APPENDIX 1 – Rose of Jericho test results.

ROSE OF JERICHO
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MANUFACTURER OF TRADITIONAL LIMES . MORTARS & PAINTS . MORTAR ANALYSIS & CONSULTANTS

Henry Skinner
Head of Projects and Facilities Management
The Treasury
Lincoln's Inn
London WC2A 3TL

February 28, 2023.

Dear Henry,

Lincoln's Inn, New Square.
Results Summary. Test reports 5521 to 5531.

Test 5521. Sample 1, Building 2 (north end).
This is a high strength uncarbonated Portland cement based render at c.1: 3 (binder: aggregate by volume). The aggregate is principally fine quartz. This is very likely to be a 20th century material.

Test 5522. Sample 2, Building 2 (south end).
This is a moderate/high strength carbonated render of the Roman cement type at c.1: 2.5 (binder: aggregate by volume). The aggregate is principally fine quartz and flint. This is very likely to be a 19th century material.

Test 5523. Sample 3, Building 3.
This is a moderate strength carbonated render of the Roman cement type at c.1: 2.5 (binder: aggregate by volume). The aggregate is principally fine quartz. This is likely to date from the first half of the 19th century.

Test 5524. Sample 4, Building 4.
This is a moderate/low strength oil-mastic render. Oil mastics were sand and a lead compound, normally litharge (lead monoxide) mixed with linseed oil. Lead is a potent neurotoxin that affects multiple body systems, and there are Health & Safety issues to be considered when this material is repaired, and a risk assessment must be carried out in accordance with CLAW 2002. The XRF scan did not detect any other toxic elements and heavy metals in significant quantity, but did identify sulphur in greater concentration than determined by chemical analysis. This presumably indicates the sulphur to be present as an ingredient in a form that does not dissolve in hydrochloric acid, conceivably as a pigment or fungicide. This material is either late 18th or early 19th century.

Test 5525. Sample 6, Building 6.
This is a moderate strength carbonated render of the Roman cement type at c.1: 2.5 (binder: aggregate by volume), similar to Sample 3: 5523. The aggregate is principally fine quartz and flint. This is likely to date from the first half of the 19th century. Sample 5 from Building 5 has not been tested as it appears visually to be the same as Sample 6.

Test 5526. Sample 7, Building 7.
This is a high strength uncarbonated Portland cement based render at c.1: 3 to 4 (binder: aggregate by volume). The aggregate is principally fine quartz. This is very likely to be a 20th century material.

Test 5527. Sample 8, Building 8.
This is a high strength uncarbonated Portland cement based render at c.1: 3 to 4 (binder: aggregate by volume). The aggregate is a coarse quartz and flint sand. This is very likely to be a 20th century material.

Test 5528. Sample 9A, Building 9.
This thin (<1.5mm) 'finish-coat' has not been tested as there is insufficient material to analyse by chemical dissolution. The sample reacted slowly with 10% hydrochloric acid indicating it to be a calcareous material and supporting the visual assessment that it appears to be neat Roman cement binder. The sample is likely to be of historic significance and analysis by SEM/EDX (scanning electron microscope with X-ray microanalysis) could be considered to determine and identify the constituent compounds.

Test 5529. Sample 9B, Building 9.
This is a moderate/high strength carbonated render of the Roman cement type at c.1: 2.5 to 3 (binder: aggregate by volume). The aggregate is principally fine quartz. This is very likely to be a 19th century material.

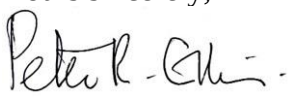
Test 5530. Sample 10A, Building 11.
This top-coat material is a high strength carbonated Portland cement based render at c.1: 5 (binder: aggregate by volume). The aggregate is principally quartz. This is very likely to be a 20th century material.

Test 5531. Sample 10B, Building 11.
This base-coat material is a high strength uncarbonated Portland cement based render at c.1: 4 (binder: aggregate by volume). The aggregate is a medium-coarse quartz and flint sand. This is very likely to be a 20th century material.

Please do contact me if you would like to discuss the results.

Kind regards,

Yours sincerely,



Peter Ellis FSA

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Mortar Analysis

Test Report No. 5521.

Lincoln's Inn, New Square, London WC2A.

Sample 1. Building 2.

Sample as received.

A core sample (15.2g) of external render collected at basement level from the North end of the west-facing elevation of Building 2 has been analysed chemically and microscopically. This is a late 19th or 20th century repair and not original late 17th century material.

Sample Assessment and Microscopic Observations.

Paint removed prior to analysis. Intact grey render c.12mm thick. High strength (sample could not be broken by hand nor crumbled in fingers; crushed using pestle with difficulty). Aggregate is principally fine pale grey-brown quartz. Calcareous aggregate not determined. Kiln-fuel particles not found. Hair or fibre reinforcement not present.

Preliminary Tests.

Dry sample. Generally un-carbonated (phenolphthalein carbonation test).
Apparent water permeability very low (water droplet absorption on dried surface).
Slight effervescence on addition of dilute (10%) hydrochloric acid.

Chemical Dissolution Analysis (% dry mass) to BS4551:2005+A2:2013 (+ICP-OES).

%	Initial Moisture (oven @ 40^0C)	4.27
%	Total Calcium as CaO (titrimetric method)	16.47
%	Total Magnesium as MgO (ICP-OES method)	0.21
%	Acid & alkali soluble Silicon as SiO_2 (gravimetric method)	5.21
%	Soluble Aluminium as Al_2O_3 (ICP-OES method)	1.56
%	Soluble Iron as Fe_2O_3 (ICP-OES method)	0.69
%	Total (acid-soluble) sulphate as SO_3 (gravimetric method)	0.97
%	Total Acid Insolubles	68.1

BINDER

The binder in this sample is un-carbonated Portland cement as confirmed by the soluble silica and alumina test results and the CaO:SiO_2 ratio.

AGGREGATE

Insoluble particle size range: 1.18mm to 63µm (88.9%) : <63µm (11.1%)

The acid-insoluble material principally comprises:

Fine grey-brown quartz
Pale brown fines (clay, silt and very fine quartz).

TEST REPORT 5521

MORTAR BY VOLUME

Acid-soluble calcareous aggregate particles were not determined to be present and an allowance has therefore not been made. The results, adjusted for typical bulk density, indicate a volumetric mix of **approximately:**

1 part	Portland cement
3 parts	Aggregate.

COMPARATIVE HYDRAULICITY

The hydraulicity determined is approximately equivalent to modern NHL5+.

SUGGESTED MATCHING MIX

This is not a specification for a repair mortar, nor must it be treated as one.

If this material is to be matched on a 'like-for-like' basis, the following approximate volumetric matching mix recipe might be helpful. This does not necessarily imply that we recommend a 'like-for-like' repair mortar mix design in this particular situation, as there are many relevant factors in addition to mortar analysis that must be taken into account.

1 part	Portland cement*
3 to 4 parts	Grey-brown quartz sand <2.36mm

***Note:** This suggested matching-mix would only be appropriate for small patch-repairs. It is widely agreed that Portland cement-based mortars, plasters and renders are not appropriate for repairs to traditional buildings where permeability is important.

