SCOTTISH LIME CENTRE TRUST

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MORTAR ANALYSIS REPORT

AP 2898
Cupar Stone Survey, Cupar

Sample MS1

Bedding Mortar

SITE	Cupar Stone Survey
CLIENT	Fife Historic Buildings Trust
DATE SAMPLE RECEIVED	05.07.16
ANALYSIS DATES	11.07.16 – 21.07.16
CLIENT REQUIREMENTS	Standard Mortar Analysis by acid digestion
STRUCTURE DATE	Unknown
STRUCTURE TYPE	Close along Bishopgate
MORTAR DATING	Likely to be original
LOCATION/ FUNCTION IN BUILDING	Bedding mortar, but likely also representative of pointing mortar used throughout Cupar
CONDITION OF SAMPLE RECEIVED	The sample received consisted of a bag containing intact pieces of mortar plus fines. Size of largest piece = 60mm x 37mm x 17mm Total mass of sample received = 106.52 grams

SUMMARY AND INTERPRETATION OF ANALYSIS RESULTS

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

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 7/2 'light grey' – 10YR 7/3 and 10YR 8/3 'very pale brown'.

The mix ratio of the sample is approximately 1 part moderately hydraulic quicklime to 0.54 parts 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).

Plate 2. A freshly broken face of the sample at higher magnification showing the individual aggregate grains.

PROCEDURE	OBSERVATIONS
PRELIMINARY VISUAL ANALYSIS OF SAMPLE	The sample was received as fully carbonated intact pieces of mortar plus fines. The sample varied in strength, ranging in the largest sub-samples from moderate to strong and non-friable to weak and slightly friable in the smallest fragments. The mortar contains visibly well graded, fine to medium grained matrix aggregate (with occasional coarse fragments) which is composed of quartz (including larger clasts of vein quartz), feldspar, generally indiscernible weathered crystalline lithic fragments, brick fragments, orange to yellow coloured clay inclusions, coal fragments and lime inclusions. The mortar was received in a relatively good condition, with only minor discolouration present and with no evidence of biological growth. The sample experienced a fast water absorption rate on all exposed faces, with little lateral spreading of moisture when subjected to the water droplet test. This fast water absorption rate indicates an interconnected internal pore network which permits the fast and efficient absorption and transportation of moisture through its thickness. The total sample weighed 106.52g and the largest intact piece measured 60mm x 37mm x 17mm.
EXAMINATION OF PREPARED SAMPLE BY BINOCULAR MICROSCOPE (X40 MAGNIFICATION)	Once dried the mortar was found to be 10YR 7/2 ‘light grey’ to 10YR 7/3 – 8/3 ‘very pale brown’ when assessed against the Munsell Soil Colour Charts. When assessing the sample by means of binocular microscope the binder was found to contain a high proportion of small surface pores and a moderate proportion of medium sized spherical pores internally throughout the depth of the sample; appearing as entrained air. The binder contains a slight ‘granular’ texture that is relatively friable at the micro-scale, which shows an overall good binder to aggregate coverage, sufficiently coating aggregate grains. The aggregate is generally medium to fine grained and appears to be well graded, comprising angular to rounded, sub-spherical to spherical clear and glassy textured to grey, light buff and dusty textured quartz grains, dark indiscernible minerals/lithic fragments, pyrite, muscovite mica, lime inclusions and coal fragments, with the largest visible lime inclusion measuring ~1.2mm in diameter.

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 with some steam, bubbling and thick, long lasting foaming as well as slight temperature rise. This reaction indicates a moderate to high free lime content and moderate level of hydraulicity.	
FILTRATION	GRADE: 20	PAPER TYPE: Whatman Type 41

CONSTITUENTS OF ANALYSIS SAMPLE

MATERIAL	WEIGHT (g)	COMMENTS
A: DRY WEIGHT OF ANALYSIS SAMPLE	104.38	Mass of sample analysed (before acid digestion).
B: DRY WEIGHT OF ALL INSOLUBLES	75.02	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	75.02	Corrected for retention of hydraulic components or other non-soluble reaction products.
E: (A-D) DRY WEIGHT OF LIME	29.36	Including insoluble binder where present.
MOISTURE CONTENT (%)	1.96	Based on mass of sample before and after drying.
OTHER	-	Gypsum and other non-binder related contaminants or reaction products.

