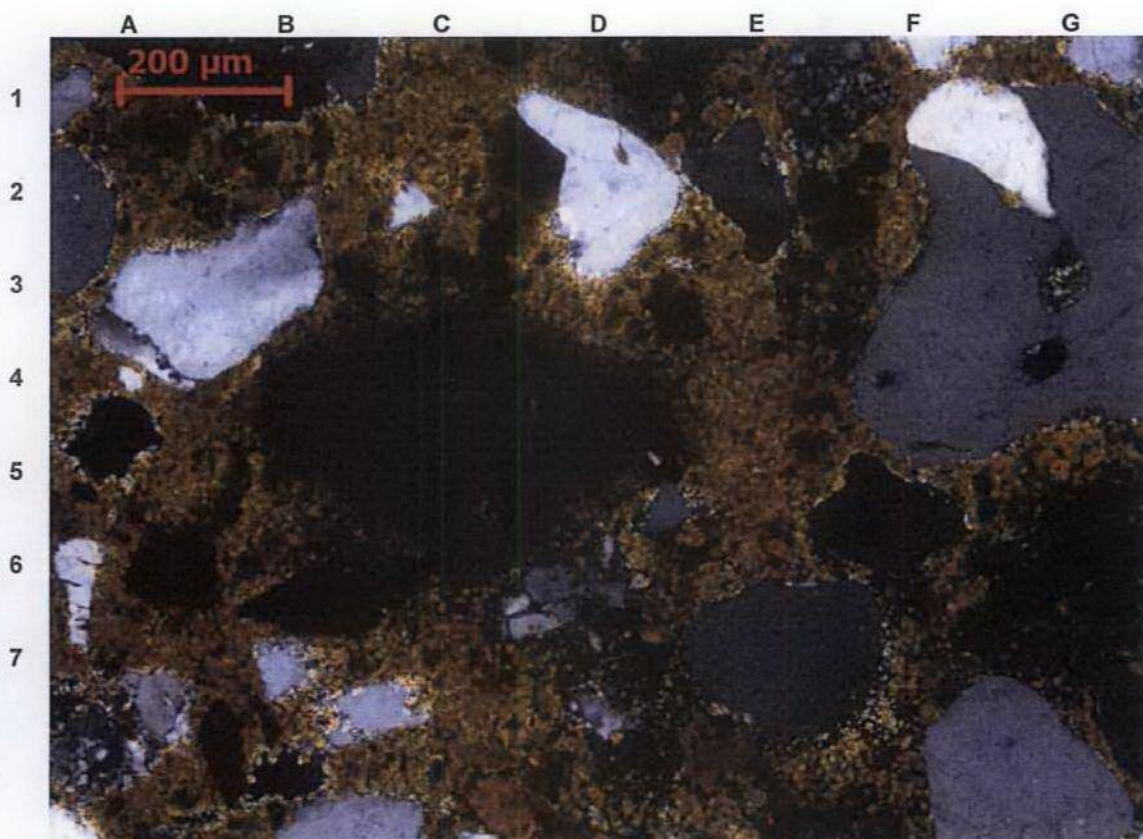
Sandberg Sample Reference:	G34760
Client Reference/Site Mark:	Lump 2
Sample Location Details:	Western Range - Central Block, Level 8, Cornice
Date of Test/Petrographer:	23.2.2010/PS
Specimen Preparation Details: (size, impregnation)	The mortar sample received was impregnated with an epoxy resin and used 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 microscopes employing magnifications up to x1000
Position of Specimen: (relationship to sample)	The slice was taken through the pieces of mortar sample. Thin section dimensions: 60mm x 35mm
MORTAR COMPOSITION AND FEATURES	
Fine Aggregate: (incl. particle size, grading, distribution, shape and composition)	Natural or partially crushed natural sand comprising mainly quartz, occasional quartzite and chert and sporadic shell pieces and glauconite.
Colour of Cement Matrix:	Dark grey/brown in hand specimen and orange in thin section
Cement Type: (Portland, lime etc)	Probably Roman cement.
Unhydrated grains: (incl. size, abundance and degree of hydration)	Frequent partially burnt cement grains up to 1mm across.
Mineral Additives:	None seen
Carbonation and Portlandite: (incl. depth and degree of carbonation, size and distribution of Ca(OH) ₂)	The mortar sample was carbonated throughout.
Compaction and Void Details: (incl. microporosity and void types, sizes, distribution)	The sample appeared to be generally well compacted for a mortar with occasional irregular to rounded and cavitaceous compaction voids up to 10mm across and commonly below 3mm in size.
Cracks and Microcracks: (incl. sizes, abundance, distribution relationships to other features)	Occasional fine cracks (<30µm in width) probably due to sampling operation.
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.