SOURCES OF MATERIALS

Many limes, sands, stonedusts and aggregates are available from **Rose of Jericho.**

NOTES:

1. Sample mixes must always be prepared to ensure suitability and an accurate colour and texture match.
2. Sands and aggregates conforming to the relevant British/European Standard and with a particle size and grading appropriate for the intended use must be selected.
3. Manufacturers advice should be sought and recommended application mix proportions and 'Best Practice' guides must be complied with.
4. It should be remembered that mortars change over time. When analysing an aged material, one is ascertaining what it now is and looking for evidence for what it originally was. Calcium hydroxide carbonates to form calcium carbonate, and calcium silicate hydrate (C-S-H), the principal reaction product in hydraulic limes and pozzolanic limes itself reacts over time with carbonic acid to produce calcium carbonate and hydrous siliceous, aluminate and silico-aluminate gels.

Peter Ellis FSA
23.02.2023

TEST REPORT 5521

PHOTOGRAPHIC ILLUSTRATION OF SAMPLES

5521 sample as tested.

5521 Insolubles >63µm
Stereomicroscope x10

5521 Insolubles <63µm
Stereomicroscope x20

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Mortar Analysis

Test Report No. 5522.

Lincoln's Inn, New Square, London WC2A.

Sample 2. Building 2.

Sample as received.

A core sample (14.5g) of external render collected at basement level from the South end of the west-facing elevation of Building 2 has been analysed chemically and microscopically. This is a late 18th or 19th century material and not original late 17th century render.

Sample Assessment and Microscopic Observations.

Paint removed prior to analysis. Intact grey-brown render c.12mm thick. Moderate/high strength (sample could not be broken by hand nor crumbled in fingers; crushed using pestle with some difficulty). Aggregate is principally fine brown quartz and occasional flint. Calcareous aggregate not determined. Black kiln-fuel particles found. Hair or fibre reinforcement not present.

Preliminary Tests.

Dry sample. Fully carbonated (phenolphthalein carbonation test).
Apparent water permeability moderate (water droplet absorption on dried surface).
Moderate effervescence on addition of dilute (10%) hydrochloric acid. Slight H_2S odour.

Chemical Dissolution Analysis (% dry mass) to BS4551:2005+A2:2013 (+ICP-OES).

%	Initial Moisture (oven @ 40^0C)	0.85
%	Total Calcium as CaO (titrimetric method)	14.2
%	Total Magnesium as MgO (ICP-OES method)	0.37
%	Acid & alkali soluble Silicon as SiO_2 (gravimetric method)	2.71
%	Soluble Aluminium as Al_2O_3 (ICP-OES method)	1.53
%	Soluble Iron as Fe_2O_3 (ICP-OES method)	1.29
%	Total (acid-soluble) sulphate as SO_3 (gravimetric method)	2.61
%	Total Acid Insolubles	71.6

BINDER

The carbonated binder in this sample is hydraulic as confirmed by the soluble silica test result and the $CaO:SiO_2$ ratio, and although the alumina and iron test results are a little lower than expected, the binder is of the Roman cement type. The sulphate is elevated.

AGGREGATE

Insoluble particle size range: 2.36mm to 63µm (89.9%) : <63µm (10.1%)

The acid-insoluble material principally comprises:

Brown quartz
Occasional particles of flint and other geological types.
Occasional black kiln-fuel particles
Greyish-brown fines – principally clay.

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TEST REPORT 5522

MORTAR BY VOLUME

Acid-soluble calcareous aggregate particles were not determined to be present and an allowance has therefore not been made. The results, adjusted for typical bulk density, indicate a volumetric mix of **approximately:**

1 part	Roman cement
2 to 2.5 parts	Aggregate.

COMPARATIVE HYDRAULICITY

The hydraulicity determined is approximately equivalent to modern NHL5.

SUGGESTED MATCHING MIX

This is not a specification for a repair mortar, nor must it be treated as one.

Roman cement was patented in 1796 and used extensively as binder for external render in the 19th century. True Roman cements are no longer available, and repairs are now normally carried out using either Prompt natural cement or Natural Hydraulic Lime (and occasionally a blend of the two).

The following approximate volumetric matching mix recipe might be helpful. This does not necessarily imply that we recommend a 'like-for-like' repair mortar mix design in this particular situation, as there are many relevant factors in addition to mortar analysis that must be taken into account.

1 part	Prompt Natural Cement or Natural Hydraulic Lime.
2.25 parts	Yellow-brown quartz and flint sand <2.36mm
c.0.25 parts	Brown pigment*.

***Note:** It will be necessary to add a natural brown pigment to achieve an accurate colour match. Sample trials will be necessary to confirm dosage.

SOURCES OF MATERIALS

Many limes, sands, stonedusts and aggregates are available from **Rose of Jericho.**

NOTES:

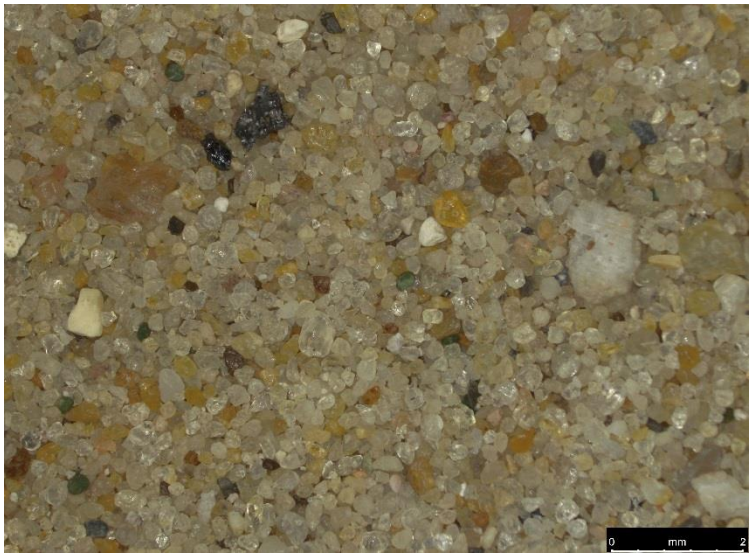
1. Sample mixes must always be prepared to ensure suitability and an accurate colour and texture match.
2. Sands and aggregates conforming to the relevant British/European Standard and with a particle size and grading appropriate for the intended use must be selected.
3. Manufacturers advice should be sought and recommended application mix proportions and 'Best Practice' guides must be complied with.
4. It should be remembered that mortars change over time. When analysing an aged material, one is ascertaining what it now is and looking for evidence for what it originally was. Calcium hydroxide carbonates to form calcium carbonate, and calcium silicate hydrate (C-S-H), the principal reaction product in hydraulic limes and pozzolanic limes itself reacts over time with carbonic acid to produce calcium carbonate and hydrous siliceous, aluminate and silico-aluminate gels.

Peter Ellis FSA
27.02.2023

TEST REPORT 5522

PHOTOGRAPHIC ILLUSTRATION OF SAMPLES

5522 sample as tested.



5522 Insolubles >63µm
Stereomicroscope x10

5522 Insolubles <63µm
Stereomicroscope x20

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Mortar Analysis

Test Report No. 5523.

