CHARLESTOWN CONSULTANTS
TRADITIONAL BUILDINGS INVESTIGATION, ANALYSIS & SURVEYS

PART OF THE SCOTTISH LIME CENTRE

MORTAR ANALYSIS REPORT

AP 2204
Balmerino Abbey
Balmerino Village
Newport-on-Tay
Fife
DD6 8SB

Sample S1
Bedding Mortar

SCOTTISH LIME CENTRE TRUST is a charity registered in Scotland no SC022692
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SITE	Balmarino Abbey
CLIENT	The National Trust for Scotland
DATE SAMPLE RECEIVED	16.06.11
ANALYSIS DATES	16.06.11 – 23.06.11
CLIENT REQUIREMENTS	Standard Mortar Analysis
STRUCTURE DATE	13Th Century
STRUCTURE TYPE	Boundary Wall to the Abbey
MORTAR DATING	c. 1850
LOCATION/ FUNCTION IN BUILDING	Bedding mortar
CONDITION OF SAMPLE RECEIVED	The sample received consisted of a bag containing intact pieces and fines. Size of largest piece = 100 x 66 x 37mm Total mass of sample received = 242.9 grams

SUMMARY AND INTERPRETATION OF ANALYSIS RESULTS

The mortar appears to consist of a moderately hydraulic lime binder, prepared as a 'hot lime' mortar by slaking quicklime and sand together in one operation.

The sand had the appearance of an 'as dug' sand. The colour of the mortar assessed against the Munsell Soil Colour Charts was found to be 10YR 7/31 "light grey".

The mix ratio of the sample is approximately 1 part moderately hydraulic quicklime to 6.1 parts aggregate (by volume). To replicate this visually and technically, a mortar mix of (nominally by volume) 1 part NHL 3.5: to 2.5 parts recommended sand.

This mortar analysis report is NOT intended as a repair specification. Details of 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.

ANALYTICAL PROCEDURES

The selected sample of material was dried to a constant weight and examined under a binocular microscope at x40 magnification. Degree of carbonation of the sample was determined using phenolphthalein indicator, which will react with any uncarbonated lime.

An assessment of the binder type was made by evaluating the physical characteristics of the mortar based on our knowledge, experience and understanding of materials.

Application of 10% Hydrochloric acid to the sample resulted in dissolution of the binder enabling relative proportions of lime (and gypsum) to aggregate to be determined; where appropriate, proportions of insoluble binder were determined and factored into this calculation. Subsequent aggregate characterisation was undertaken by means of dry sieve analysis and microscopic analysis.

The analysis results and interpretations made from it provide information on the composition and characteristics of the mortar sample(s) received by the SLCT laboratory. **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 more detailed information is required (for example, for purposes of historic research) more sophisticated analytical procedures can be undertaken.

MORTAR EXAMINATION AND ANALYSIS

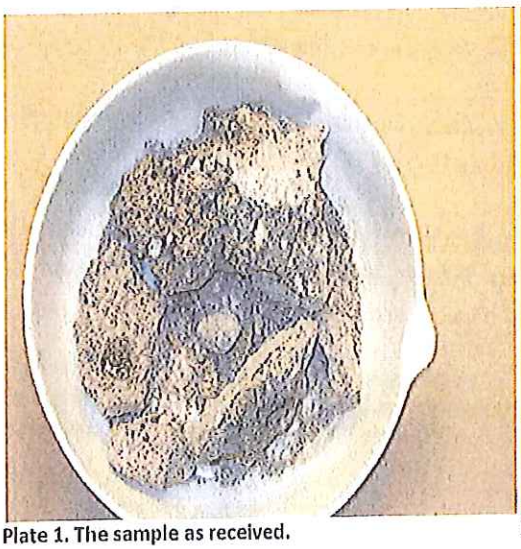


Plate 1. The sample as received.