AGGREGATE GRADING & CHARACTERISATION

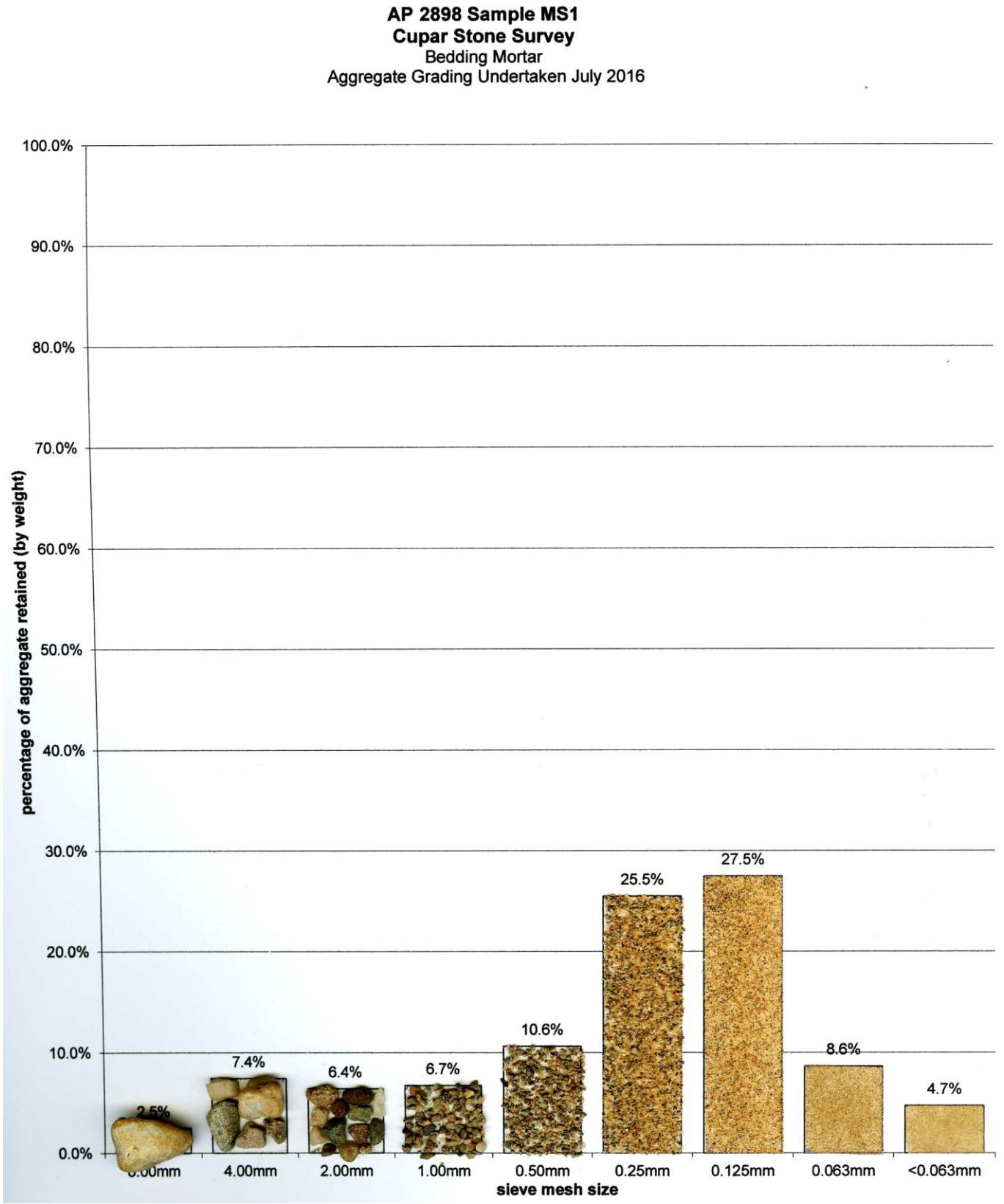
SIEVE PERFORATION SIZE*	AGGREGATE RETAINED (g)	UNDISSOLVED BINDER (%)	CORRECTED AGGREGATE WEIGHT (g)	% OF AGGREGATE	COMMENTS
8mm	1.86	0.00	1.86	2.50	White rounded quartz.
4mm	5.57	0.00	5.57	7.40	Quartz, basic to acidic igneous rock and rounded sandstone.
2mm	4.80	0.00	4.80	6.40	Same as above.
1mm	5.04	0.00	5.04	6.70	Rounded quartz grains, similarly shaped basic to acidic igneous rock fragments, sandstone and angular coal fragments.
500µm	7.96	0.00	7.96	10.60	Same as above.
250µm	19.11	0.00	19.11	25.50	Same as above.
125µm	20.60	0.00	20.60	27.50	Same as above.
63µm	6.48	0.00	6.48	8.60	Indiscernible clay.
< 63µm including filter residue	3.54	0.00	3.54	4.70	Indiscernible clay.

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

The aggregate isolated from this sample is retained from sieve mesh 8mm down, with the highest percentage of aggregate having been retrieved from sieve mesh size 0.125mm with 27.5%. The aggregate is predominantly medium grained and moderately well graded, showing a negatively skewed, uni-modal grain size distribution with no individual grain size interval exceeding 30%. The coarse fractions are comprised of sub-angular to sub-rounded, sub-elongate to sub-spherical clear coloured quartz grains, mixed weathered igneous rock and sandstone fragments. The medium to fine grain size fractions contain a majority of sub-angular to sub-rounded, sub-spherical quartz grains and relatively lower proportions of dark minerals, lithic fragments and coal. 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 Building Sand from Melville Gates Quarry (see aggregate profile below). This sand has been retained from sieve mesh 4mm down, with the highest percentage of aggregate having been retrieved from sieve mesh size 0.25mm with 41.5%. This sand is moderately to poorly graded (due to the very high 0.25mm fraction) and predominantly medium grained, showing a distinctive uni-modal grain size distribution. It is slightly darker in colour to the analysed sample owing to the slightly darker stained quartz grains and higher proportion of black minerals/lithic fragments in the medium to coarse grain size fractions. It contains a lower proportion of coarse aggregate, very similar fines and a higher proportion of grains within the 0.25mm fraction. The sand show similar mineralogical and textural characteristics to the analysed sample, containing a majority of dark lithic fragments in the coarse fractions and buff quartz grains in the medium to fine fractions. Additionally, Melville Gates Quarry is located extremely close to Cupar, therefore providing locally sourced aggregate, which is likely representative of the original sands used within the mortars of Cupar.