Lincoln's Inn, New Square, London WC2A.

Sample 3. Building 3.

Sample as received.

A core sample (13.8g) of external render collected at basement level from Building 3 has been analysed chemically and microscopically. This is a late 18th or 19th century material and not original late 17th century render.

Sample Assessment and Microscopic Observations.

Paint removed prior to analysis. Intact brown render c.10mm thick. Moderate strength (sample could be broken by hand but not crumbled in fingers; crushed using pestle with moderate ease). Aggregate is principally fine brown quartz. Calcareous aggregate not determined. Fine kiln-fuel particles (apparently charcoal) found. Hair or fibre reinforcement not present.

Preliminary Tests.

Dry sample. Fully carbonated (phenolphthalein carbonation test).
Apparent water permeability moderate/high (water droplet absorption on dried surface).
Moderate effervescence on addition of dilute (10%) hydrochloric acid.

Chemical Dissolution Analysis (% dry mass) to BS4551:2005+A2:2013 (+ICP-OES).

%	Initial Moisture (oven @ 40^0C)	1.52
%	Total Calcium as CaO (titrimetric method)	14.93
%	Total Magnesium as MgO (ICP-OES method)	0.49
%	Acid & alkali soluble Silicon as SiO_2 (gravimetric method)	3.97
%	Soluble Aluminium as Al_2O_3 (ICP-OES method)	2.50
%	Soluble Iron as Fe_2O_3 (ICP-OES method)	2.10
%	Total (acid-soluble) sulphate as SO_3 (gravimetric method)	1.12
%	Total Acid Insolubles	70.7

BINDER

The carbonated binder in this sample is hydraulic as confirmed by the soluble silica test result and the $CaO:SiO_2$ ratio. The elevated aluminium and iron results confirm the binder to be of the Roman cement type. The sulphate is slightly elevated.

AGGREGATE

Insoluble particle size range: 2.36mm to 63µm (84.8%) : <63µm (15.2%)

The acid-insoluble material principally comprises:

Brown quartz
Particles of other geological types.
Occasional black kiln-fuel particles
Red-brown fines – principally clay and fine quartz (in high proportion).

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TEST REPORT 5523

MORTAR BY VOLUME

Acid-soluble calcareous aggregate particles were not determined to be present and an allowance has therefore not been made. The results, adjusted for typical bulk density, indicate a volumetric mix of **approximately:**

1 part	Roman cement
2 to 2.5 parts	Aggregate.

COMPARATIVE HYDRAULICITY

The hydraulicity determined is approximately equivalent to modern NHL3.5/NHL5.

SUGGESTED MATCHING MIX

This is not a specification for a repair mortar, nor must it be treated as one.

Roman cement was patented in 1796 and used extensively as binder for external render in the 19th century. True Roman cements are no longer available, and repairs are now normally carried out using either Prompt natural cement or Natural Hydraulic Lime (and occasionally a blend of the two).

The following approximate volumetric matching mix recipe might be helpful. This does not necessarily imply that we recommend a 'like-for-like' repair mortar mix design in this particular situation, as there are many relevant factors in addition to mortar analysis that must be taken into account.

1 part	Natural Hydraulic Lime
2.25 parts	Yellow-brown quartz sand <2.36mm
c.0.25 parts	Brown pigment*.

***Note:** It will be necessary to add a natural brown pigment to achieve an accurate colour match. Sample trials will be necessary to confirm dosage.

SOURCES OF MATERIALS

Many limes, sands, stonedusts and aggregates are available from **Rose of Jericho.**

NOTES:

1. Sample mixes must always be prepared to ensure suitability and an accurate colour and texture match.
2. Sands and aggregates conforming to the relevant British/European Standard and with a particle size and grading appropriate for the intended use must be selected.
3. Manufacturers advice should be sought and recommended application mix proportions and 'Best Practice' guides must be complied with.
4. It should be remembered that mortars change over time. When analysing an aged material, one is ascertaining what it now is and looking for evidence for what it originally was. Calcium hydroxide carbonates to form calcium carbonate, and calcium silicate hydrate (C-S-H), the principal reaction product in hydraulic limes and pozzolanic limes itself reacts over time with carbonic acid to produce calcium carbonate and hydrous siliceous, aluminate and silico-aluminate gels.

Peter Ellis FSA
26.02.2023

TEST REPORT 5523

PHOTOGRAPHIC ILLUSTRATION OF SAMPLES

5523 sample as tested.

5523 Insolubles >63µm
Stereomicroscope x10

5523 Insolubles <63µm
Stereomicroscope x20

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Mortar Analysis

Test Report No. 5524.

Lincoln's Inn, New Square, London WC2A.

Sample 4. Building 4.

Sample as received.

A core sample (13.3g) of external render collected at basement level from Building 4 has been analysed chemically and microscopically. This is likely to date from the late 18th or 19th century, and not original late 17th century material.

Sample Assessment and Microscopic Observations.

Paint layers removed prior to analysis. Intact yellow-brown render c.9mm thick. Moderate/low strength (sample could be broken by hand but not crumbled in fingers; crushed using pestle with ease). Aggregate is yellow quartz. Calcareous aggregate not determined. Kiln-fuel particles not found. Hair or fibre reinforcement not present.

Preliminary Tests.

Dry sample. No un-carbonated material present (phenolphthalein carbonation test).
Apparent water permeability very low (water droplet absorption on dried surface).
Slight effervescence on addition of dilute (10%) hydrochloric acid.
(Linseed?) oil present.

Chemical Dissolution Analysis (% dry mass) to BS4551:2005+A2:2013 (+ICP-OES).

%	Initial Moisture (oven @ 40^0C)	0.33
%	Total Calcium as CaO (titrimetric method)	3.69
%	Total Magnesium as MgO (ICP-OES method)	0.013
%	Total Lead as PbO (XRF spectroscopy)	4.38
%	Acid & alkali soluble Silicon as SiO_2 (gravimetric method)	0.097
%	Soluble Aluminium as Al_2O_3 (ICP-OES method)	0.019
%	Soluble Iron as Fe_2O_3 (ICP-OES method)	0.116
%	Total (acid-soluble) sulphate as SO_3 (gravimetric method)	0.095
%	Total Acid Insolubles	76.5

BINDER

This sample is an 'oil-mastic'. These materials were sand and lead normally in the form of litharge (lead monoxide) mixed with (linseed) oil. Later early 19th century types included different lead oxides, lime and turpentine. There are Health & Safety issues associated with the repair of this material as lead is a potent neurotoxin.

AGGREGATE

Insoluble particle size range: 1.18mm to 63µm (87.7%) : <63µm (12.3%)

The acid-insoluble material principally comprises:

Yellow-brown quartz

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TEST REPORT 5524

MORTAR BY VOLUME

Volumetric calculations will depend on the specific gravity of the particular lead oxide(s) present in this sample. For information, a documented recipe for 'London Mastic' is:

1 part	Litharge (PbO)
10 parts	Sand or stone-dust
1 part	Red lead (Pb_3O_4) *

*Note: Sometimes included for 'extra tenacity'.

COMPARATIVE HYDRAULICITY

The hydraulicity determined is approximately equivalent to modern NHL2.

