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REPORT 41260/G

PETROGRAPHIC EXAMINATION

OF STONE, RENDER AND MORTAR SAMPLES

EX KING'S CROSS

Stonewest Limited
Lamberts Place,
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This report comprises
3 pages of text
Appendix A of 3 sheets
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For the attention of Mr James Kennett

1 December 2009

SANDBERG
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REPORT 41260/G

PETROGRAPHIC EXAMINATION

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Reference: Purchase Order : 56346/41672 dated 21 October 2009

1. INTRODUCTION

Six samples, including stone, render and mortar, were received in our laboratory on 30 October 2009 and subjected to testing in accordance with your instructions.

We were asked to carry out a petrographic examination on each of the submitted samples.

2. SAMPLES RECEIVED

Sandberg Ref.	Client Ref.	Approximate Weight Rec'd, g
G34465	Stone, GL 19, Lift 6	121
G34466	1. Stucco/Render, GL 19, Lift 6	95
G34467	2. Stucco/Render, GL 19, Lift 6	358
G34468	3. Stucco/Render, GL 19, Lift 4	254
G34469	Lime Mortar, South Train Shed 1	88
G34470	Lime Mortar, South Train Shed 2	75

3. TEST METHOD AND RESULTS

3.1 General

Each sample was first photographed and a record colour photograph for each sample is given in Appendix A of this report.

3.2 Petrographic Examination of Stone sample G34465/GL 19, Lift 6

The sample was subjected to petrographic examination in accordance with the methods described in BS 5930:1999[1], ISRM[2] and BS EN 12407:2007[3].

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

A representative portion from the 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 Table 1 of this report and may be summarised as follows.

Pale beige to buff, fine to medium grained, bedded SANDSTONE, well compacted, hard and strong (subjective estimates). Bedding structure was defined by generally parallel, discontinuous dark brown streaks. The thickness of the bedding as defined by the streaks ranged in the millimetre to centimetre scale.

3.3 Petrographic Examination of Render and Lime Mortar Samples

Each render and lime mortar sample was subjected to examination following the methods given in ASTM 856-04[4]. Each sample was first subjected to macroscopical and low power stereomicroscopical examination supported by simple physical and chemical tests.

A slice specimen, across the thickness of each render sample was diamond sawn, and at least 5No. pieces of lime mortar from each mortar sample, were all impregnated with fluorescent epoxy resin, and each specimen was used to prepare a sawn surface and a large area thin section each of which was examined under a stereoscopic zoom microscope and a high-power petrological microscope respectively, employing magnifications up to x1000 in incident, plane, cross polarised and ultra violet light.

The detailed results of the petrographic examination are given in Tables 2 to 6 of this report and may be summarised as follows.

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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.

4 ASTM C856-04 'Standard Practice for Petrographic Examination of Hardened Concrete'

3.3.1 Render samples G34466/1, G34467/2 & G34468/3

The three render samples were found to be very similar in composition and texture containing a natural sand and Portland cement paste.

The sand comprised mainly quartz/metaquartzite, occasional flint, sporadic limestone, feldspar and glauconite and rare ironstone.

The cement paste was found to made using Portland cement probably early Portland cement on account of the coarse unhydrated cement grains.

The render samples were well compacted for render, hard and strong (subjective estimate) and no evidence of chemical attack or deterioration was identified in the specimens examined.

3.3.2 Lime Mortar samples G34469/1 & G34470/2

The two lime mortar samples were found to be very similar in composition and texture containing a natural sand and a lime matrix.

The sand comprised mainly quartz, occasional quartzite, chert and sporadic feldspar and rare relict shell and glauconite. Occasional coal (coke) pieces and rare possible clay clots and wood slivers were also present.

The mortar samples were well compacted for lime mortar but the lime matrix was microporous.

The samples were found to contain a well burnt lime binder.

4. REMARKS

These results and comments conclude the testing requested to date. Please contact us if we can be of any further assistance in this matter.