An alternative aggregate match is Concrete Sand from Lomond Quarry (see aggregate profile below). This sand has been retained from sieve mesh 4mm down, with the highest percentage of aggregate having been retrieved from sieve mesh size 0.125mm with 26.7%. It is moderately well graded, medium to coarse grained sand that shows a very similar grain size distribution to the analysed sample. The coarse grained aggregate is comprised of dark, sub-angular lithic fragments, while the medium to fine fractions contain a majority of sub-angular to sub-rounded, sub-spherical quartz grains. The coarse fractions are slightly darker than the equivalent fractions in the analysed sample, while the medium to fine fractions impart a more yellowish colour to the sand. Lomond Quarry is located in Leslie, Fife, which is also in relatively close proximity to Cupar, providing a similar sand in terms of texture and mineralogy.

Contact details for these quarries are listed below.

Angle Park Sand & Gravel Co. Ltd.,
Melville Gates Quarry,
Ladybank,
Cupar,
Fife
KY7 7RF

Tel: 01337 830 303

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

Tel: 01562 741 590

However, the named source(s) is/are not the only potentially suitable source(s) available, but is/are the closest, with

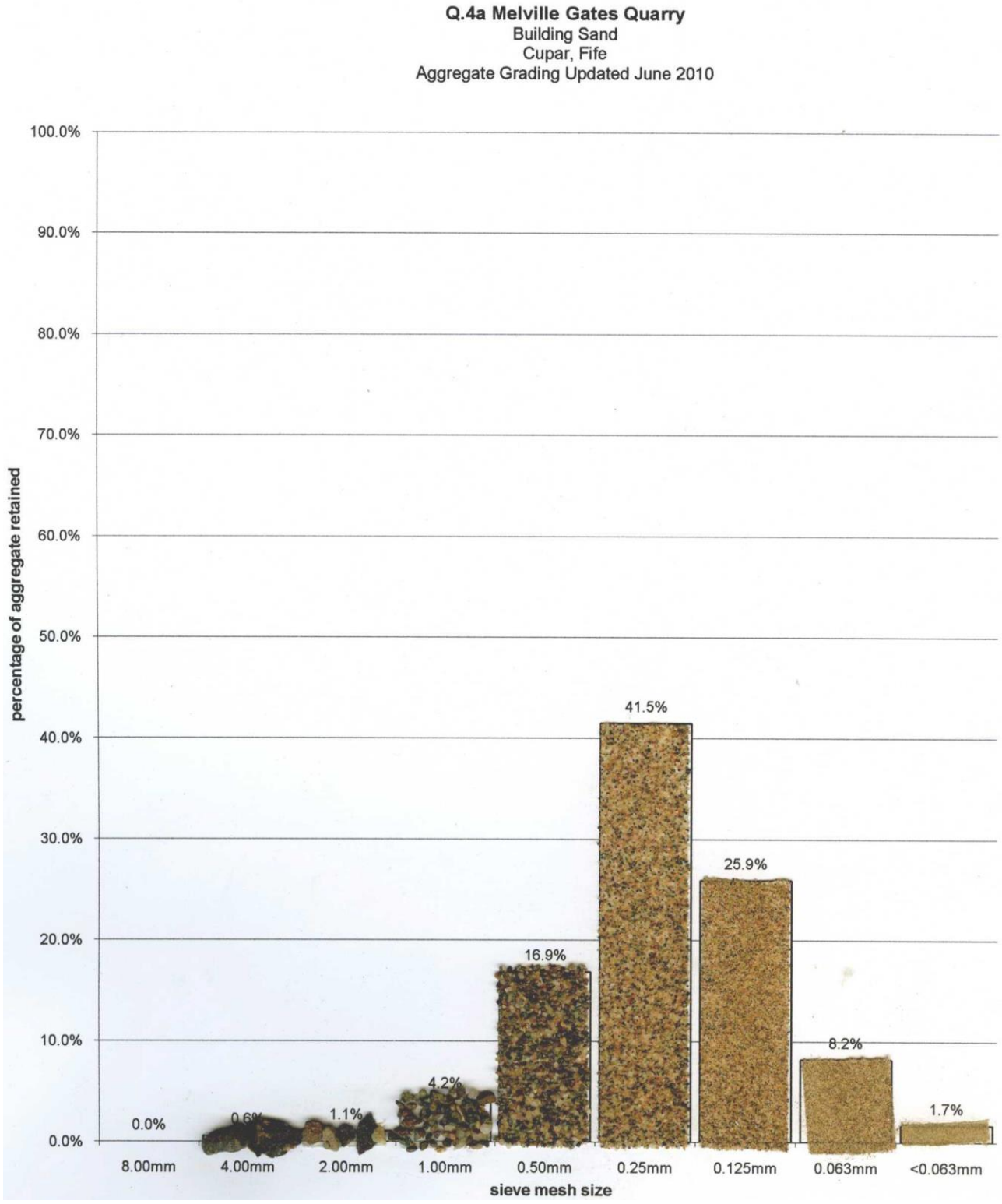
respect to visual characteristics and physical properties, on the basis of the work carried out to date, on the sample submitted to examination.

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.