SUGGESTED MATCHING MIX

This is not a specification for a repair mortar, nor must it be treated as one.

The first oil mastic patent was Liadet's cement of 1773. This was enthusiastically used by the Adam brothers in the 1770s and 1780s and indeed became known as Adam's cement. Later early 19th century patents included Dahl's cement 1815, and Hamelin's cement 1817. Oil mastics are no longer produced and should be repaired with a material of similar strength.

The repair mix must be carefully considered but the following approximate volumetric suggested mix recipe might be helpful, but this does not necessarily imply that we recommend this particular mortar mix design, as there are many relevant factors in addition to mortar analysis that must be taken into account.

1 part	Natural Hydraulic Lime NHL2
2.5 parts	Yellow-brown quartz sand <1.18mm

SOURCES OF MATERIALS

Many limes, sands, stonedusts and aggregates are available from **Rose of Jericho.**

NOTES:

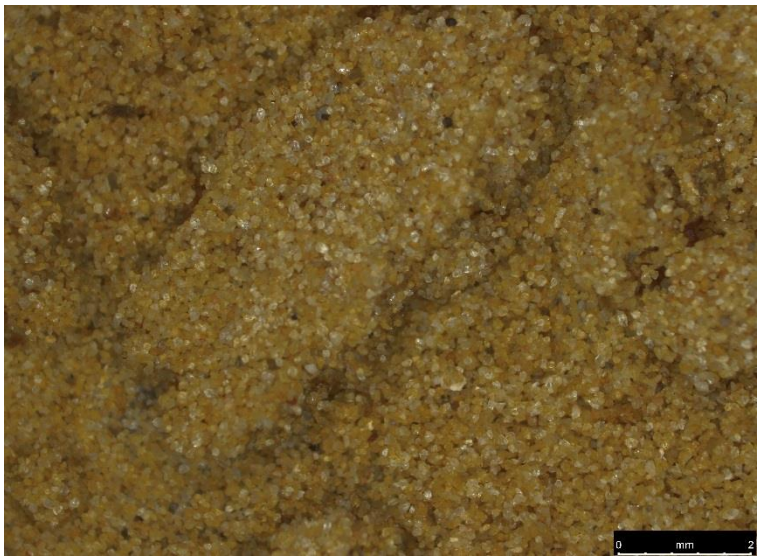
1. Sample mixes must always be prepared to ensure suitability and an accurate colour and texture match.
2. Sands and aggregates conforming to the relevant British/European Standard and with a particle size and grading appropriate for the intended use must be selected.
3. Manufacturers advice should be sought and recommended application mix proportions and 'Best Practice' guides must be complied with.
4. It should be remembered that mortars change over time. When analysing an aged material, one is ascertaining what it now is and looking for evidence for what it originally was. Calcium hydroxide carbonates to form calcium carbonate, and calcium silicate hydrate (C-S-H), the principal reaction product in hydraulic limes and pozzolanic limes itself reacts over time with carbonic acid to produce calcium carbonate and hydrous siliceous, aluminate and silico-aluminate gels.

Peter Ellis FSA
27.02.2023

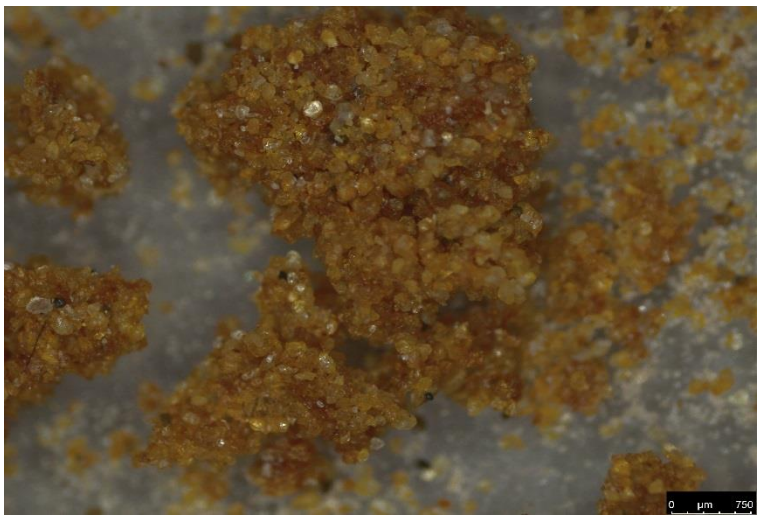
TEST REPORT 5524

PHOTOGRAPHIC ILLUSTRATION OF SAMPLES

5524 sample as tested.



5524 Insolubles >63µm
Stereomicroscope x10



5524 Insolubles <63µm retained on filter paper.
Stereomicroscope x20

Determinand (Total by X-Ray Fluorescence Spectroscopy)	Sample Ref:	Ref 5763/2: Sample 5524 - Lincolns Inn, New Square - S.4. Bldg 4. Render.
	Unit:	%
Calcium expressed as Calcium Oxide	CaO %	4.38
Total Silicon expressed as Silica	SiO2 %	16.5
Total Sulfur (including Sulfide / Oxidizable Sulfur / Potential Sulfate) expressed as Sulfur Trioxide	SO3 %	11.6
Iron expressed as Iron Oxide	Fe2O3 %	0.0955
Aluminium expressed as Aluminium Oxide	Al2O3 %	< 0.2
Magnesium expressed as Magnesium Oxide	MgO %	< 1.3
Manganese expressed as as Manganese Oxide	Mn2O3 %	< 0.08
Potassium expressed as Potassium Oxide	K2O %	< 0.03
Total Phosphorous expressed as Phosphate	PO4 %	< 0.06
Titanium expressed as Titanium Dioxide	TiO2 %	< 0.06
Zinc	Zn %	< 0.001
Copper	Cu %	0.0561
Nickel	Ni %	< 0.001
Tin	Sn %	0.0133
Lead	Pb %	4.07
Cadmium	Cd %	0.0125
Chromium	Cr %	< 0.002
Antimony	Sb %	< 0.02
Mercury	Hg %	0.0014
Selenium	Se %	< 0.002
Arsenic	As %	< 0.02
Vanadium	V %	< 0.003
Strontium	Sr %	0.0043
Cobalt	Co %	< 0.0002
Rubidium	Rb %	< 0.0007
Yttrium	Y %	< 0.003
Zirconium	Zr %	< 0.02
Niobium	Nb %	< 0.003
Molybdenum	Mo %	< 0.003
Silver	Ag %	< 0.007
Tungsten	W %	< 0.005
Bismuth	Bi %	< 0.008
Tantalum	Ta %	< 0.02
Thorium	Th %	< 0.005
Uranium	U %	< 0.004

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Mortar Analysis

Test Report No. 5525.

Lincoln's Inn, New Square, London WC2A.

Sample 6. Building 6.

Sample as received.

A core sample (16.5g) of external render collected at basement level from Building 6 has been analysed chemically and microscopically. This is a late 18th or 19th century material and not original late 17th century render.

Sample Assessment and Microscopic Observations.