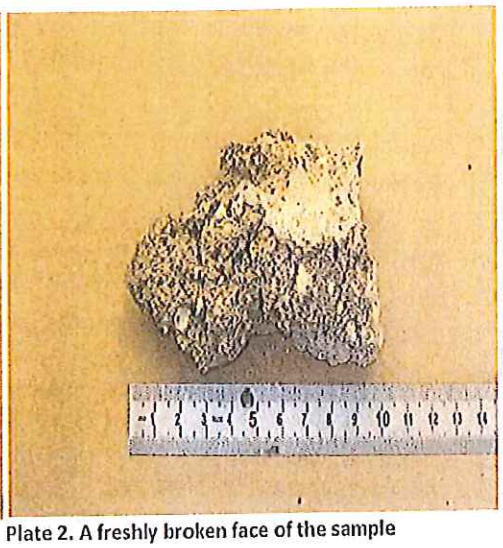


Plate 2. A freshly broken face of the sample

PROCEDURE	OBSERVATIONS
PRELIMINARY VISUAL ANALYSIS OF SAMPLE	The sample was received as fully carbonated intact pieces and fines of mortar. The sample Intact pieces are moderate to firm-not easily friable. The total sample weighed 242.9g and the largest intact piece measured 100mm x 66mm x 37mm
EXAMINATION OF PREPARED SAMPLE BY BINOCULAR MICROSCOPE (X40 MAGNIFICATION)	Once dried the mortar was found to be 10Y 7/1 'light grey' when assessed against the Munsell Soil Colour Charts. Frequent creamy coloured lime inclusions were identified up to 8mm long as well as burnt coal ash fragments (from the lime burning process). The sample is well bound with frequent pores indicating the mortar was well air entrained as a result of the mortar being mixed as a 'hot' lime mortar (ie slaking quicklime and sand together in one operation – which produces steam).

SALT TEST PROCEDURE	OBSERVATIONS
SILVER NITRATE APPLICATION (TEST FOR CHLORIDE SALTS)	N/A
BARIUM CHLORIDE APPLICATION (TEST FOR SULPHATE SALTS)	N/A

ACID DISSOLUTION & FILTRATION

PROCEDURE	OBSERVATIONS/COMMENTS	
DISSOLUTION OF BINDER USING 10% HCl	On addition of the acid to the powdered sample there was a strong reaction.	
FILTRATION	GRADE: 20 -25 µm	PAPER TYPE: Whatman Type 41

CONSTITUENTS OF ANALYSIS SAMPLE

MATERIAL	WEIGHT (g)	COMMENTS
A: DRY WEIGHT OF ANALYSIS SAMPLE	74.75	Mass of sample analysed (before acid digestion).
B: DRY WEIGHT OF ALL INSOLUBLES	61.15	Insoluble residue recovered after acid digestion (before sieving).
C: DRY WEIGHT OF INSOLUBLE BINDER	0	Determined from microscopic examination of filter residue (presence of insoluble hydraulic components can be confirmed by XRD analysis).
D: (B-C) DRY WEIGHT OF AGGREGATE	61.15	Corrected for retention of hydraulic components or other non-soluble reaction products.
E: (A-D) DRY WEIGHT OF LIME	13.6	Including insoluble binder where present.
MOISTURE CONTENT (%)	2.92	Based on mass of sample before and after drying.
OTHER	-	Gypsum and other non-binder related contaminants or reaction products.