Stonewest Limited
Lamberts Place,
St James's Road,
Croydon
CR9 2HX,

for Sandberg LLP

For the attention of Mr James Kennett

Panos Sotiropoulos
Principal Geologist / Associate

1 December 2009

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Table/Sheet
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Date of Test / by
27.11.2009/PS

PETROGRAPHICAL EXAMINATION OF ROCK

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

SAMPLE DETAILS			
Sample Reference	G34465	Client Reference/Site Mark	GL19, Lift 6
Sample Type, Source and Sampling Location Details:	Sandstone sample ex King's Cross.		
Condition on Receipt:	Dry	Sample approx. weight, g:	120
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 slice specimen was diamond-sawn and used to prepare a thin section which was then examined under a high power petrological microscope.		
Any Other Details:	The slice specimen was taken perpendicular to the apparent bedding of the sample. Thin section dimensions, mm: 47 (across bedding) x 49 (along bedding).		

MATERIAL DESCRIPTION:	Pale beige to buff, fine to medium grained, bedded SANDSTONE, well compacted, hard and strong (subjective estimates). Bedding structure was defined by generally parallel, discontinuous dark brown streaks. The thickness of the bedding as defined by the streaks ranged in the millimetre to centimetre scale.

MATERIAL COMPOSITION:	
COMPONENT	Volume % (estimated)
Quartz	75
Feldspar	6
Chlorite	8
Mica	10
Voids	1
Zircon	<<1
TOTAL:	100

PETROGRAPHICAL DETAILS[n]

The stone was found to be a grain supported sandstone comprising predominantly grains of quartz, frequent chlorite and mica, occasional feldspar and rare zircon.

Quartz ranged in size from 50µm to 300µm with most common size range between 100µm to 200µm and therefore fine to medium grained.

Quartz grains were angular to subangular, irregular to elongate with medium to low sphericity exhibiting sutured boundaries.

Feldspar included plagioclase and microcline, both of which occasionally exhibited a murky appearance due to incipient alteration.

Chlorite was present as intergranular materials occasionally stained brown possibly due to oxidation. Chlorite was also associated with mica.

Mica, mainly brown (biotite) and sporadically white (muscovite) grains were also present as intergranular material, frequently associated with chlorite and contained iron oxide. Mica was occasionally aligned along grain boundaries forming streaks which were seen in hand specimen to run parallel to subparallel to each other.

The stone was generally well compacted with sporadic intergranular voids up to 100µm across and commonly less than 100µm in size. The intergranular chlorite however was microporous and may contributed to the overall microporosity of the stone.

UE = Undulatory Extinction. ND = Not Determined. NA = Not Applicable. NS = Not Supplied.

[n] Details mainly relate to components or features of possible engineering significance.

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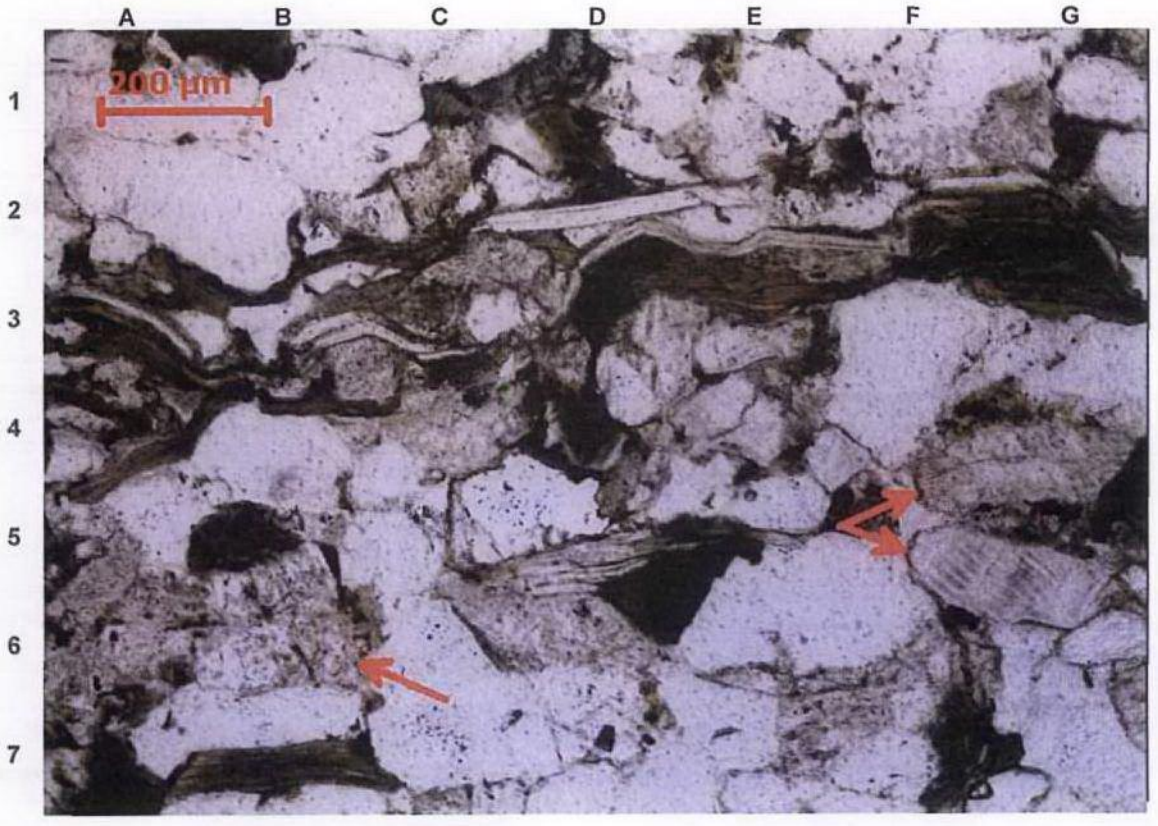
Table/Sheet 1/2
Plate 1