Paint removed prior to analysis. Intact brown render c.10mm thick. Moderate strength (sample could be broken by hand but not crumbled in fingers; crushed using pestle with moderate ease). Aggregate is principally fine brown quartz and flint. Calcareous aggregate not determined. Black kiln-fuel particles (apparently charcoal) found. Hair or fibre reinforcement not present.

Preliminary Tests.

Dry sample. Fully carbonated (phenolphthalein carbonation test).
Apparent water permeability moderate/high (water droplet absorption on dried surface).
Moderate effervescence on addition of dilute (10%) hydrochloric acid.

Chemical Dissolution Analysis (% dry mass) to BS4551:2005+A2:2013 (+ICP-OES).

%	Initial Moisture (oven @ 40^0C)	1.44
%	Total Calcium as CaO (titrimetric method)	15.46
%	Total Magnesium as MgO (ICP-OES method)	0.61
%	Acid & alkali soluble Silicon as SiO_2 (gravimetric method)	3.76
%	Soluble Aluminium as Al_2O_3 (ICP-OES method)	3.10
%	Soluble Iron as Fe_2O_3 (ICP-OES method)	1.86
%	Total (acid-soluble) sulphate as SO_3 (gravimetric method)	0.66
%	Total Acid Insolubles	69.8

BINDER

The carbonated binder in this sample is hydraulic as confirmed by the soluble silica test result and the $CaO:SiO_2$ ratio. The highly elevated aluminium and iron results confirm the binder to be of the Roman cement type.

AGGREGATE

Insoluble particle size range: 3.35mm to 63µm (80.5%) : <63µm (19.5%)

The acid-insoluble material principally comprises:

Brown quartz
Particles of flint and other geological types.
Occasional black kiln-fuel particles
Greyish-brown fines – principally clay (in high proportion).

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TEST REPORT 5525

MORTAR BY VOLUME

Acid-soluble calcareous aggregate particles were not determined to be present and an allowance has therefore not been made. The results, adjusted for typical bulk density, indicate a volumetric mix of **approximately:**

1 part	Roman cement
2 to 2.5 parts	Aggregate.

COMPARATIVE HYDRAULICITY

The hydraulicity determined is approximately equivalent to modern NHL3.5/NHL5.

SUGGESTED MATCHING MIX

This is not a specification for a repair mortar, nor must it be treated as one.

Roman cement was patented in 1796 and used extensively as binder for external render in the 19th century. True Roman cements are no longer available, and repairs are now normally carried out using either Prompt natural cement or Natural Hydraulic Lime (and occasionally a blend of the two).

The following approximate volumetric matching mix recipe might be helpful. This does not necessarily imply that we recommend a 'like-for-like' repair mortar mix design in this particular situation, as there are many relevant factors in addition to mortar analysis that must be taken into account.

1 part	Natural Hydraulic Lime.
2.25 parts	Yellow-brown quartz and flint sand <2.36mm
c.0.25 parts	Brown pigment*.

***Note:** It will be necessary to add a natural brown pigment to achieve an accurate colour match. Sample trials will be necessary to confirm dosage.

SOURCES OF MATERIALS

Many limes, sands, stonedusts and aggregates are available from **Rose of Jericho.**

NOTES:

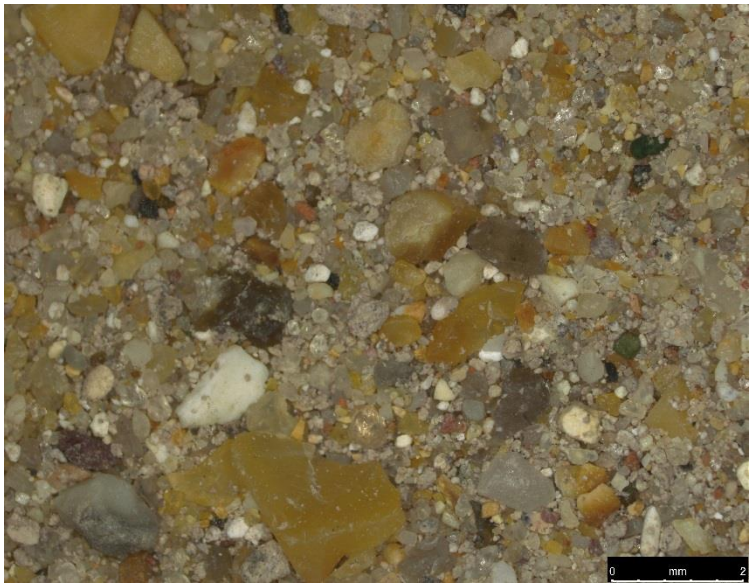
1. Sample mixes must always be prepared to ensure suitability and an accurate colour and texture match.
2. Sands and aggregates conforming to the relevant British/European Standard and with a particle size and grading appropriate for the intended use must be selected.
3. Manufacturers advice should be sought and recommended application mix proportions and 'Best Practice' guides must be complied with.
4. It should be remembered that mortars change over time. When analysing an aged material, one is ascertaining what it now is and looking for evidence for what it originally was. Calcium hydroxide carbonates to form calcium carbonate, and calcium silicate hydrate (C-S-H), the principal reaction product in hydraulic limes and pozzolanic limes itself reacts over time with carbonic acid to produce calcium carbonate and hydrous siliceous, aluminate and silico-aluminate gels.

Peter Ellis FSA
25.02.2023

TEST REPORT 5525

PHOTOGRAPHIC ILLUSTRATION OF SAMPLES

5525 sample as tested.



5525 Insolubles >63µm
Stereomicroscope x10

5525 Insolubles <63µm
Stereomicroscope x20

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Mortar Analysis

Test Report No. 5526.

Lincoln's Inn, New Square, London WC2A.

Sample 7. Building 7.

Sample as received.

A core sample (14.6g) of external render collected at basement level from Building 7 has been analysed chemically and microscopically. This is a late 19th or 20th century repair and not original late 17th century material.

Sample Assessment and Microscopic Observations.

Paint removed prior to analysis. Intact grey render c.20mm thick – two coats of the same mix tested as one sample. High strength (sample could not be broken by hand nor crumbled in fingers; crushed using pestle with some difficulty). Aggregate is principally fine pale yellow-brown quartz. Calcareous aggregate not determined. Kiln-fuel particles not found. Hair or fibre reinforcement not present.

Preliminary Tests.

Dry sample. Partially carbonated (phenolphthalein carbonation test).
Apparent water permeability very low (water droplet absorption on dried surface).
Slight/moderate effervescence on addition of dilute (10%) hydrochloric acid.

Chemical Dissolution Analysis (% dry mass) to BS4551:2005+A2:2013 (+ICP-OES).

%	Initial Moisture (oven @ 40^0C)	1.99
%	Total Calcium as CaO (titrimetric method)	11.73
%	Total Magnesium as MgO (ICP-OES method)	0.15
%	Acid & alkali soluble Silicon as SiO_2 (gravimetric method)	3.56
%	Soluble Aluminium as Al_2O_3 (ICP-OES method)	1.26
%	Soluble Iron as Fe_2O_3 (ICP-OES method)	0.36
%	Total (acid-soluble) sulphate as SO_3 (gravimetric method)	0.69
%	Total Acid Insolubles	76.9

BINDER

The binder in this sample is partially carbonated Portland cement as confirmed by the soluble silica and alumina test results and the CaO:SiO_2 ratio.