MICROSCOPICAL EXAMINATION OF HARDENED MORTAR



Sandberg Sample Ref:	G34760	Client Ref/Site Mark:	Lump 2 (Roman Cement Mortar)
Microscope Light:	Plane polarised	Objective Magnification:	x10
Photomicrograph Description			
General view of the matrix of Roman cement mortar. White grains are quartz. The yellow/orange matrix is hydrated paste, whilst the orange particles are partially burnt cement clinker grains.			

MICROSCOPICAL EXAMINATION OF HARDENED MORTAR



Sandberg Sample Ref:	G34760	Client Ref/Site Mark:	Lump 2 (Roman Cement Mortar)
Microscope Light:	Cross polarised	Objective Magnification:	x10
Photomicrograph Description			
General view of the matrix of Roman cement mortar. White and grey/blue grains are quartz. The yellow/orange matrix is hydrated paste, whilst the orange/brown particles are partially burnt cement clinker grains.			



MICROSCOPICAL EXAMINATION OF HARDENED MORTAR Based on ASTM C856- 04

Sandberg Sample Reference:	G34761
Client Reference/Site Mark:	Lump 5
Sample Location Details:	Western Range - Central Block, Level 8, Cornice
Date of Test/Petrographer:	23.2.2010/PS
Specimen Preparation Details: (size, impregnation)	The mortar sample received 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 microscopes employing magnifications up to x1000
Position of Specimen: (relationship to sample)	The slice was taken through the pieces of mortar sample. Thin section dimensions: 43mm x 73mm
MORTAR COMPOSITION AND FEATURES	
Fine Aggregate: (incl. particle size, grading, distribution, shape and composition)	Natural sand comprising entirely quartz irregular to subrounded grains up to 600µm across. Very fine crushed quartz fines were also present
Colour of Cement Matrix:	Pale grey top layer and very pale grey lower layer in hand specimen. The top layer was pale grey and the lower layer was dark grey in thin section.
Cement Type: (Portland, lime etc)	Air entrained resin
Unhydrated grains: (incl. size, abundance and degree of hydration)	Not applicable
Mineral Additives:	The resin matrix in both layers exhibited numerous spherical air void evenly distributed, up to 200µm in diameter probably due to air entraining agent.
Carbonation and Portlandite: (incl. depth and degree of carbonation, size and distribution of Ca(OH) ₂)	Not applicable
Compaction and Void Details: (incl. microporosity and void types, sizes, distribution)	The sample appeared to be generally well compacted with some irregular voids associated with the reinforcement (see below).
Cracks and Microcracks: (incl. sizes, abundance, distribution relationships to other features)	None seen
Secondary Deposits:	None seen.
Other Information: (incl. any evidence of deterioration, chemical attack, surface coatings, multiple layering etc.)	The sample exhibited two layers with a good bond. The top layer was up to 15mm and the lower layer up to 30mm in thickness. The top layer comprised mainly resin and sparse very fine crushed quartz and sand grains, whilst the lower layer contained mainly quartz sand and sparse quartz crushed fines. Both layers of the mortar were hard to very hard (subjective scratch test). The lower layer exhibited copper rod and a chicken wire type reinforcement.