PETROGRAPHICAL EXAMINATION OF STONE - PHOTOMICROGRAPH



Photomicrograph Details			
Sandberg Sample Ref:	G34465	Client Ref/Site Mark:	CL 19, Lift 6
Microscope Light:	Plane polarised	Objective Magnification:	x10

Photomicrograph Description

General view of stone structure. Aligned brown (biotite) and white (muscovite) mica forming a streak. Red arrows point to feldspar grains. At C-D/1 is chlorite infilling an intergranular space.

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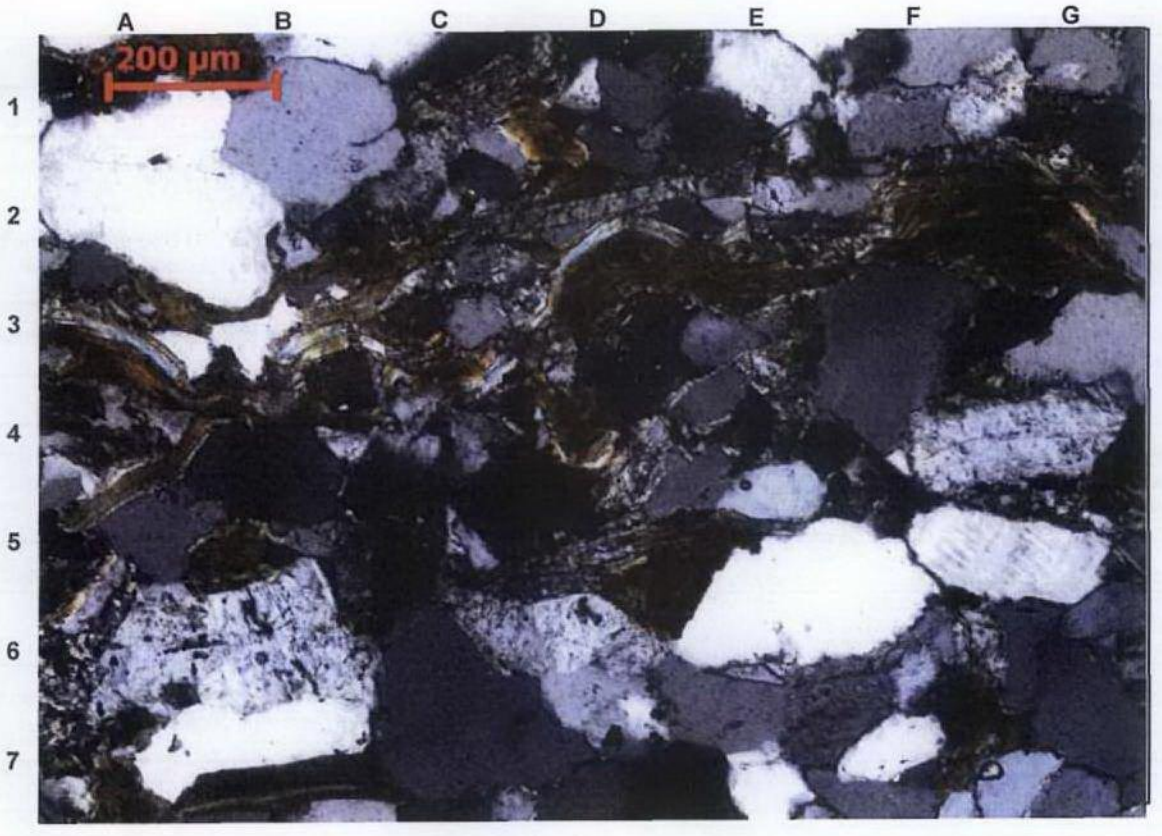
Table/Sheet 1/3
Plate 2