AGGREGATE

Insoluble particle size range: 1.18mm to 63µm (90.7%) : <63µm (9.3%)

The acid-insoluble material principally comprises:

Fine yellow-brown quartz
Pale yellow-brown fines (clay, silt and very fine quartz).

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TEST REPORT 5526

MORTAR BY VOLUME

Acid-soluble calcareous aggregate particles were not determined to be present and an allowance has therefore not been made. The results, adjusted for typical bulk density, indicate a volumetric mix of **approximately:**

1 part	Portland cement
3 to 4 parts	Aggregate.

COMPARATIVE HYDRAULICITY

The hydraulicity determined is approximately equivalent to modern NHL5+.

SUGGESTED MATCHING MIX

This is not a specification for a repair mortar, nor must it be treated as one.

If this material is to be matched on a 'like-for-like' basis, the following approximate volumetric matching mix recipe might be helpful. This does not necessarily imply that we recommend a 'like-for-like' repair mortar mix design in this particular situation, as there are many relevant factors in addition to mortar analysis that must be taken into account.

1 part	Portland cement*
4 parts	Yellow-brown quartz sand <2.36mm

***Note:** This suggested matching-mix would only be appropriate for small patch-repairs. It is widely agreed that Portland cement-based mortars, plasters and renders are not appropriate for repairs to traditional buildings where permeability is important.

SOURCES OF MATERIALS

Many limes, sands, stonedusts and aggregates are available from **Rose of Jericho.**

NOTES:

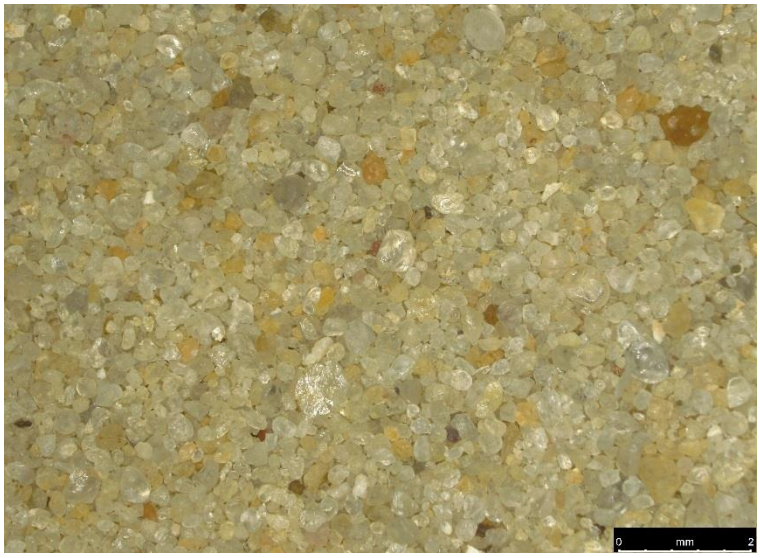
1. Sample mixes must always be prepared to ensure suitability and an accurate colour and texture match.
2. Sands and aggregates conforming to the relevant British/European Standard and with a particle size and grading appropriate for the intended use must be selected.
3. Manufacturers advice should be sought and recommended application mix proportions and 'Best Practice' guides must be complied with.
4. It should be remembered that mortars change over time. When analysing an aged material, one is ascertaining what it now is and looking for evidence for what it originally was. Calcium hydroxide carbonates to form calcium carbonate, and calcium silicate hydrate (C-S-H), the principal reaction product in hydraulic limes and pozzolanic limes itself reacts over time with carbonic acid to produce calcium carbonate and hydrous siliceous, aluminate and silico-aluminate gels.

Peter Ellis FSA
24.02.2023

TEST REPORT 5526

PHOTOGRAPHIC ILLUSTRATION OF SAMPLES

5526 sample as tested.



5526 Insolubles >63µm
Stereomicroscope x10

5526 Insolubles <63µm
Stereomicroscope x20

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Mortar Analysis

Test Report No. 5527.

Lincoln's Inn, New Square, London WC2A.

Sample 8. Building 8.

Sample as received.

A core sample (23.7g) of external render collected at basement level from Building 8 has been analysed chemically and microscopically. This is a late 19th or 20th century repair and not original late 17th century material.

Sample Assessment and Microscopic Observations.

Paint layers removed prior to analysis. Intact grey render c.21mm thick. High strength (sample could not be broken by hand nor crumbled in fingers; crushed using pestle with some difficulty). Aggregate is principally pale brown quartz and larger particles of flint and other types. Calcareous aggregate not determined. Kiln-fuel particles not found. Hair or fibre reinforcement not present.

Preliminary Tests.

Dry sample. Generally un-carbonated (phenolphthalein carbonation test).
Apparent water permeability very low (water droplet absorption on dried surface).
Moderate effervescence on addition of dilute (10%) hydrochloric acid.

Chemical Dissolution Analysis (% dry mass) to BS4551:2005+A2:2013 (+ICP-OES).

%	Initial Moisture (oven @ 40^0C)	2.01
%	Total Calcium as CaO (titrimetric method)	11.9
%	Total Magnesium as MgO (ICP-OES method)	0.183
%	Acid & alkali soluble Silicon as SiO_2 (gravimetric method)	3.39
%	Soluble Aluminium as Al_2O_3 (ICP-OES method)	1.39
%	Soluble Iron as Fe_2O_3 (ICP-OES method)	0.66
%	Total (acid-soluble) sulphate as SO_3 (gravimetric method)	0.330
%	Total Acid Insolubles	73.8

BINDER

The binder in this sample is un-carbonated Portland cement as confirmed by the soluble silica and alumina test results and the $CaO:SiO_2$ ratio.

AGGREGATE

Insoluble particle size range: 5mm to 63µm (93.8%) : <63µm (6.2%)

The acid-insoluble material principally comprises:

Brown quartz
Particles of flint and various other geological types
Yellow-brown fines (principally clay and very fine quartz).

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TEST REPORT 5527

MORTAR BY VOLUME

Acid-soluble calcareous aggregate particles were not determined to be present and an allowance has therefore not been made. The results, adjusted for typical bulk density, indicate a volumetric mix of **approximately:**

1 part	Portland cement
3 to 4 parts	Aggregate.

COMPARATIVE HYDRAULICITY

The hydraulicity determined is approximately equivalent to modern NHL5+.

SUGGESTED MATCHING MIX

This is not a specification for a repair mortar, nor must it be treated as one.

If this material is to be matched on a 'like-for-like' basis, the following approximate volumetric matching mix recipe might be helpful. This does not necessarily imply that we recommend a 'like-for-like' repair mortar mix design in this particular situation, as there are many relevant factors in addition to mortar analysis that must be taken into account.

1 part	Portland cement*
4 parts	Yellow-brown quartz and flint sand <5mm

***Note:** This suggested matching-mix would only be appropriate for small patch-repairs. It is widely agreed that Portland cement-based mortars, plasters and renders are not appropriate for repairs to traditional buildings where permeability is important.