AGGREGATE GRADING & CHARACTERISATION

SIEVE PERFORATION SIZE*	AGGREGATE RETAINED (g)	UNDISSOLVED BINDER (%)	CORRECTED AGGREGATE WEIGHT (g)	% OF AGGREGATE	COMMENTS
8mm	0	0	0	0	N/A
4mm	2.65	0	2.65	4.3	Clasts of quartz generally black to orange In colour
2mm	2.85	0	2.85	4.7	Clasts of quartz(sr-r), coal
1mm	5.35	0	5.35	8.7	As Above with (sr-a)
500µm	15.95	0	15.95	26.1	As above
250µm	26.55	0	26.55	43.4	As above
125µm	6.7	0	6.7	11.0	As above
63µm	0.65	0	0.65	1.1	As above
< 63µm including filter residue	0.45	0	0.45	0.7	As above

a= angular, sa= sub-angular, sr= sub-rounded, r= rounded, wr= well rounded

*Sieve perforation sizes correspond to those stated in BS EN 1015.1:1999

The aggregate isolated from this sample is fairly well graded with a high peak in grain size at 0.25mm. The angular aggregate was of a Quartz composition. The aggregate is composed of clasts of pinkish sandstone and blonde sandstone, dark grey vesicular igneous clasts and grains of quartz and orthoclase feldspar. Coal fragments were also identified. This aggregate is well sorted and relatively mature and was most likely to have been sourced from the shores of the estuarine River Tay.

Because sand and gravel aggregates are ultimately derived from the weathering of solid rock, most aggregates contain course grained rock fragments and finer mineral grains. Physical weathering

breaks down the rock fragments within the aggregate into the constituent minerals, resulting in smaller and rounder particles; chemical weathering breaks down unstable minerals, such as feldspars resulting in the formation of clay, which may be washed away. Both weathering processes eventually result in the formation of quartz-rich sand.

AGGREGATE MATCHING

The closest commercially available matching aggregate, from the SLCT Sands and Aggregates Database is BUILDING SAND from MELVILLE GATE QUARRY (see attached sand profiles).

Both select quarries appear to be a good grade and colour match. Samples are slightly lighter due to coal residue in bedding mortar from the lime burning process.

Contact details for these quarries are listed below.

Quarry Name	Melville Gate Quarry	Quarry Name	Lomond Quarry
Address	Ladybank	Address	Falkland Hills Road,
Address 2	Fife	Address 2	Leslie
Postcode	KY15 7RF	Postcode	KY6 3HD
Tel:	01337 831526	Tel:	01592 632230