PETROGRAPHICAL EXAMINATION OF STONE - PHOTOMICROGRAPH



Photomicrograph Details			
Sandberg Sample Ref:	G34465	Client Ref/Site Mark:	CL 19, Lift 6
Microscope Light:	Cross polarised	Objective Magnification:	x10
Photomicrograph Description			
General view of stone structure. Aligned brown (biotite) and white (muscovite) mica forming a streak.			

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Table
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MICROSCOPICAL EXAMINATION OF RENDER
Based on ASTM C856-04

Sandberg Sample Reference:	G34466
Client Reference/Site Mark:	Sample 2 - GL19, Lift 6 - Stucco Render
Sample Location Details:	King's Cross
Date of Test/Petrographer:	27.11.2009/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 microscopes employing magnifications up to x1000
Position of Specimen: *(relationship to sample)*	Thin section was taken across the thickness of the submitted sample
RENDER COMPOSITION AND FEATURES	
Fine Aggregate: *(incl. particle size, grading, distribution, shape and composition)*	Natural sand comprising irregular particles, up to 5mm and commonly less than 600µm across down to 75µm, of mainly quartz/metaquartzite, occasional flint, sporadic limestone, feldspar and glauconite and rare ironstone.
Colour of Cement Matrix:	Pale grey to grey in hand specimen and grey/brown in thin section.
Cement Type: *(Portland, lime etc)*	Portland cement (early Portland cement
Unhydrated grains: *(incl. size, abundance and degree of hydration)*	Frequent unhydrated and/or partially hydrated cement grains up to 1mm across and commonly less than 300µm in size.
Mineral Additives:	None identified
Carbonation and Portlandite: *(incl. depth and degree of carbonation, size and distribution of $Ca(OH)_2$)*	The matrix appeared carbonated throughout although some areas appeared partially or moderately carbonated. The unhydrated cement grains however were predominantly uncarbonated.
Compaction and Void Details: *(incl. microporosity and void types, sizes, distribution)*	Generally good for a render with occasional voids up to 2mmacross. The microporosity was generally low similar to reference specimens made using water cement ratio 0.3 and 0.4.
Cracks and Microcracks: *(incl. sizes, abundance, distribution relationships to other features)*	A few cracks possibly due to sampling
Secondary Deposits:	Calcite lining some voids
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 render sample was hard and strong (subjective estimate), up to 30mm in thickness.