SOURCES OF MATERIALS

Many limes, sands, stonedusts and aggregates are available from **Rose of Jericho.**

NOTES:

1. Sample mixes must always be prepared to ensure suitability and an accurate colour and texture match.
2. Sands and aggregates conforming to the relevant British/European Standard and with a particle size and grading appropriate for the intended use must be selected.
3. Manufacturers advice should be sought and recommended application mix proportions and 'Best Practice' guides must be complied with.
4. It should be remembered that mortars change over time. When analysing an aged material, one is ascertaining what it now is and looking for evidence for what it originally was. Calcium hydroxide carbonates to form calcium carbonate, and calcium silicate hydrate (C-S-H), the principal reaction product in hydraulic limes and pozzolanic limes itself reacts over time with carbonic acid to produce calcium carbonate and hydrous siliceous, aluminate and silico-aluminate gels.

Peter Ellis FSA
27.02.2023

TEST REPORT 5527

PHOTOGRAPHIC ILLUSTRATION OF SAMPLES

5527 sample as tested.

5527 Insolubles >63µm
Stereomicroscope x10

5527 Insolubles <63µm
Stereomicroscope x20

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Mortar Analysis

Test Report No. 5529.

Lincoln's Inn, New Square, London WC2A.

Sample 9B. Basecoat. Building 9.

Sample as received.

A core sample (11.5g) of basecoat external render collected at basement level from Building 9 has been analysed chemically and microscopically. This is a late 18th or 19th century material and not original late 17th century render.

Sample Assessment and Microscopic Observations.

Paint and thin (<1.5mm) red layer, thought to be neat Roman cement binder, removed prior to analysis. Intact pink-brown render c.12mm thick. Moderate/high strength (sample could not be broken by hand nor crumbled in fingers; crushed using pestle with some difficulty). Aggregate is principally fine pale yellow-brown quartz. Calcareous aggregate not determined. Fine kiln-fuel particles found. Hair or fibre reinforcement not present.

Preliminary Tests.

Dry sample. Fully carbonated (phenolphthalein carbonation test).
Apparent water permeability moderate (water droplet absorption on dried surface).
Moderate effervescence on addition of dilute (10%) hydrochloric acid.

Chemical Dissolution Analysis (% dry mass) to BS4551:2005+A2:2013 (+ICP-OES).

%	Initial Moisture (oven @ 40^0C)	2.68
%	Total Calcium as CaO (titrimetric method)	9.63
%	Total Magnesium as MgO (ICP-OES method)	0.32
%	Acid & alkali soluble Silicon as SiO_2 (gravimetric method)	3.98
%	Soluble Aluminium as Al_2O_3 (ICP-OES method)	1.81
%	Soluble Iron as Fe_2O_3 (ICP-OES method)	0.98
%	Total (acid-soluble) sulphate as SO_3 (gravimetric method)	1.15
%	Total Acid Insolubles	80.1

BINDER

The carbonated binder in this sample is hydraulic as confirmed by the soluble silica and alumina test results and the $CaO:SiO_2$ ratio, and although the alumina and iron test results are a little lower than expected, the binder is of the Roman cement type.

AGGREGATE

Insoluble particle size range: 2.36mm to 63µm (91.5%) : <63µm (8.5%)

The acid-insoluble material principally comprises:

Yellow-brown quartz
Occasional particles of other geological types.
Occasional fine black kiln-fuel particles
Red-brown fines – principally clay.

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TEST REPORT 5529

MORTAR BY VOLUME

Acid-soluble calcareous aggregate particles were not determined to be present and an allowance has therefore not been made. The results, adjusted for typical bulk density, indicate a volumetric mix of **approximately:**

1 part	Roman cement
2.5 to 3 parts	Aggregate.

COMPARATIVE HYDRAULICITY

The hydraulicity determined is approximately equivalent to modern NHL5+.

SUGGESTED MATCHING MIX

This is not a specification for a repair mortar, nor must it be treated as one.

Roman cement was patented in 1796 and used extensively as binder for external render in the 19th century. True Roman cements are no longer available, and repairs are now normally carried out using either Prompt natural cement or Natural Hydraulic Lime (and occasionally a blend of the two).

The following approximate volumetric matching mix recipe might be helpful. This does not necessarily imply that we recommend a 'like-for-like' repair mortar mix design in this particular situation, as there are many relevant factors in addition to mortar analysis that must be taken into account.

1 part	Prompt Natural Cement or Natural Hydraulic Lime
2.25 parts	Yellow-brown quartz sand <2.36mm
0.25 parts	Red and brown pigments*.

***Note:** It will be necessary to add natural red and brown pigments to achieve an accurate colour match. Sample trials will be necessary to confirm dosages. Alternatively, red quartz sand could be substituted for the yellow-brown quartz.

SOURCES OF MATERIALS

Many limes, sands, stonedusts and aggregates are available from **Rose of Jericho.**

NOTES:

1. Sample mixes must always be prepared to ensure suitability and an accurate colour and texture match.
2. Sands and aggregates conforming to the relevant British/European Standard and with a particle size and grading appropriate for the intended use must be selected.
3. Manufacturers advice should be sought and recommended application mix proportions and 'Best Practice' guides must be complied with.
4. It should be remembered that mortars change over time. When analysing an aged material, one is ascertaining what it now is and looking for evidence for what it originally was. Calcium hydroxide carbonates to form calcium carbonate, and calcium silicate hydrate (C-S-H), the principal reaction product in hydraulic limes and pozzolanic limes itself reacts over time with carbonic acid to produce calcium carbonate and hydrous siliceous, aluminate and silico-aluminate gels.

Peter Ellis FSA
26.02.2023

TEST REPORT 5529

PHOTOGRAPHIC ILLUSTRATION OF SAMPLES

5529 sample as tested.

5529 Insolubles >63µm
Stereomicroscope x10

5529 Insolubles <63µm
Stereomicroscope x20

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Mortar Analysis

Test Report No. 5530.

Lincoln's Inn, New Square, London WC2A.

Sample 10A. Top-coat. Building 11.

Sample as received.

A core sample (16.4g) of top-coat external render collected at basement level from Building 11 has been analysed chemically and microscopically. This is a late 19th or 20th century repair and not original late 17th century material.

Sample Assessment and Microscopic Observations.

Paint removed prior to analysis. Intact brown render c.12mm thick. High strength (sample could not be broken by hand nor crumbled in fingers; crushed using pestle with some difficulty). Aggregate is principally brown quartz with occasional particles of other types. Calcareous aggregate not determined. Kiln-fuel particles not found. Hair or fibre reinforcement not present.

Preliminary Tests.

Dry sample. Fully carbonated (phenolphthalein carbonation test).
Apparent water permeability very low (water droplet absorption on dried surface).
Moderate effervescence on addition of dilute (10%) hydrochloric acid.

Chemical Dissolution Analysis (% dry mass) to BS4551:2005+A2:2013 (+ICP-OES).

