SCOTTISH LIME CENTRE TRUST

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MORTAR ANALYSIS REPORT

AP 3428
Woodstock Church, Kilmarnock

Sample 3

Construction mortar

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And a charitable company limited by guarantee, registered in Scotland no: **SC151481**
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SITE	Woodstock Church, Kilmarnock
CLIENT	John Gilbert Architects
DATE SAMPLE RECEIVED	15/07/2019
ANALYSIS DATES	15/07/2019 – 19/07/2019
ANALYSIS, INTERPRETATION & REPORT BY	Dr Katie Strang and Roz Artis
CLIENT REQUIREMENTS	Standard Mortar Analysis
STRUCTURE DATE	1879
STRUCTURE TYPE	Church
MORTAR DATING	Original?
LOCATION/ FUNCTION IN BUILDING	Construction mortar
CONDITION OF SAMPLE RECEIVED	The sample received consisted of a bag containing intact pieces of mortar plus fines. Size of largest piece = 57.61mm x 39.13mm x 13.01mm Total mass of sample received = 82.63 grams

SUMMARY AND INTERPRETATION OF ANALYSIS RESULTS

The mortar appears to consist of a moderately to eminently hydraulic lime binder, prepared as a 'hot mixed' lime mortar by slaking quicklime and sand together in one operation. To confirm the binder type and strength, further analysis by thin section (petrography) and X-Ray Diffraction would be required (in this sample the strength of binder is inferred from the hardness of the specimens examined and therefore might not be representative of the mortar overall).

The aggregate 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 8/2 'very pale brown' to 10YR 6/3 'pale brown'.

The mix ratio of the sample is approximately 1 part moderately to eminently hydraulic quicklime to 0.34parts aggregate (by volume).

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

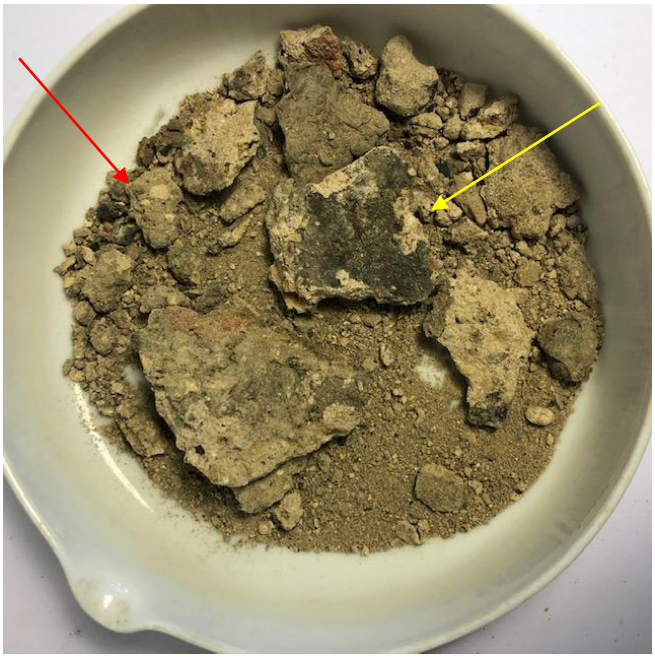


Plate 1. The total sample received (dish c.160mm diameter). There were two different mortars in the received sample (one indicated by red arrow, and the other by the yellow arrow).

Plate 2. Showing a freshly broken face of the sample. Scale is in mm.

PROCEDURE	OBSERVATIONS
PRELIMINARY VISUAL ANALYSIS OF SAMPLE	The sample was received as a fully carbonated intact pieces of mortar plus fines. The sample received contained two distinctly different binders, so these were separated and the most abundant one chosen for analysis (see plate 1). The sample is very firm and requires significant pressure to disrupt, however once disrupted it is easy to powder. There was irregular shaped, large, cracked lime inclusions throughout the sample along with occasional coal/burnt fuel fragments. The phenolphthalein indicator test confirmed that the mortar was fully carbonated whilst a water droplet test confirmed that the mortar was porous as the droplets were rapidly absorbed and the water diffused throughout the mortar.
EXAMINATION OF PREPARED SAMPLE BY BINOCULAR MICROSCOPE (X40 MAGNIFICATION)	Once dried the mortar was found to be 10YR 8/2 ‘very pale brown’ to 10YR 6/3 ‘pale brown’ when assessed against the Munsell Soil Colour Charts. The surface of the sample appeared microporous and had a granular texture. Larger lithic fragments appear to make up the courser aggregate fractions, and

PROCEDURE	OBSERVATIONS
	are well weathered and the majority are grey/dark in colour. The finer fractions of aggregate appear to consist mainly of sub-angular to angular quartz grains with a buff/orange/grey tint. The mortar contained an abundance of air voids, some of which contained linings of calcite as secondary products, soiling and organic matter, all indicating that water percolation through the mortar had occurred, resulting in leaching, and the re-precipitation, of binder components and the deposition of transported debris.