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Table
3

MICROSCOPICAL EXAMINATION OF RENDER
Based on ASTM C856-04

Sandberg Sample Reference:	G34467
Client Reference/Site Mark:	Sample 2 - GL19, Lift 6 - Stucco Render
Sample Location Details:	King's Cross
Date of Test/Petrographer:	27.11.2009/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 microscopes employing magnifications up to x1000
Position of Specimen: *(relationship to sample)*	Thin section was taken across the thickness of the submitted sample
RENDER COMPOSITION AND FEATURES	
Fine Aggregate: *(incl. particle size, grading, distribution, shape and composition)*	Natural sand comprising irregular particles, up to 7mm and commonly less than 600µm across down to 75µm, of mainly quartz/metaquartzite, occasional flint, sporadic limestone, feldspar and glauconite and rare ironstone.
Colour of Cement Matrix:	Pale grey to grey in hand specimen and grey/brown in thin section.
Cement Type: *(Portland, lime etc)*	Portland cement (early Portland cement
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.
Mineral Additives:	None identified
Carbonation and Portlandite: *(incl. depth and degree of carbonation, size and distribution of $Ca(OH)_2$)*	The matrix appeared carbonated throughout although some areas appeared partially or moderately carbonated. The unhydrated cement grains however were predominantly uncarbonated.
Compaction and Void Details: *(incl. microporosity and void types, sizes, distribution)*	Generally good for a render with occasional voids up to 2mmacross. The microporosity was generally low similar to reference specimens made using water cement ratio 0.3 and 0.4.
Cracks and Microcracks: *(incl. sizes, abundance, distribution relationships to other features)*	A few cracks possibly due to sampling
Secondary Deposits:	Calcite lining some voids
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 render sample was hard and strong (subjective estimate), up to 25mm in thickness. The top surface of the sample exhibited a multilayer pant coat up to 1.4mm in thickness.

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Table
4

MICROSCOPICAL EXAMINATION OF RENDER
Based on ASTM C856-04

Sandberg Sample Reference:	G34468
Client Reference/Site Mark:	Sample 3 - GL19, Lift 4 - Stucco Render
Sample Location Details:	King's Cross
Date of Test/Petrographer:	27.11.2009/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 microscopes employing magnifications up to x1000
Position of Specimen: *(relationship to sample)*	Thin section was taken across the thickness of the submitted sample
RENDER COMPOSITION AND FEATURES	
Fine Aggregate: *(incl. particle size, grading, distribution, shape and composition)*	Natural sand comprising irregular particles, up to 9mm and commonly less than 600µm across down to 75µm, of mainly quartz/metaquartzite, occasional flint, sporadic limestone, feldspar and glauconite and rare ironstone.
Colour of Cement Matrix:	Pale grey to grey in hand specimen and grey/brown in thin section.
Cement Type: *(Portland, lime etc)*	Portland cement (early Portland cement.
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.
Mineral Additives:	None identified
Carbonation and Portlandite: *(incl. depth and degree of carbonation, size and distribution of $Ca(OH)_2$)*	The matrix appeared carbonated throughout although some areas appeared partially or moderately carbonated. The unhydrated cement grains however were predominantly uncarbonated.
Compaction and Void Details: *(incl. microporosity and void types, sizes, distribution)*	Generally good for a render with occasional voids up to 2mmacross. The microporosity was generally low similar to reference specimens made using water cement ratio 0.3 and 0.4.
Cracks and Microcracks: *(incl. sizes, abundance, distribution relationships to other features)*	A few cracks possibly due to sampling
Secondary Deposits:	Calcite lining some voids
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 render sample was hard and strong (subjective estimate), up to 40mm in thickness.

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Table
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MICROSCOPICAL EXAMINATION OF HARDENED MORTAR
Based on ASTM C856 - 04

Sandberg Sample Reference:	G34469
Client Reference/Site Mark:	Lime mortar sample 1
Sample Location Details:	King's Cross, South Train Shed 1
Date of Test/Petrographer:	27.11.2009/PS
Specimen Preparation Details: *(size, impregnation)*	Pieces from the mortar sample received were impregnated with an epoxy resin and used to prepare one 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)*	Thin section was taken through at least 5No. pieces of the mortar sample. Thin section dimensions, mm: 65 x 45.
MORTAR COMPOSITION AND FEATURES	
Fine Aggregate: *(incl. particle size, grading, distribution, shape and composition)*	Natural sand comprising mainly quartz, occasional quartzite, chert and sporadic feldspar and rare relict shell and glauconite, subrounded to irregular particles up to 5mm across and commonly less than 600µm down to 75µm across. Occasional coal (coke) pieces were present. Rare possible clay clots and wood slivers were also seen.
Colour of Cement Matrix:	Pale cream/grey in hand specimen and thin section.
Cement Type: *(Portland, lime etc)*	Lime
Unhydrated grains: *(incl. size, abundance and degree of hydration)*	Sporadic unburnt and partially burnt limestone pieces up to 500µm 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 mainly carbonated throughout.
Compaction and Void Details: *(incl. microporosity and void types, sizes, distribution)*	The sample pieces appeared to be well compacted for mortar. The lime matrix was microporous.
Cracks and Microcracks: *(incl. sizes, abundance, distribution relationships to other features)*	Occasional cracks in places indicative of drying shrinkage.
Secondary Deposits:	None seen
Other Information: *(incl. any evidence of deterioration, chemical attack, surface coatings, multiple layering etc.)*	The samples was found to contain a well burnt lime binder.

