SCOTTISH LIME CENTRE TRUST

Charlestown Workshops
2 Rocks Road
Charlestown
Fife
KY11 3EN
T: + 44 (0)1383 872722
F: + 44 (0)1383 872744

REPORT ON MORTAR ANALYSIS BY BS 4551: 2005 + A1: 2010 + A2: 2003

AP 2420
The Elms,
Fitzroy Park, Highgate, London

Samples S1 and S2

External Render

SITE	The Elms, Fitzroy Park, Highgate, London
CLIENT	Luard Conservation Ltd.
DATE SAMPLE RECEIVED	22nd May 2013
ANALYSIS DATES	22nd may and 10th & 11th June 2013
ANALYSIS, INTERPRETATION & REPORT BY	W A Revie & D Clark
CLIENT REQUIREMENTS	Mortar Analysis by the methods of BS 4551:2005 + A1:2010 + A2:2013
STRUCTURE DATE	Building from 1840, with 2010 additions
STRUCTURE TYPE	Masonry Building, Brick & Block construction
MORTAR DATING	Recent render work
LOCATION/ FUNCTION IN BUILDING	External Render from the South West corner, 350mm
CONDITION OF SAMPLE RECEIVED	A pair of samples were received, each consisting of several pieces of render, which were weighed and the largest intact piece measured: Sample S1 = 97.4grams, with the largest piece = 63.4 x 33.7 x 10.7mm Sample S2 = 240.4grams. with the largest piece = 67.3 x 52.6 x 41.3mm

GENERAL COMMENTS

Two samples of a three coat render, stated to have been sampled from the South West corner of The Elms, Fitzroy Park, Highgate, London, were received in the laboratory for analysis. Each coat of the render was to be analysed to establish the mix composition of the mortar used in each. To achieve this, sub-samples from each of the coats were obtained and analysed by the methods of BS 4551: 2005 + A1: 2010 + A2: 2013 to establish their mix composition.

The mortar in each of the coats within the sample is well compacted, dense, hard and strong. Where intact samples have been examined the bond between the coats is well formed. Evidence of air entrainment was observed in all three coats, with this being patchy in both the intermediate and finish coats, and uniform in the base coat.

The aggregate is fine graded with the bulk of the aggregate finer than 1.5mm and although it is dominated by quartz, the aggregate also contains a high proportion of other lithic fragments, including flint and quartzite.

On analysis the mortar within each of the coats analysed were found to be composed of a Portland type cement, lime and sand, with the analysis results indicating that all were equivalent to a type *i* mortar, having a mix composition of 1 part Portland cement to 2.8 parts sand, a type one consists typically of 1 part cement to 3 parts sand.

ANALYTICAL PROCEDURES

A representative sub-sample was extracted from the as received sample; the material was dried, weighed, and examined under a binocular microscope at x 40 magnification. If indicated to be a lime based binder, the sample is crushed, and the binder separated from the aggregate by dissolution in dilute hydrochloric acid, and the relative proportions of lime (and gypsum) to aggregate determined. If a Portland cement binder is indicated, the sample is analysed by the methods of BS 4551: 2005. Where appropriate aggregate characterisation is undertaken by means of sieve separation and further microscopic examination. Where required, to confirm binder type this is determined by X-Ray Powder Diffraction (XRD) analysis.

Our comments are based on an interpretation of the relevant factors. The analysis and evaluation provide information on the composition and characteristics of the mortar sample(s) received by us. Provided the sample was representative of the mortar generally, the analysis will give a reasonable indication of the original materials and provide a basis for specification of repair mortars. If information that is more detailed is required (for example for purposes of historic research), more sophisticated analytical procedures can be undertaken. Detailed repair specifications based on information from this report should also take account of prevailing site conditions, including stone type and condition, location and function of the new mortar, building details, exposure, seasonal working, etc

MORTAR EXAMINATION AND ANALYSIS

Plate 1. Sample S1 as received, with the sample consisting of several piece of the finishing coat, with adhering paint finish on the outer surface and traces of the underlying intermediate coat adhering to its underside.

Plate 2. Close-up of a freshly fractured surface through the thickness of one of the pieces of mortar. Note the patchy air entrainment and the light coloured matrix. It is indicated that a white cement was used in the production of this mortar.

	
Plate 3. Sample S2 as received, with the sample reconstructed to show the top coat, intermediate coat and base coat. The coat interfaces are highlighted by broken lines superimposed onto the image.	**Plate 4**. Separate sub-sample of the base coat with adhering intermediate coat on top. Again the intermediate coat appears to be a white cement mix, whereas the base coat is a grey OPC mix.