ACID DISSOLUTION & FILTRATION

PROCEDURE	OBSERVATIONS/COMMENTS	
DISSOLUTION OF BINDER USING 10% HCl	On addition of the acid to the powdered sample there was a moderate reaction producing a moderate amount of steam and foam. The reaction slowed after 3 mins but was still producing bubbles but the volume of steam was reduced. This shows a moderate to high free lime content.	
FILTRATION	GRADE: 20	PAPER TYPE: Whatman Type 41

CONSTITUENTS OF ANALYSIS SAMPLE

MATERIAL	WEIGHT (g)	COMMENTS
A: DRY WEIGHT OF ANALYSIS SAMPLE	29.18	Mass of sample analysed (before acid digestion).
B: DRY WEIGHT OF ALL INSOLUBLES	14.13	Insoluble residue recovered after acid digestion (before sieving).
C: DRY WEIGHT OF INSOLUBLE BINDER	0.00	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	14.13	Corrected for retention of hydraulic components or other non-soluble reaction products.
E: (A-D) DRY WEIGHT OF LIME	15.05	Including insoluble binder where present.
MOISTURE CONTENT (%)	1.80	Based on mass of sample before and after drying.
OTHER	-	Gypsum and other non-binder related contaminants or reaction products.

AGGREGATE GRADING & CHARACTERISATION

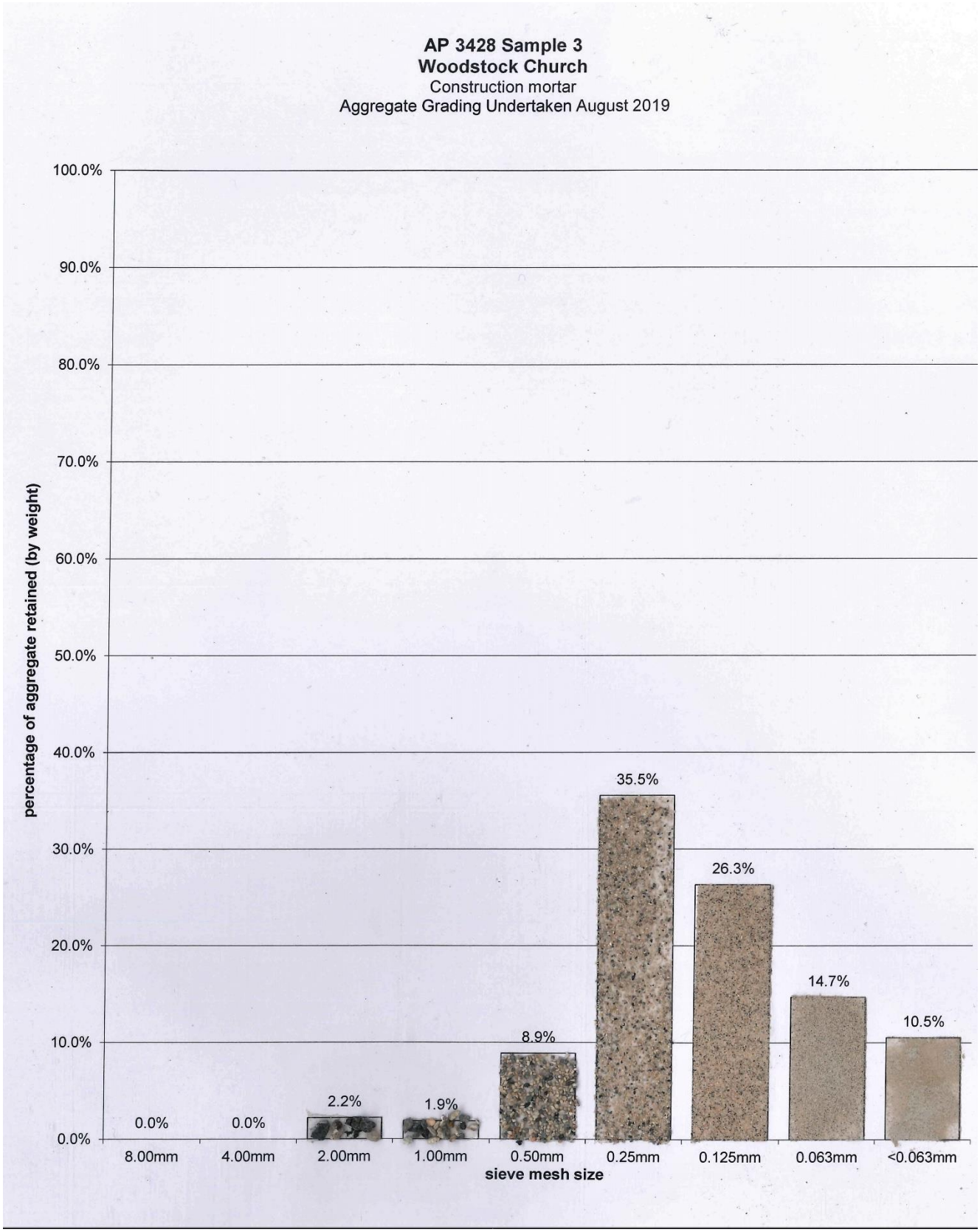
SIEVE PERFORATION SIZE*	AGGREGATE RETAINED (g)	UNDISSOLVED BINDER (%)	CORRECTED AGGREGATE WEIGHT (g)	% OF AGGREGATE	COMMENTS
8mm	0.00	0	0.00	0.0	
4mm	0.00	0	0.00	0.0	
2mm	0.20	0	0.20	2.2	Sub-rounded to sub-angular well weathered lithic fragments plus sub-angular to angular quartz grains
1mm	0.17	0	0.17	1.9	As above
500µm	0.81	0	0.81	8.9	As above
250µm	3.24	0	3.24	35.5	Predominantly composed of angular – sub-angular quartz grains, cloudy, glassy, grey and orange/buff tinted. With dark grey weathered lithic fragments
125µm	2.40	0	2.40	26.3	As above
63µm	1.34	0	1.34	14.7	As above with indiscernible silt and clay.
< 63µm including filter residue	0.96	0	0.96	10.5	As above with indiscernible silt and clay.

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