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Table
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MICROSCOPICAL EXAMINATION OF HARDENED MORTAR
Based on ASTM C856 - 04

Sandberg Sample Reference:	G34470
Client Reference/Site Mark:	Lime mortar sample 2
Sample Location Details:	King's Cross, South Train Shed 2
Date of Test/Petrographer:	27.11.2009/PS
Specimen Preparation Details: *(size, impregnation)*	Pieces from the mortar sample received were impregnated with an epoxy resin and used to prepare one 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)*	Thin section was taken through at least 5No. pieces of the mortar sample. Thin section dimensions, mm: 65 x 45.
MORTAR COMPOSITION AND FEATURES	
Fine Aggregate: *(incl. particle size, grading, distribution, shape and composition)*	Natural sand comprising mainly quartz, occasional quartzite, chert and sporadic feldspar and rare relict shell and glauconite, subrounded to irregular particles up to 5mm across and commonly less than 600µm down to 75µm across. Occasional coal (coke) pieces were present. Rare possible clay clots and wood slivers were also seen.
Colour of Cement Matrix:	Pale cream/grey in hand specimen and thin section.
Cement Type: *(Portland, lime etc)*	Lime
Unhydrated grains: *(incl. size, abundance and degree of hydration)*	Sporadic unburnt and partially burnt limestone pieces up to 500µm 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 mainly carbonated throughout.
Compaction and Void Details: *(incl. microporosity and void types, sizes, distribution)*	The sample pieces appeared to be well compacted for mortar. The lime matrix was microporous.
Cracks and Microcracks: *(incl. sizes, abundance, distribution relationships to other features)*	Occasional cracks in places indicative of drying shrinkage.
Secondary Deposits:	None seen
Other Information: *(incl. any evidence of deterioration, chemical attack, surface coatings, multiple layering etc.)*	The sample was found to contain a well burnt lime binder.