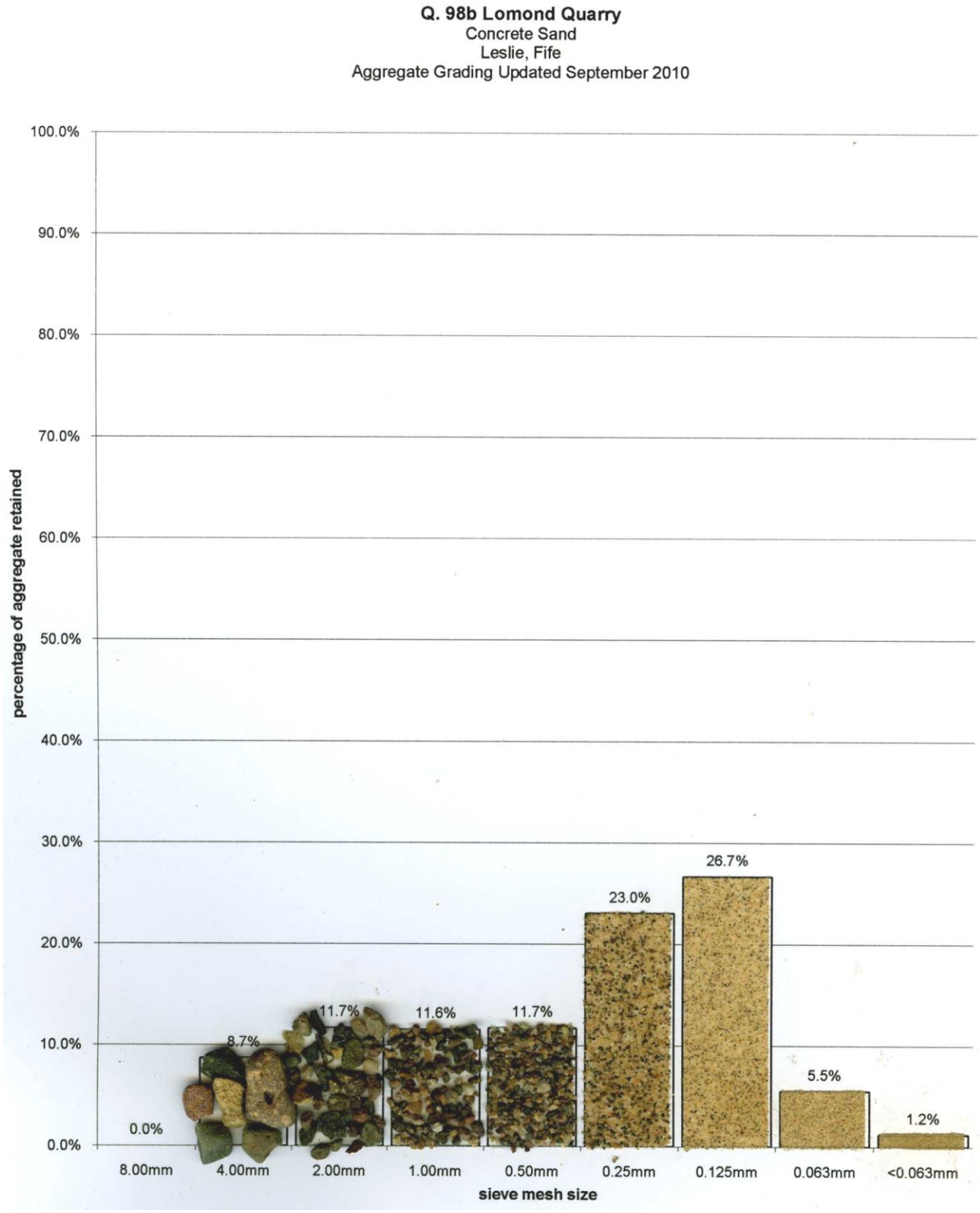
Quarries can change hands, open or close down with a relatively high frequency and therefore the source(s) identified above may become unavailable with no notice. If you are unable to obtain one of the above aggregates within 6 months of us completing this report then we will identify a new source free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



Aggregate Profile of an Alternate Matching Currently Available Aggregate: Concrete 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	:	2.6

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 moderately hydraulic quicklime.

1 PART MODERATELY HYDRAULIC QUICKLIME	**:**	**3.8 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.

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MORTAR ANALYSIS REPORT

AP 2898
Cupar Stone Survey, Cupar

Sample MS2

Bedding Mortar

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And a charitable company limited by guarantee, registered in Scotland no: **SC151481**
www.scotlime.org VAT no 671 2677 22 admin@scotlime.org

SITE	Cupar stone survey
CLIENT	Fife Historic Buildings Trust
DATE SAMPLE RECEIVED	05.07.16
ANALYSIS DATES	11.07.16 –21.07.16
CLIENT REQUIREMENTS	Standard Mortar Analysis by acid digestion
STRUCTURE DATE	Unknown
STRUCTURE TYPE	House
MORTAR DATING	Likely to be original
LOCATION/ FUNCTION IN BUILDING	Bedding mortar from South-most House
CONDITION OF SAMPLE RECEIVED	The sample received consisted of a bag containing intact pieces of mortar plus a large amount of fines. Size of largest piece = 26mm x 26mm x 13mm Total mass of sample received = 131.83 grams

SUMMARY AND INTERPRETATION OF ANALYSIS RESULTS

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

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 7/3 'very pale brown' – 10YR 6/3 'pale brown'.

The mix ratio of the sample is approximately 1 part eminently hydraulic quicklime to 0.42 parts 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).

Plate 2. A freshly broken face of the sample at higher magnification.