The aggregate isolated from this sample is moderately well graded and aggregate is retained from sieve size 2mm down with the highest percentage of grains being retained in sieve mesh size 0.250mm with 35.5%. Well weathered lithic fragments and sub angular quartz make up the courser fractions. Smaller fractions are composed predominately of angular to sub-angular quartz grains and the buff/orange/cream tinted grains give the sand its overall pale brown colour. See aggregate profile below.

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 Profile of the Aggregate Separated from the Mortar Sample



AGGREGATE MATCHING

The closest commercially available matching aggregate, from the SLCT Sands and Aggregates Database taking into account location, grading, grain size, colour and texture is 0/4mm Washed Building Sand from Snabe Quarry (see aggregate profile below). This sand has been retained from sieve mesh size 4mm down, with the highest percentage of grains being retained from sieve mesh size 0.250mm with 30.8%. It is predominantly medium grained with a uni-modal grain size distribution, lithic fragments give a slightly darker colour and a more buff colour is due to the silts and clays at finer fractions with quartz grains present throughout.

An alternative aggregate match is Building Sand from Lomond Quarry (see aggregate profile below). This sand has been retained from sieve mesh size 4mm down, with the highest percentage of grains being retained from sieve mesh size 0.125mm with 40.7%. It is well graded with a uni-modal grain size distribution, lithic fragments give a slightly darker colour and a more buff colour is due to the silts and clays at finer fractions with quartz grains present throughout.

Contact details for these quarries are listed below.

Snabe Quarry,
Strathaven Road,
Drumclog,
South Lanarkshire
ML10 6QF

Tel.: 01357 440 070

Skene Group,
Lomond Quarry,
Balsillie Farm,
Falkland Hills Road,
Leslie,
Fife
KY6 3HD

Tel.: 01592 741 590

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.