SANDBERG

CONSULTING, INSPECTING
AND TESTING ENGINEERS



41378/G/2

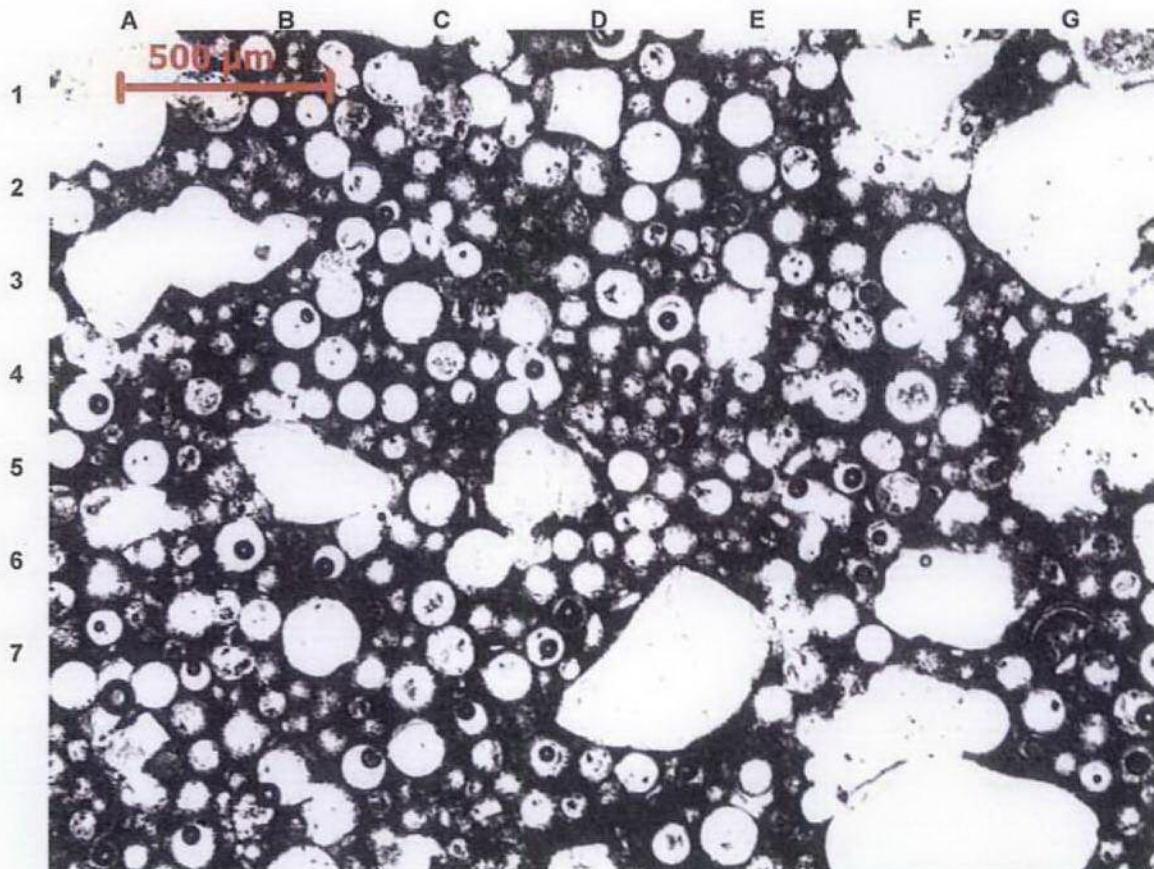
Table/Sheet

3/2

Plate

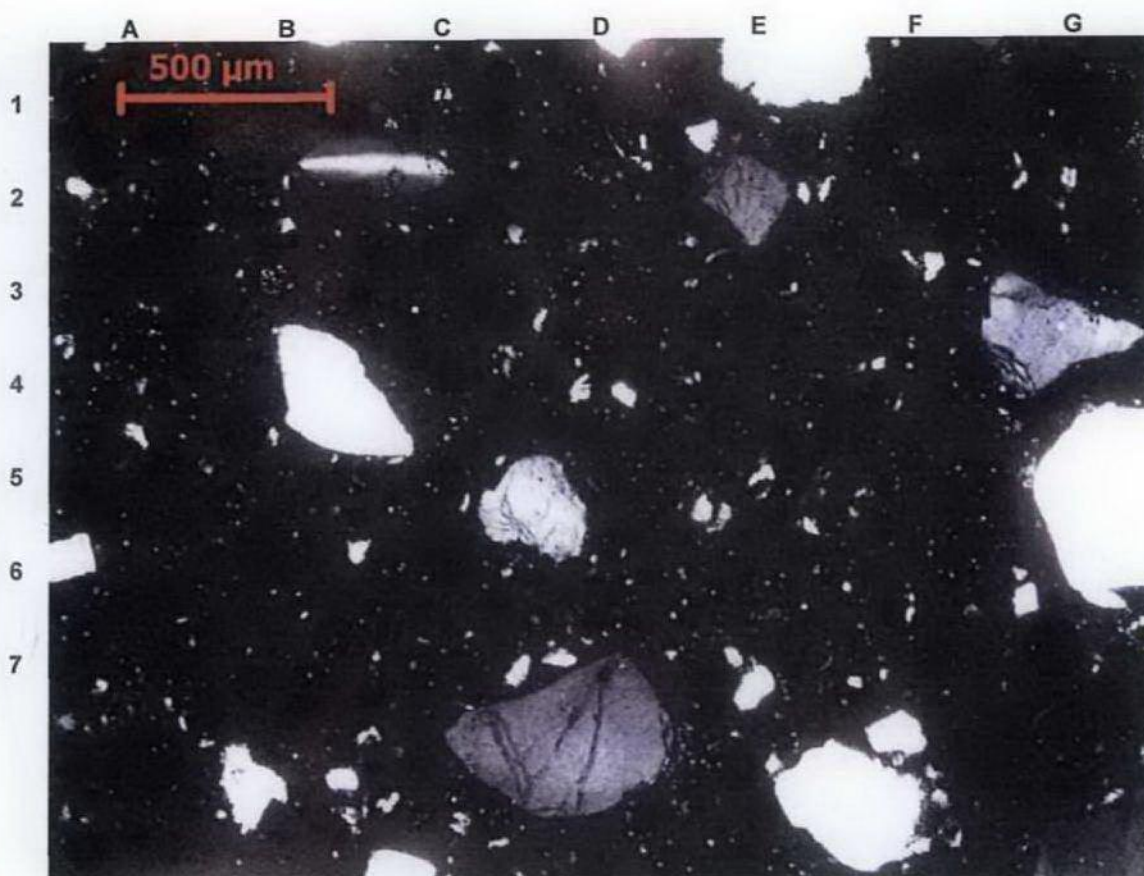
1

MICROSCOPICAL EXAMINATION OF HARDENED MORTAR



Sandberg Sample Ref:	G34761	Client Ref/Site Mark:	Lump 5 (Air Entrained Resin Mortar)
Microscope Light:	Plane polarised	Objective Magnification:	x5
Photomicrograph Description			
Typical view of the matrix of the air entrained resin repair mortar. White irregular grains are quartz. The dark background is resin. Spherical voids are air bubbles.			

MICROSCOPICAL EXAMINATION OF HARDENED MORTAR



Sandberg Sample Ref:	G34761	Client Ref/Site Mark:	Lump 5 (Air Entrained Resin Mortar)
Microscope Light:	Cross polarised	Objective Magnification:	x5
Photomicrograph Description			
Typical view of the matrix of the air entrained resin repair mortar. White and grey/blue irregular grains are quartz. The dark background is resin. Spherical black voids are air bubbles.			

3.2.7 Sandberg Consulting Engineers Report no. 41378/G/3

- West Elevation Link Building Sills