PROCEDURE	OBSERVATIONS
PRELIMINARY VISUAL ANALYSIS OF SAMPLE	The sample was received as fully carbonated intact pieces of mortar plus a high proportion of fines. The strength of the mortar was difficult to accurately assess owing to the small size of the received sub-samples and high proportion of fines; however in relation to sample size, the mortar appears to be generally firm and moderately friable, with the sample disrupted under moderate finger pressure. The sample contains generally indiscernible fine grained aggregate that includes quartz grains, weathered crystalline lithic fragments, orange to brown coloured clay inclusions, coal fragments and a relatively high proportion of lime inclusions, with the largest measuring ~8mm in length. The fines experienced a moderate water absorption rate, while fully intact sub-samples of mortar experienced fast water absorption rates when subjected to the water droplet test. This fast water absorption rate within the intact sub-samples indicates an interconnected internal pore network that permits the fast and efficient absorption and transportation of moisture through the thickness of the mortar. The total sample weighed 131.83g and the largest intact piece measured 26mm x 26mm x 13mm.
EXAMINATION OF PREPARED SAMPLE BY BINOCULAR MICROSCOPE (X40 MAGNIFICATION)	Once dried the mortar was found to be 10YR 7/3 ‘very pale brown’ to 10YR 6/3 ‘pale brown’ when assessed against the Munsell Soil Colour Charts. When assessing the sample by means of binocular microscope the binder was shown to display an uneven, friable and ‘granular’ texture that is characterised by poor binder to aggregate coverage and a high intergranular porosity; influencing the high water absorption rate experienced by the mortar. The aggregate was difficult to assess owing to the friable and granular nature of the binder, but is identified as contained sub-angular to rounded, grey to buff coloured quartz grains, coal fragments and dark indiscernible lithic fragments.

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 initial reaction with the production of steam and a temperature rise, continued bubbling and lots of foaming occurring. More bubbling than MS1. This reaction indicates a high free lime content and moderate to high level of hydraulicity.	
FILTRATION	GRADE: 20	PAPER TYPE: Whatman Type 41

CONSTITUENTS OF ANALYSIS SAMPLE

MATERIAL	WEIGHT (g)	COMMENTS
A: DRY WEIGHT OF ANALYSIS SAMPLE	120.93	Mass of sample analysed (before acid digestion).
B: DRY WEIGHT OF ALL INSOLUBLES	85.33	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	85.33	Corrected for retention of hydraulic components or other non-soluble reaction products.
E: (A-D) DRY WEIGHT OF LIME	35.60	Including insoluble binder where present.
MOISTURE CONTENT (%)	8.26	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	6.55	0.00	6.55	7.70	Rounded to well-rounded quartz grains.
4mm	0.81	0.00	0.81	1.00	Rounded quartz grains and similarly shaped weathered rock plus muscovite mica.
2mm	1.02	0.00	1.05	1.20	Rounded weathered stone, quartz, coal and feldspar grains.
1mm	1.32	0.00	1.32	1.60	Same as above.
500µm	4.26	0.00	4.26	5.00	Same as above with some clay.
250µm	27.34	0.00	27.34	32.10	Rounded weathered stone, quartz, mica, feldspar grains and clay inclusions.
125µm	31.51	0.00	31.51	37.00	Same as above.
63µm	9.19	0.00	9.19	10.80	Indiscernible clay.
< 63µm including filter residue	3.16	0.00	3.16	3.70	Indiscernible clay.

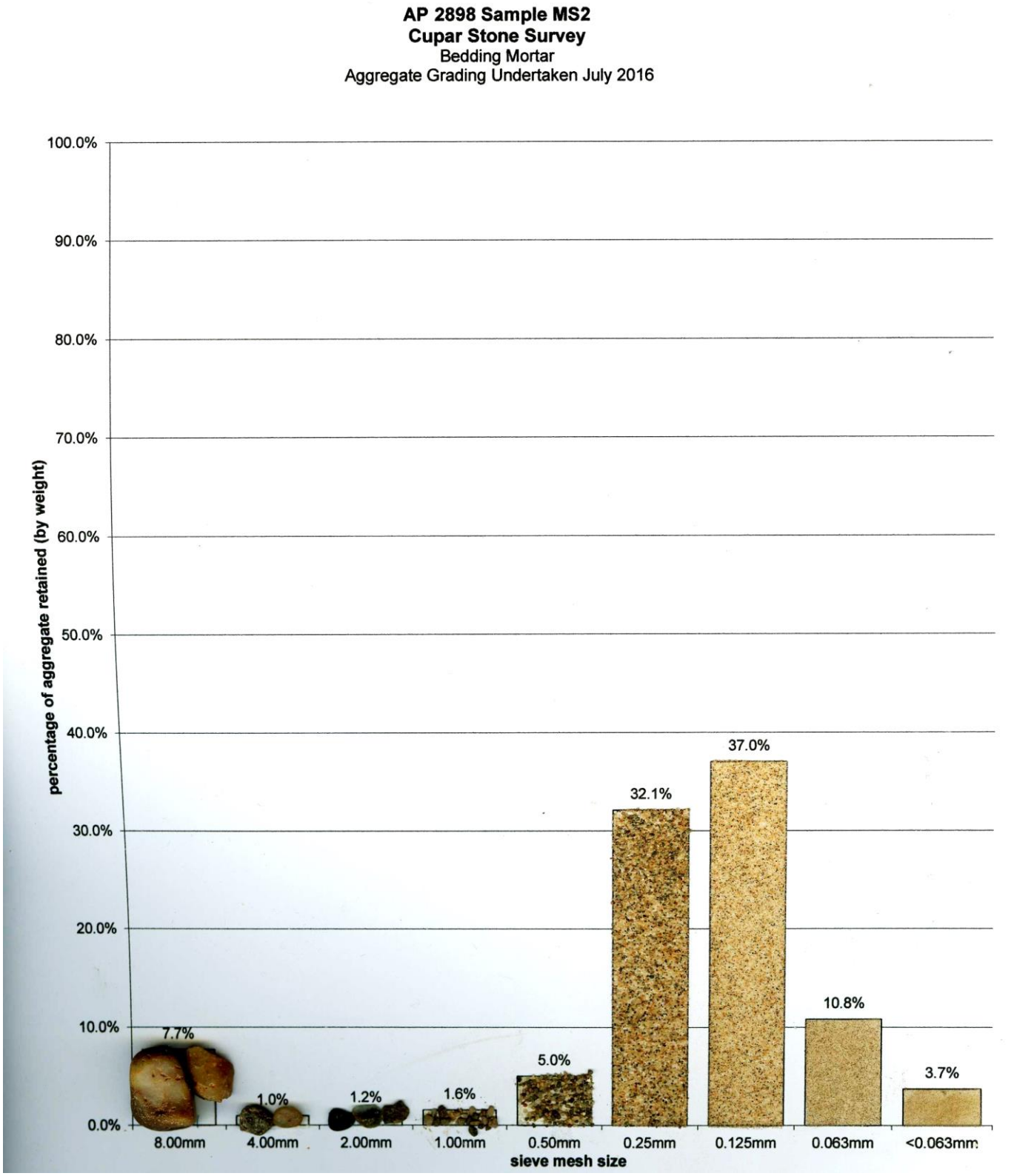
***Sieve perforation sizes correspond to those stated in BS EN 1015.1:1999**