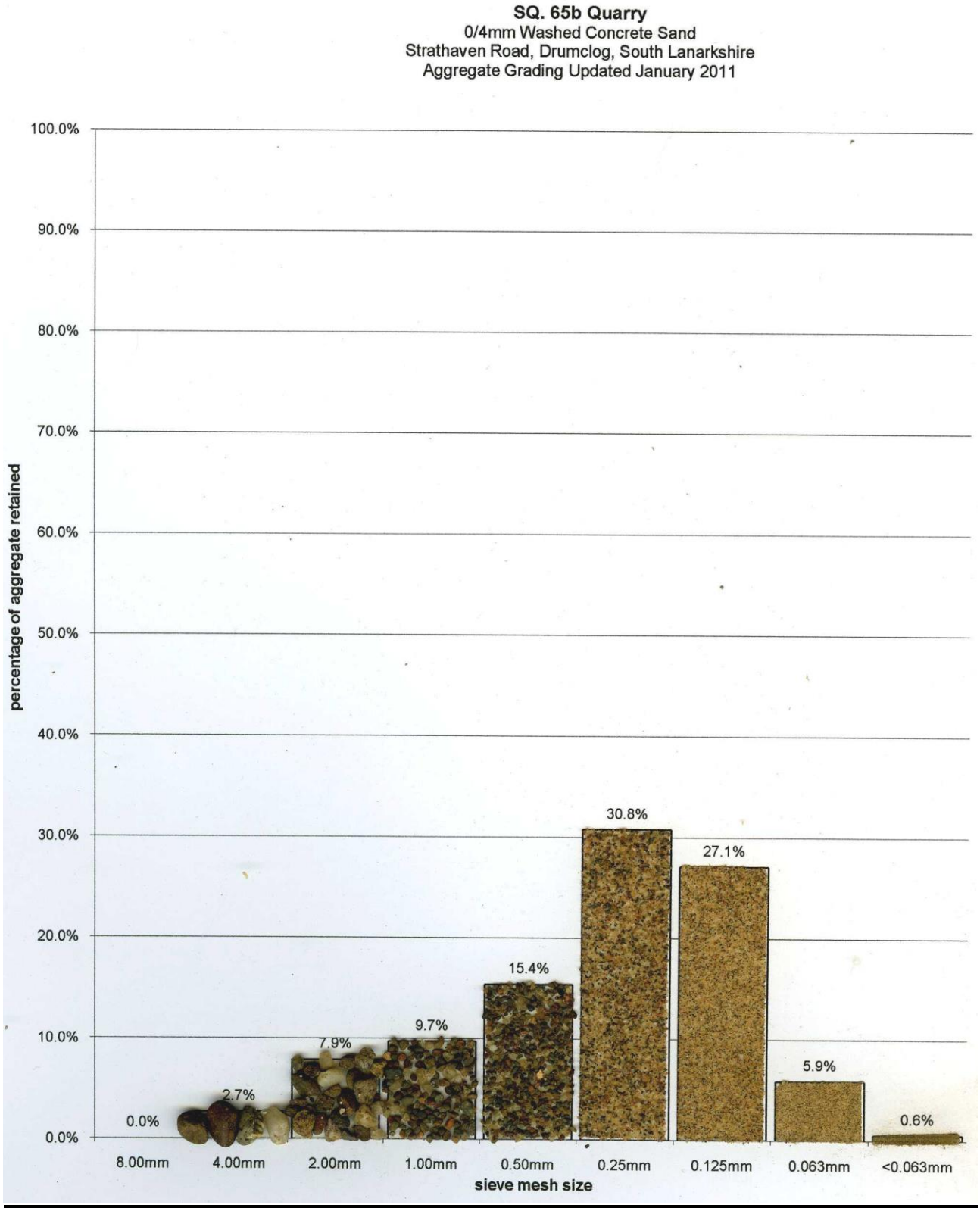
The currently available aggregate samples held in the Scottish Lime Centre Trust's Aggregates Database are provided by the individual quarries/operators and therefore we have to assume that they are representative of the aggregate being produced at the time of receipt of the sample. As with all quarries 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.