The mortar in all three coats was found to be firm and very hard, requiring a hammer impact to break and the use of an impact mortar to disrupt the mortar further to permit representative sub-samples to be obtained in preparation for chemical analysis.

On testing a freshly fractured surface with a phenolphthalein indicator solution, the mortar was found to be only carbonated to a depth of 0.8mm from the outer surface in the finishing coat, with the intermediate coat only carbonated at the outer contact surface, whereas the base coat showed no indication of carbonation.

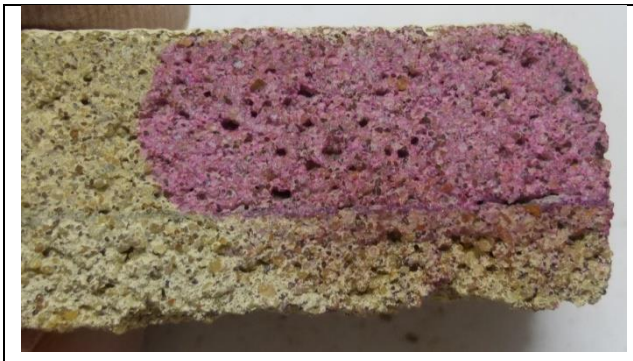	
Plate 5. Finish coat tested with a droplet of phenolphthalein indicator solution, the fuchsia colour indicating that the mortar had not carbonated, except close to the outer surface.	**Plate 6**. Phenolphthalein indicator test on intermediate coat and base coat again indicating no carbonation.

The mortar in each coat was noted to display air entrainment, with this typical of what is observed in cement/lime mortars, with that in the finishing and intermediate coats being patchy in occurrence and variable in abundance, the base coat displayed more uniform entrainment throughout its depth. Water droplets placed onto freshly fractured surfaces were rapidly absorbed, which would suggest that the mortar is micro-porous with a well connected pore structure.

Evidence of the addition of lime to the mix was indicated in the intermediate and finishing coats in which small lime inclusions were seen randomly distributed, these were small <1.0mm in size and typical of accumulations of powdered dry lime hydrate. There was no evidence of the presence of lime inclusions within the base coat.

The aggregates, within the mortar were fully encapsulated within the binder and they could only be plucked from the edges of fractured surfaces under persistent pressure, in all coats examined. The aggregates have a maximum particle size of 2.7mm, but are predominantly less than 1.5mm in size. They are sub-rounded to sub-angular in shape and are dominated by quartz, with a proportion of other lithic fragments also present, with feldspar, flint, quartzite and indeterminate rock fragments also indicated to be present.

Due to the hardness and the texture of the mortar in each coat it was considered that they were most likely cement based materials and, therefore, sub-samples from each were prepared and submitted to analysis by the methods of BS 4551: 2005.

In the preparation of the samples the individual coats were separated with the aid of a constant rim trim saw, the slices were dried to a constant mass at 70°C, prior to being disrupted in an impact mortar. The disaggregated material was then ground in a gyro-mill until all of the material passed a 75µm sieve.

The samples analysed were all from sample S2 as this sample contained all three coats. The results obtained from the analysis carried out are as follows:

Results of Composition analysis by the Methods of BS 4551:2005 + A1:2010 + A2: 2013

Chemical Analysis		**% by mass**	
Sample Reference: **Coat**	**Sample A** **Finish**	**Sample B** **Intermediate**	**Sample C** **Base**
Insoluble Residue	73.35	77.98	73.53
Soluble Silica (SiO2)	3.67	2.75	3.33
Calcium Oxide (CaO)	13.33	10.58	13.60
Loss on Ignition	8.39	8.32	8.55
Calculated composition of the sample expressed to the nearest 0.5% by mass on dry mass.			
Portland cement	19.0	14.5	17.0
Lime	2.5	2.5	4.5
Sand	78.5	83.0	78.5
Approximate volume Proportions, calculated on the basis of the standard assumptions.			
Portland Cement	1.0	1.0	1.0
Lime	0.3	0.4	0.7
Sand	3.6	5.0	4.0
Mortar Designation BS4551:2005			
Class: Table 6:	*type ii.*	*type ii.*	*type ii.*

Comments

The analytical results presented above were evaluated by the method of BS 4551: 2005 + A1: 2010 + A2: 2013, on the basis of the following assumptions:

a. The cement content has been calculated on the basis that the cement contained 20.5 % soluble silica and 64.5% calcium oxide and had a dry bulk density of 1450 kg/m3.
b. The hydrated lime contained 75.6% calcium oxide, no soluble silica compounds and had a dry bulk density of 575kg/m3
c. The sand contained 0.2% soluble silica and no soluble calcium compounds and had a dry bulk density of 1675kg/m3.
d. The mortar contained no mineral admixtures such as PFA, GGBFS or silica fume.