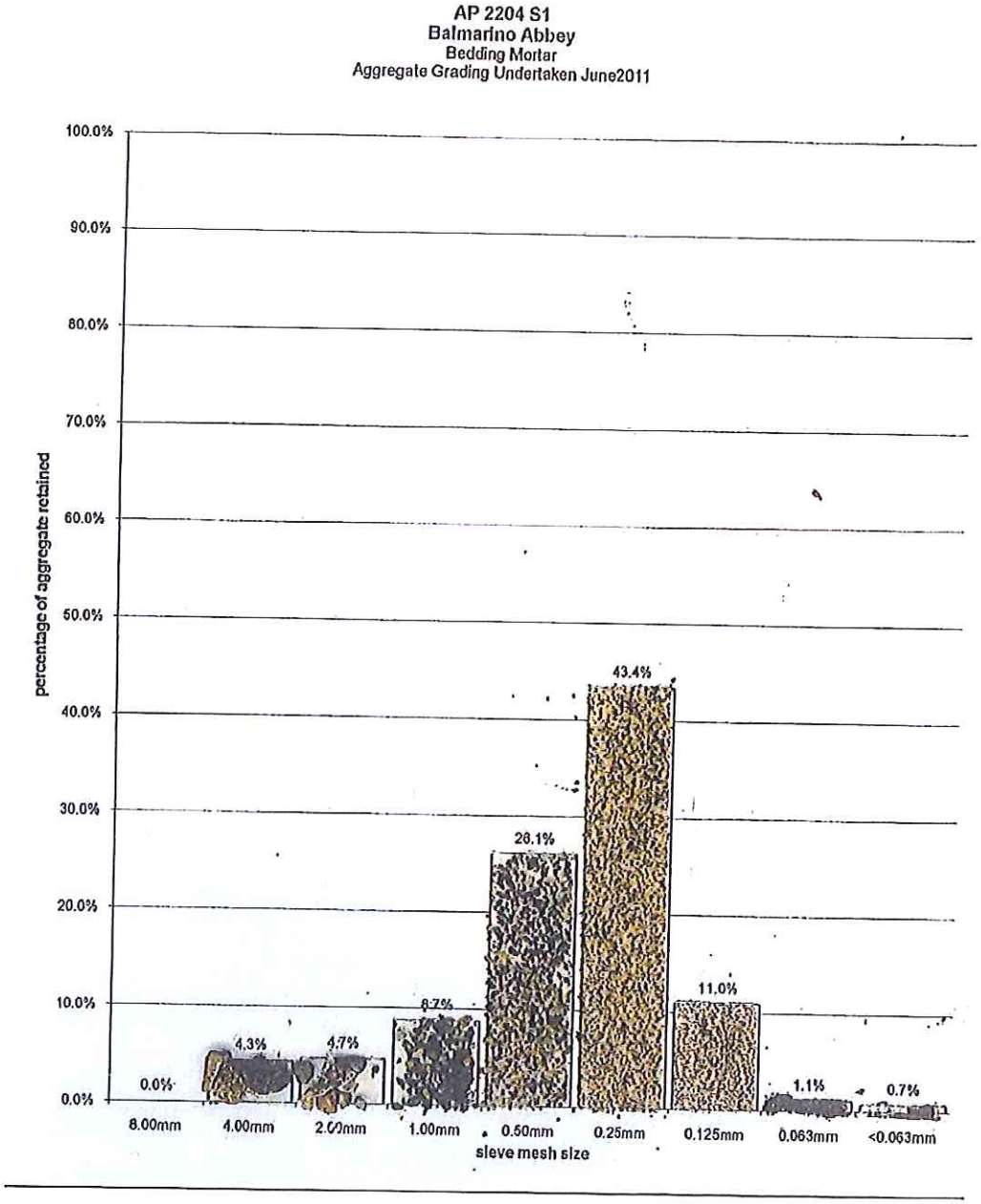
However, the named source(s) is/are not the only potentially suitable source(s) available, but is/are the closest, with respect to visual characteristics and physical properties, on the basis of the work carried out to date, on the sample submitted to examination.

The currently available aggregate samples held in the Scottish Lime Centre Trust's Aggregates Database are provided by the individual quarries/operators and therefore we have to assume that they are representative of the aggregate being produced at the time of receipt of the sample. As with all quarries the actual properties of the aggregate available will be dependent on the area being worked at any given time and it is, therefore, always prudent to obtain samples of the current production for comparison with the aggregate to be matched, prior to ordering supplies for a particular project/application.