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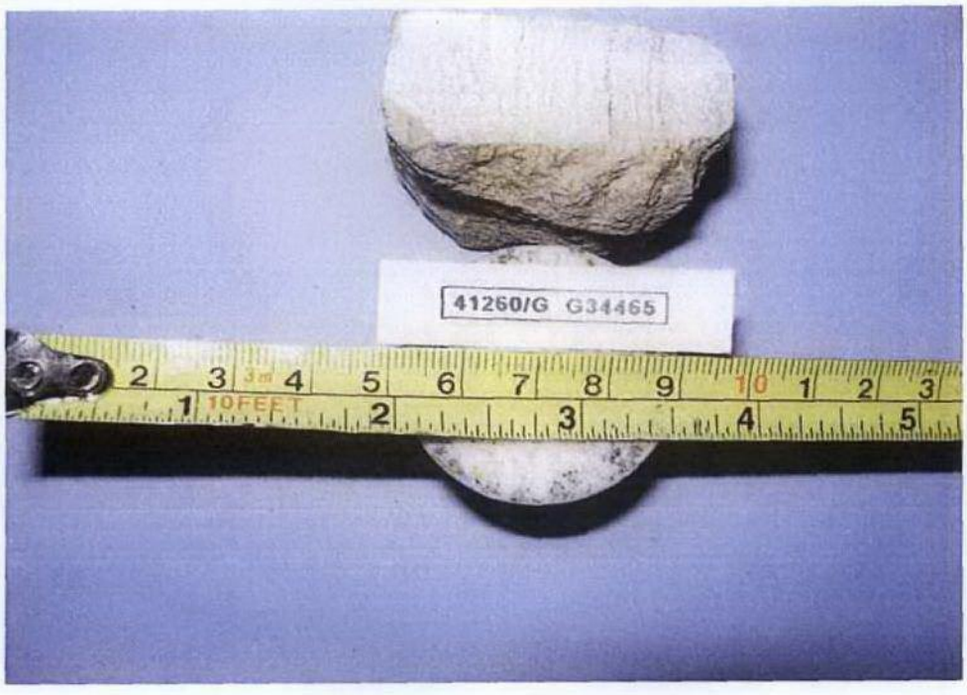
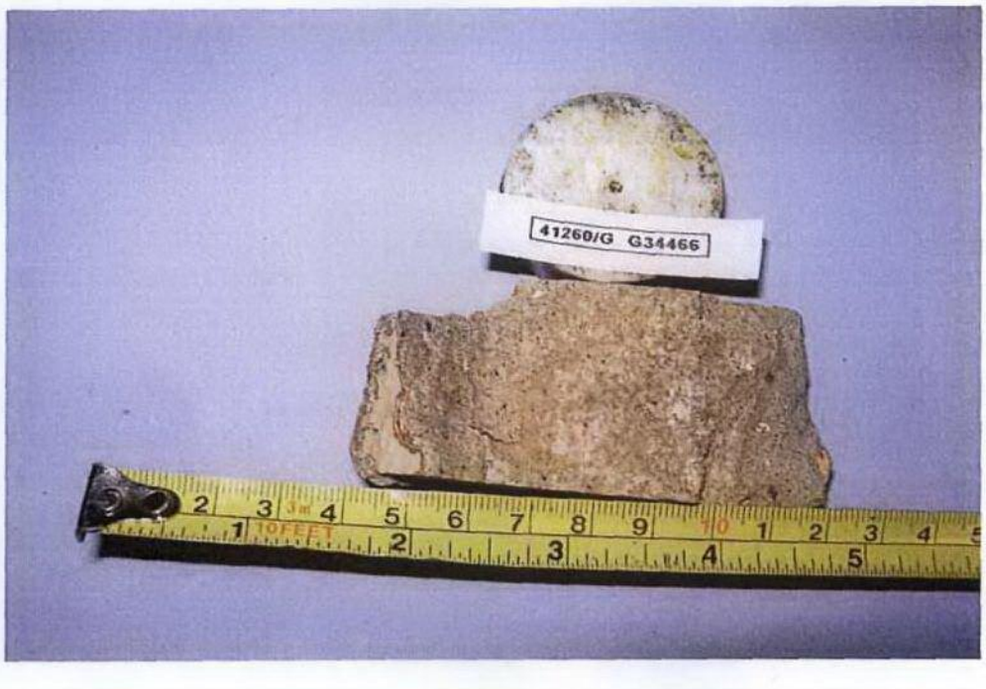
SAMPLE PHOTOGRAPHS