The aggregate isolated from this sample is retained from sieve mesh 8mm down, with the highest percentage of aggregate having been retrieved from sieve mesh size 0.125mm with 37%. The sand is predominantly fine to medium grained and poorly graded, with over 69% of the retained aggregate lying within the 0.125mm to 0.250mm grain size fractions. The coarse fractions are comprised of vein quartz and mixed weathered crystalline lithic fragments, while the medium to fine fractions contain a majority of sub-rounded, sub-spherical quartz and feldspar grains, with minor proportions of coal fragments and muscovite. 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 Building Sand from Melville Gates Quarry (see aggregate profile below). This sand has been retained from sieve mesh 4mm down, with the highest percentage of aggregate having been retrieved from sieve mesh size 0.25mm with 41.5%. This sand is moderately to poorly graded (due to the very high 0.25mm fraction) and predominantly medium grained, showing a distinctive uni-modal grain size distribution. It is slightly darker in colour to the analysed sample owing to the slightly darker stained quartz grains and higher proportion of black minerals/lithic fragments in the medium to coarse grain size fractions. It contains a lower proportion of coarse aggregate, very similar fines and a higher proportion of grains within the 0.25mm fraction. The sand show similar mineralogical and textural characteristics to the analysed sample, containing a majority of dark lithic fragments in the coarse fractions and buff quartz grains in the medium to fine fractions. Additionally, Melville Gates Quarry is located extremely close to Cupar, therefore providing locally sourced aggregate, which is likely representative of the original sands used within the mortars of Cupar.

An alternative aggregate match is Building Sand from Cotside Quarry (see aggregate profile below). This sand has been retained from sieve mesh 2mm down, with the highest percentage of aggregate having been retrieved from sieve mesh size 0.125mm with 44.2%. It is poorly graded, medium to fine grained sand that shows a very similar grain size distribution to the analysed sample. It is slightly darker in colour owing to the higher relative proportion of coarse grained dark minerals and lithic fragments and medium grained buff stained quartz grains. It shares similar textural and mineralogical characteristics to the analysed sample and is relatively close proximity to Cupar, located within Angus.

Contact details for these quarries are listed below.

Angle Park Sand & Gravel Co. Ltd.	William Clark
Melville Gates Quarry	Cotside Quarry
Ladybank,	Barry,
Cupar,	Carnoustie,
Fife	Angus
KY7 7RF	DD7 7RR
Tel: 01337 830 303	Tel: 01382 532 848

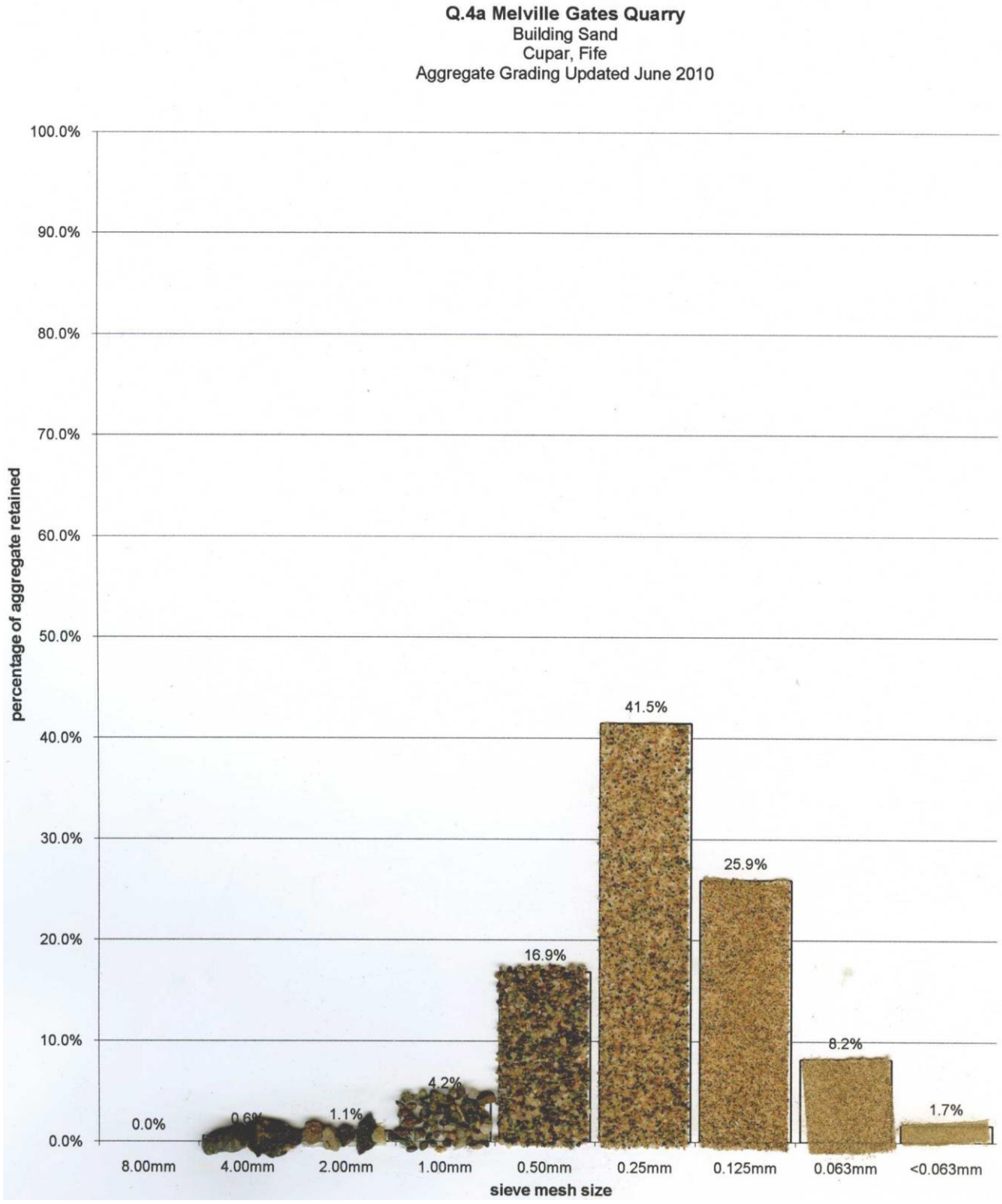
However, the named source(s) is/are not the only potentially suitable source(s) available, but is/are the closest, with respect to visual characteristics and physical properties, on the basis of the work carried out to date, on the sample submitted to examination.