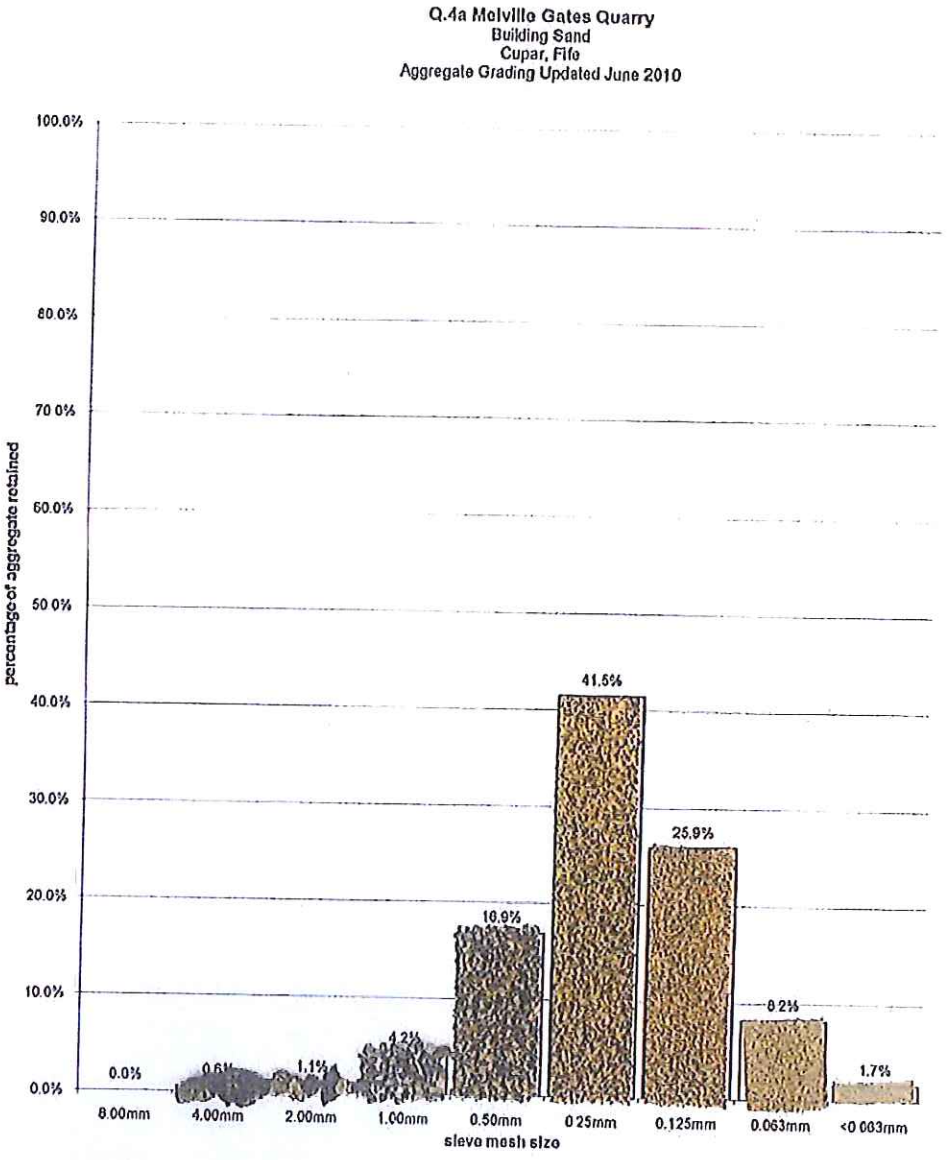
Quarries can change hands, open or close down with a relatively high frequency and therefore the source(s) identified above may become unavailable with no notice. If you are unable to obtain one of the above aggregates within 6 months of us completing this report then we will identify a new source free of charge (after this time period a charge will be incurred).

*If ordered please say that the aggregate was identified by the Scottish Lime Centre Trust.