Sample G34465. Stone, GL 19, Lift 6



Sample G34466. 1. Stucco/Render, GL 19, Lift 6

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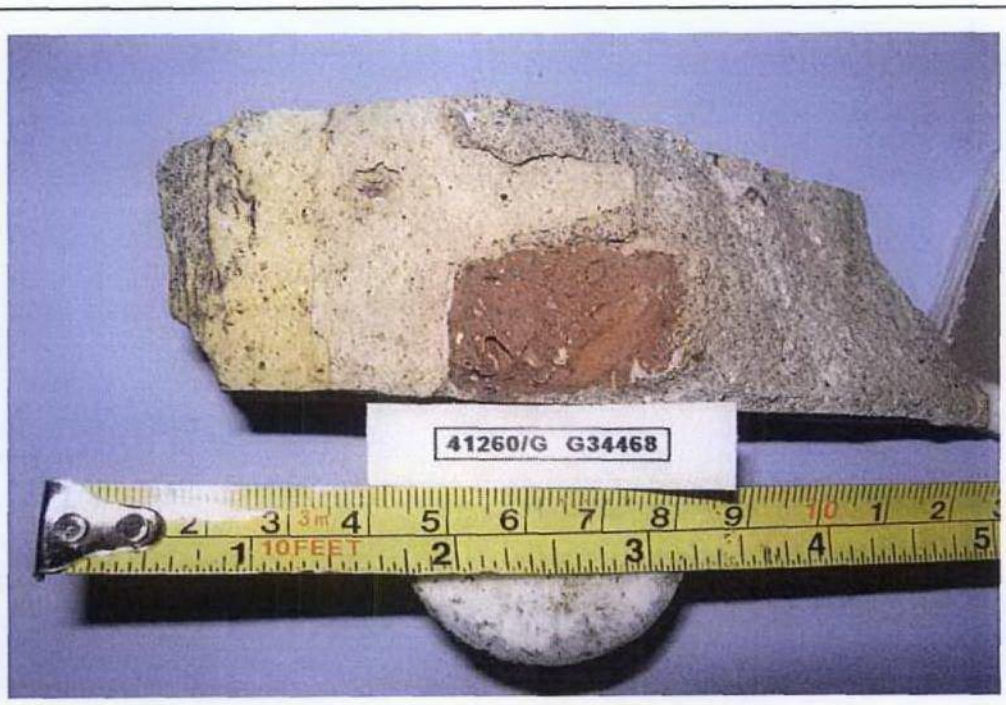
SAMPLE PHOTOGRAPHS

Sample G34467. 2. Stucco/Render, GL 19, Lift 6



Sample G34468. 3. Stucco/Render, GL 19, Lift 4

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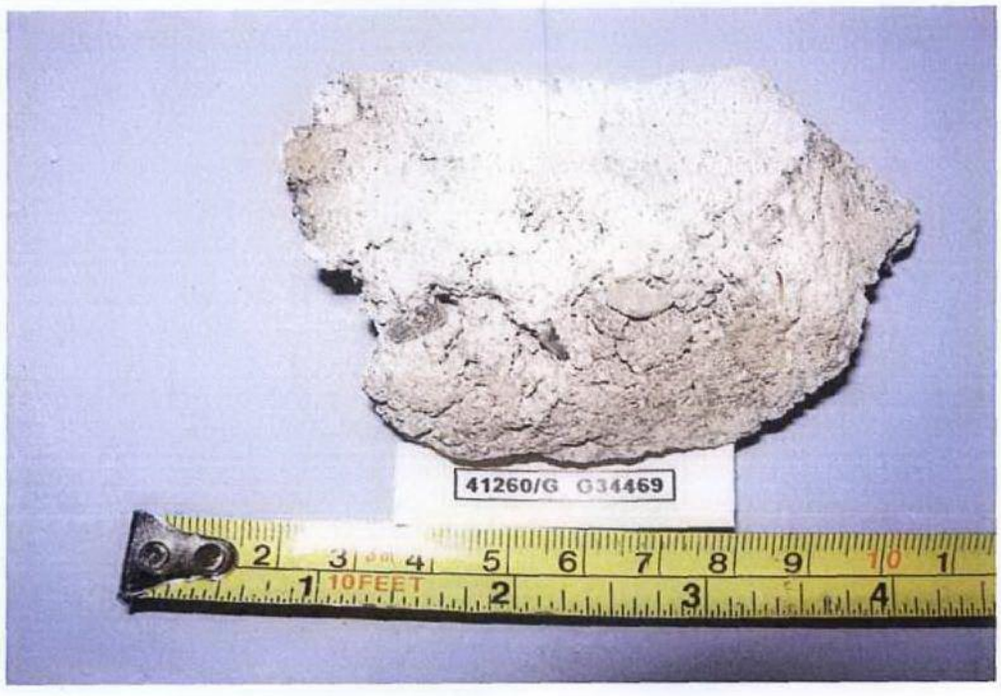
SAMPLE PHOTOGRAPHS



Sample G34469. Lime Mortar, South Train Shed 1

Sample G34470. Lime Mortar, South Train Shed 2

3.2.4 Sandberg Consulting Engineers Report no. 41378/G

- West Elevation Central Block Window Surrounds