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.

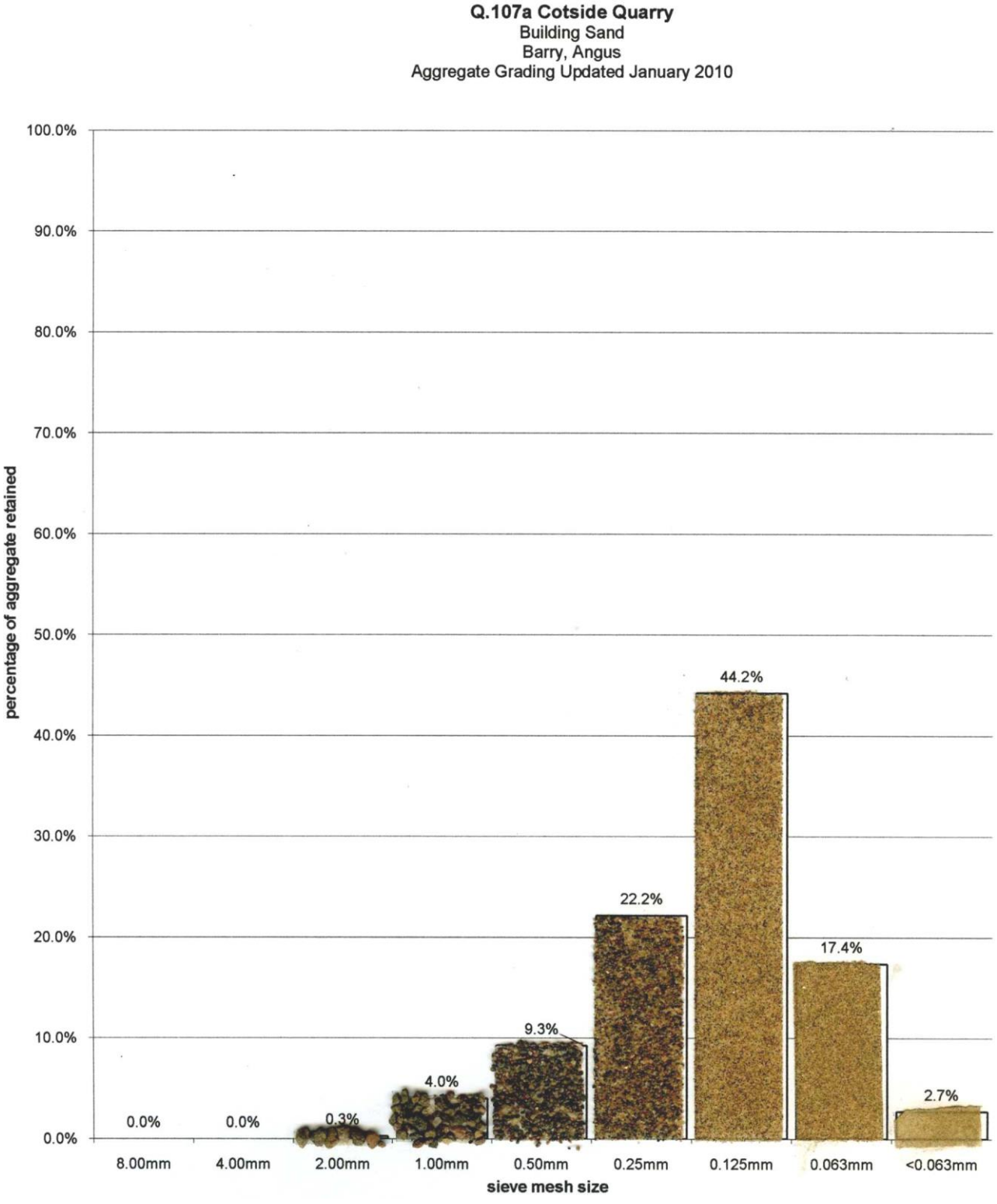
Quarries can change hands, open or close down with a relatively high frequency and therefore the source(s) identified above may become unavailable with no notice. If you are unable to obtain one of the above aggregates within 6 months of us completing this report then we will identify a new source free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



Aggregate Profile of an Alternate Matching Currently Available Aggregate: Building Sand, Cotside 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	:	2.4

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 moderately to eminently hydraulic quicklime.