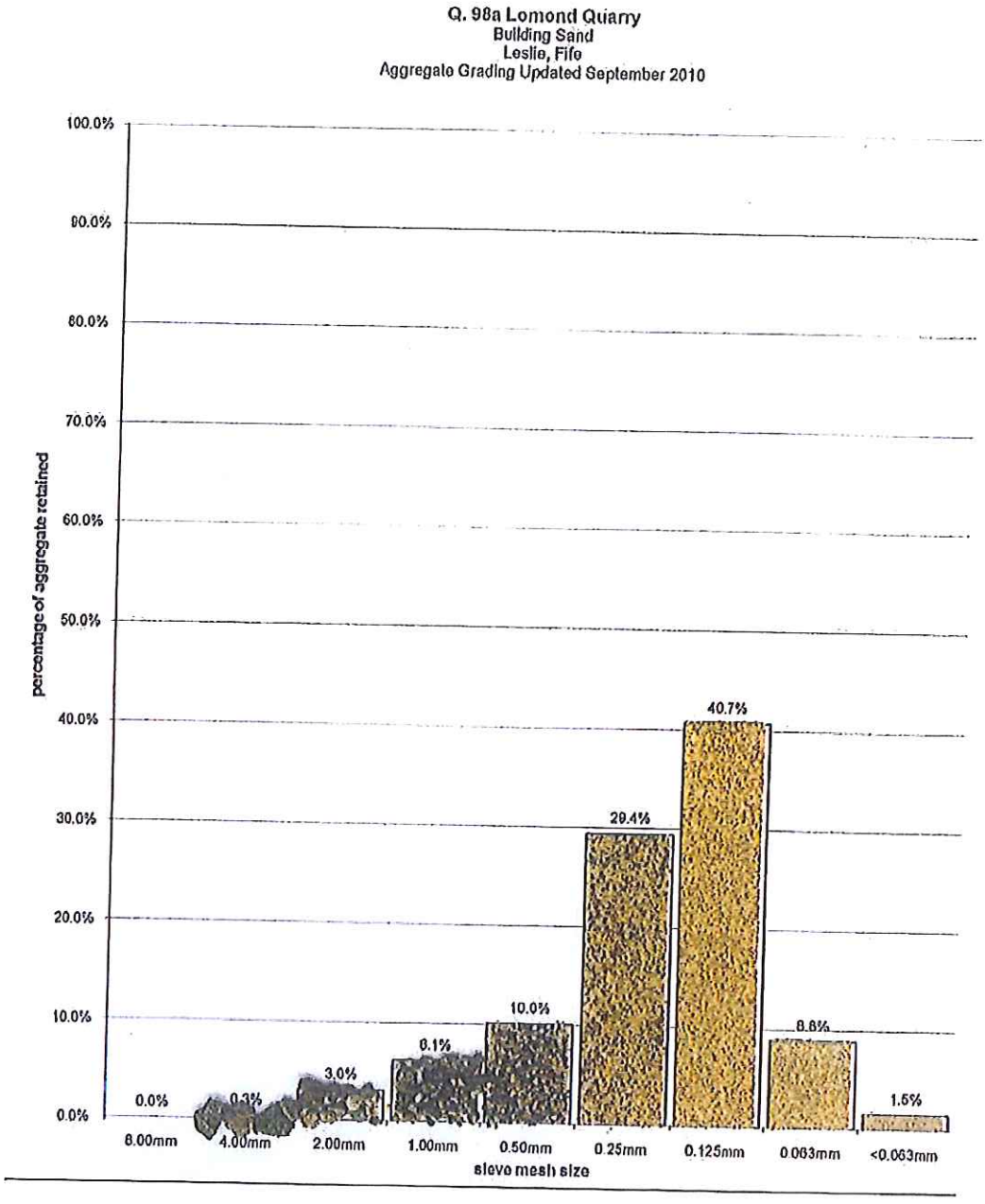
Aggregate Profile of the Aggregate Separated from the Mortar Sample



Aggregate Profile of the Closest Matching Currently Available Aggregate: Building sand, Melville Gates Quarry



Aggregate Profile of an Alternate Matching Currently Available Aggregate: Building sand, Lomond Quarry



PROPORTIONS OF ANALYSIS SAMPLE

The sample proportions give the relative weights of aggregate and carbonated or set lime, unless otherwise stated.

LIME	:	AGGREGATE
1	:	4.5

PROBABLE ORIGINAL MIX

The original mix gives the relative weights of the mortar constituents as mixed on site and before carbonation. From the nature of the binding matrix of the mortar sample and from information gained from the analysis, it is probable that the mortar was made up from a moderately hydraulic quicklime.

1 PART MODERATELY HYDRAULIC QUICKLIME	:	**6.1 PARTS AGGREGATE (BY WEIGHT)**

Please note that the proportions given above relate to the sample supplied, this is not a specification.

If a repair specification is required please contact us, and we can arrange for one of our surveyors/consultants to visit and inspect the building/structure, evaluate the relevant requirements, and subsequently provide recommendations and/or specifications for construction and repair work.