%	Initial Moisture (oven @ 40^0C)	0.70
%	Total Calcium as CaO (titrimetric method)	9.12
%	Total Magnesium as MgO (ICP-OES method)	0.36
%	Acid & alkali soluble Silicon as SiO_2 (gravimetric method)	2.77
%	Soluble Aluminium as Al_2O_3 (ICP-OES method)	1.08
%	Soluble Iron as Fe_2O_3 (ICP-OES method)	0.431
%	Total (acid-soluble) sulphate as SO_3 (gravimetric method)	0.601
%	Total Acid Insolubles	81.4

BINDER

The binder in this sample is carbonated Portland cement as confirmed by the soluble silica and alumina test results and the CaO:SiO_2 ratio.

AGGREGATE

Insoluble particle size range: 4.10mm to 63µm (94.8%) : <63µm (5.2%)

The acid-insoluble material principally comprises:

Brown quartz
Occasional particles of other geological types
Yellow-brown fines (clay, silt and very fine quartz).

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TEST REPORT 5530

MORTAR BY VOLUME

Acid-soluble calcareous aggregate particles were not determined to be present and an allowance has therefore not been made. The results, adjusted for typical bulk density, indicate a volumetric mix of **approximately:**

1 part	Portland cement
5 parts	Aggregate.

COMPARATIVE HYDRAULICITY

The hydraulicity determined is approximately equivalent to modern NHL5+.

SUGGESTED MATCHING MIX

This is not a specification for a repair mortar, nor must it be treated as one.

If this material is to be matched on a 'like-for-like' basis, the following approximate volumetric matching mix recipe might be helpful. This does not necessarily imply that we recommend a 'like-for-like' repair mortar mix design in this particular situation, as there are many relevant factors in addition to mortar analysis that must be taken into account.

1 part	Portland cement*
5 parts	Yellow-brown quartz sand <4.10mm

***Note:** This suggested matching-mix would only be appropriate for small patch-repairs. It is widely agreed that Portland cement-based mortars, plasters and renders are not appropriate for repairs to traditional buildings where permeability is important.

SOURCES OF MATERIALS

Many limes, sands, stonedusts and aggregates are available from **Rose of Jericho.**

NOTES:

1. Sample mixes must always be prepared to ensure suitability and an accurate colour and texture match.
2. Sands and aggregates conforming to the relevant British/European Standard and with a particle size and grading appropriate for the intended use must be selected.
3. Manufacturers advice should be sought and recommended application mix proportions and 'Best Practice' guides must be complied with.
4. It should be remembered that mortars change over time. When analysing an aged material, one is ascertaining what it now is and looking for evidence for what it originally was. Calcium hydroxide carbonates to form calcium carbonate, and calcium silicate hydrate (C-S-H), the principal reaction product in hydraulic limes and pozzolanic limes itself reacts over time with carbonic acid to produce calcium carbonate and hydrous siliceous, aluminate and silico-aluminate gels.

Peter Ellis FSA
24.02.2023

TEST REPORT 5530

PHOTOGRAPHIC ILLUSTRATION OF SAMPLES

5530 sample as tested.

5530 Insolubles >63µm
Stereomicroscope x10

5530 Insolubles <63µm
Stereomicroscope x20

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Mortar Analysis

Test Report No. 5531.

Lincoln's Inn, New Square, London WC2A.

Sample 10B. Base-coat. Building 11.

Sample as received.

A core sample (17.2g) of base-coat external render collected at basement level from Building 11 has been analysed chemically and microscopically. This is a late 19th or 20th century repair and not original late 17th century material.

Sample Assessment and Microscopic Observations.

Intact grey render c.13mm thick. High strength (sample could not be broken by hand nor crumbled in fingers; crushed using pestle with some difficulty). Aggregate is principally yellow-brown quartz and flint. Calcareous aggregate not determined. Kiln-fuel particles not found. Hair or fibre reinforcement not present.

Preliminary Tests.

Fairly dry sample. Generally un-carbonated (phenolphthalein carbonation test).
Apparent water permeability very low (water droplet absorption on dried surface).
Slight effervescence on addition of dilute (10%) hydrochloric acid.

Chemical Dissolution Analysis (% dry mass) to BS4551:2005+A2:2013 (+ICP-OES).

%	Initial Moisture (oven @ 40^0C)	4.39
%	Total Calcium as CaO (titrimetric method)	10.92
%	Total Magnesium as MgO (ICP-OES method)	0.21
%	Acid & alkali soluble Silicon as SiO_2 (gravimetric method)	3.38
%	Soluble Aluminium as Al_2O_3 (ICP-OES method)	1.27
%	Soluble Iron as Fe_2O_3 (ICP-OES method)	0.69
%	Total (acid-soluble) sulphate as SO_3 (gravimetric method)	0.79
%	Total Acid Insolubles	76.5

BINDER

The binder in this sample is un-carbonated Portland cement as confirmed by the soluble silica and alumina test results and the CaO:SiO_2 ratio.

AGGREGATE

Insoluble particle size range: 4.10mm to 63µm (92.7%) : <63µm (7.3%)

The acid-insoluble material principally comprises:

Brown quartz
Occasional particles of other geological types
Yellow-brown fines (clay, silt and very fine quartz).

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TEST REPORT 5531

MORTAR BY VOLUME

Acid-soluble calcareous aggregate particles were not determined to be present and an allowance has therefore not been made. The results, adjusted for typical bulk density, indicate a volumetric mix of **approximately:**

1 part	Portland cement
4 parts	Aggregate.

COMPARATIVE HYDRAULICITY

The hydraulicity determined is approximately equivalent to modern NHL5+.

SUGGESTED MATCHING MIX

This is not a specification for a repair mortar, nor must it be treated as one.

If this material is to be matched on a 'like-for-like' basis, the following approximate volumetric matching mix recipe might be helpful. This does not necessarily imply that we recommend a 'like-for-like' repair mortar mix design in this particular situation, as there are many relevant factors in addition to mortar analysis that must be taken into account.

1 part	Portland cement*
4 to 5 parts	Yellow-brown quartz and flint sand <4.10mm

***Note:** This suggested matching-mix would only be appropriate for small patch-repairs. It is widely agreed that Portland cement-based mortars, plasters and renders are not appropriate for repairs to traditional buildings where permeability is important.

SOURCES OF MATERIALS

Many limes, sands, stonedusts and aggregates are available from **Rose of Jericho.**

NOTES:

1. Sample mixes must always be prepared to ensure suitability and an accurate colour and texture match.
2. Sands and aggregates conforming to the relevant British/European Standard and with a particle size and grading appropriate for the intended use must be selected.
3. Manufacturers advice should be sought and recommended application mix proportions and 'Best Practice' guides must be complied with.
4. It should be remembered that mortars change over time. When analysing an aged material, one is ascertaining what it now is and looking for evidence for what it originally was. Calcium hydroxide carbonates to form calcium carbonate, and calcium silicate hydrate (C-S-H), the principal reaction product in hydraulic limes and pozzolanic limes itself reacts over time with carbonic acid to produce calcium carbonate and hydrous siliceous, aluminate and silico-aluminate gels.

Peter Ellis FSA
25.02.2023

TEST REPORT 5531

PHOTOGRAPHIC ILLUSTRATION OF SAMPLES

5531 sample as tested.

5531 Insolubles >63µm
Stereomicroscope x10

5531 Insolubles <63µm
Stereomicroscope x20