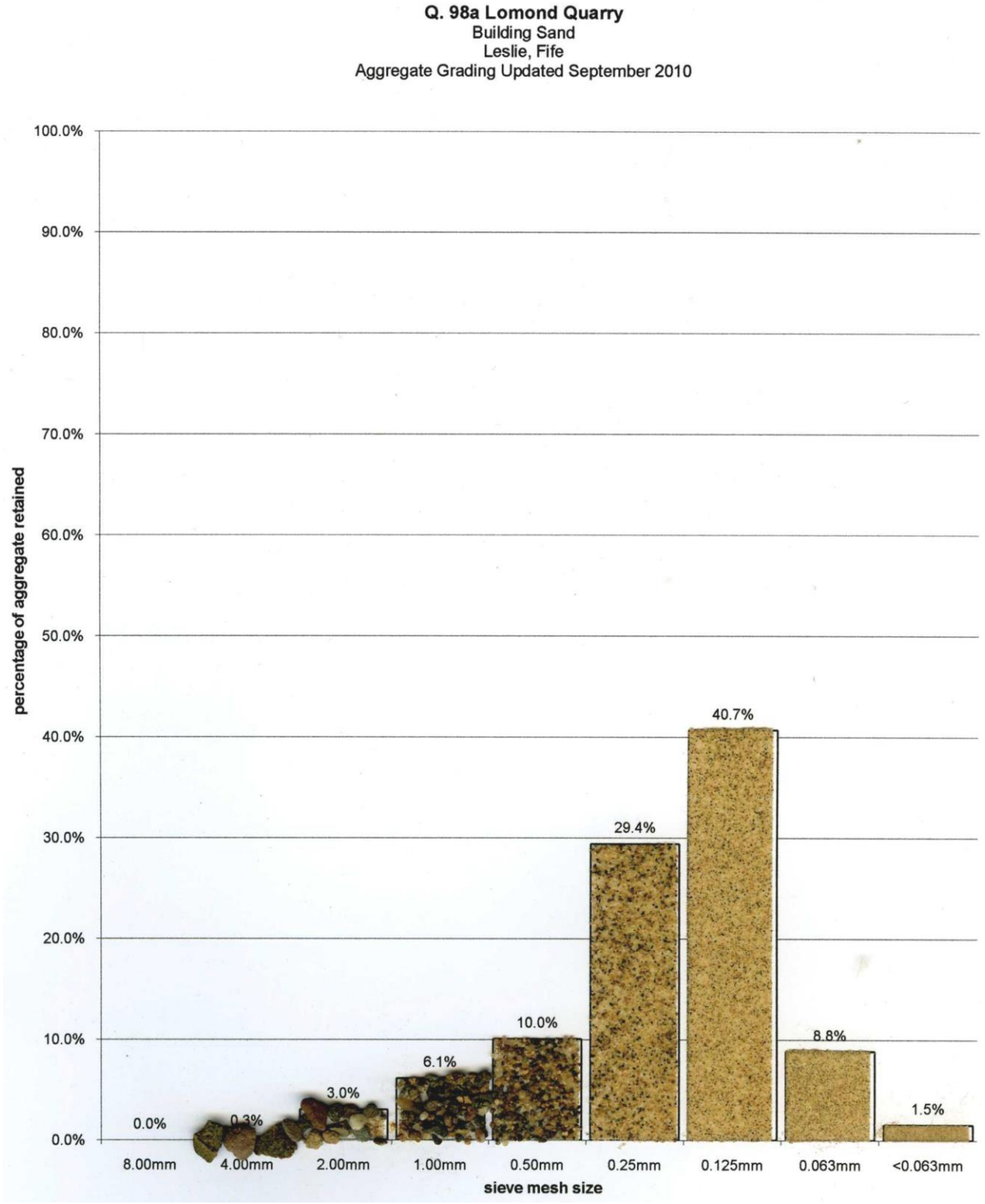
Quarries can change hands, open or close down with a relatively high frequency and therefore the source(s) identified above may become unavailable with no notice. If you are unable to obtain one of the above aggregates within 6 months of us completing this report then we will identify a new source free 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 closest Matching Currently Available Aggregate: 0/4mm Washed Concrete Sand, Snabe 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	:	0.9

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 to eminently hydraulic quicklime.

1 PART MODERATELY TO EMINENTLY HYDRAULIC QUICKLIME	**:**	**1.2 PARTS AGGREGATE (BY WEIGHT)**

Please note that the proportions given above relate to the sample supplied, this is not a specification. See associated consultancy report for specifications for replacement mortars.