1 PART EMINENTLY HYDRAULIC QUICKLIME	**:**	**3.0 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.

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Fife
KY11 3EN
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F: + 44 (0)1383 872744

MORTAR ANALYSIS REPORT

AP 2898
Cupar Stone Survey, Cupar

Sample MS3

Bedding Mortar

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And a charitable company limited by guarantee, registered in Scotland no: **SC151481**
www.scotlime.org VAT no 671 2677 22 admin@scotlime.org

SITE	Cupar stone survey
CLIENT	Fife Historic Buildings Trust
DATE SAMPLE RECEIVED	05.07.16
ANALYSIS DATES	11.07.16 – 22.07.16
CLIENT REQUIREMENTS	Standard Mortar Analysis by acid digestion
STRUCTURE DATE	Unknown
STRUCTURE TYPE	Offices
MORTAR DATING	Likely to be original
LOCATION/ FUNCTION IN BUILDING	Bedding mortar from the rubble wall at Arc Architects
CONDITION OF SAMPLE RECEIVED	The sample received consisted of a bag containing intact pieces of mortar plus a majority fines. Size of largest piece = 17mm x 10mm x 9mm Total mass of sample received = 88.45 grams

SUMMARY AND INTERPRETATION OF ANALYSIS RESULTS

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

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 7/3 'very pale brown' to 10YR 6/3 'pale brown'.

The mix ratio of the sample is approximately 1 part moderately hydraulic quicklime to 0.59 parts 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).

Plate 2. A freshly broken face of the sample at higher magnification highlighting an area of re-deposited lime within a soft and friable sub-sample of mortar.

PROCEDURE	OBSERVATIONS
PRELIMINARY VISUAL ANALYSIS OF SAMPLE	The sample was received as fully carbonated intact pieces of mortar plus fines. The sample is generally weak and friable, with some of the smallest sub-samples easily disrupted under weak finger pressure; however the overall strength, which helps to inform the hydraulicity of the sample, was difficult to accurately determine owing to the small size of sub-samples and high proportion of fines; the latter of which would also imply a soft to feebly hydraulic lime binder. The received fraction of fines contains a mixture of fine aggregate plus binder, with large crystalline lithic fragments and quartz grains/small pebbles found within this fraction. The internal aggregate is composed of fine grained sub-rounded quartz grains, dark indiscernible crystalline lithic fragments, small coal fragments and lime inclusions, with occasional lime-rich regions also present throughout the small sub-samples; possibly representing areas of leached and re-deposited lime. The mortar experienced a fast water absorption rate across all sub-samples, indicating an interconnected and permeable internal pore network that permits the fast and efficient absorption and transportation of moisture throughout its thickness. The total sample weighed 88.45g and the largest intact piece measured 17mm x 10mm x 9mm.
EXAMINATION OF PREPARED SAMPLE BY BINOCULAR MICROSCOPE (X40 MAGNIFICATION)	Once dried the mortar was found to be 10YR 7/3 ‘very pale brown’ to 10YR 6/3 ‘pale brown’ when assessed against the Munsell Soil Colour Charts. When assessing the sample by means of binocular microscope the internal aggregate was identified as containing a majority of light buff to grey coloured, sub-angular to sub-rounded, sub-spherical quartz grains, with a smaller proportion of darker indiscernible lithic fragments, coal fragments and lime inclusions; the largest of which measured 2.5mm x 3mm. The binder is soft and friable, displaying a granular and powdery texture that contains a high proportion of small pores; influencing the high water absorption rate. The mortar is very similar in composition and visual appearance to that of sample MS2.

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 to strong reaction with the production of thick foam and a slight rise in temperature. This reaction lasted in intensity for roughly 5 minutes; indicating a low level of hydraulicity. The strong initial reaction indicates 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	83.04	Mass of sample analysed (before acid digestion).
B: DRY WEIGHT OF ALL INSOLUBLES	61.29	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	61.29	Corrected for retention of hydraulic components or other non-soluble reaction products.
E: (A-D) DRY WEIGHT OF LIME	21.75	Including insoluble binder where present.
MOISTURE CONTENT (%)	5.97	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	0.00	0.00	0.00	
4mm	4.14	0.00	4.14	6.70	Sub-rounded to rounded quartz grains, weathered coarse crystalline rock (including mica schist, red and blonde sandstone) and angular coal fragments.
2mm	4.41	0.00	4.41	7.20	Same as above.
1mm	7.84	0.00	7.84	12.80	Same as above, but also including similarly shaped feldspar grains.
500µm	12.61	0.00	12.61	20.50	Same as above. Most grains are rounded.
250µm	19.55	0.00	19.55	31.80	Same as above with clay fragments.
125µm	9.49	0.00	9.49	15.50	Same as above.
63µm	2.12	0.00	2.12	3.50	Generally indiscernible.
< 63µm including filter residue	1.24	0.00	1.24	2.00	Indiscernible clay.

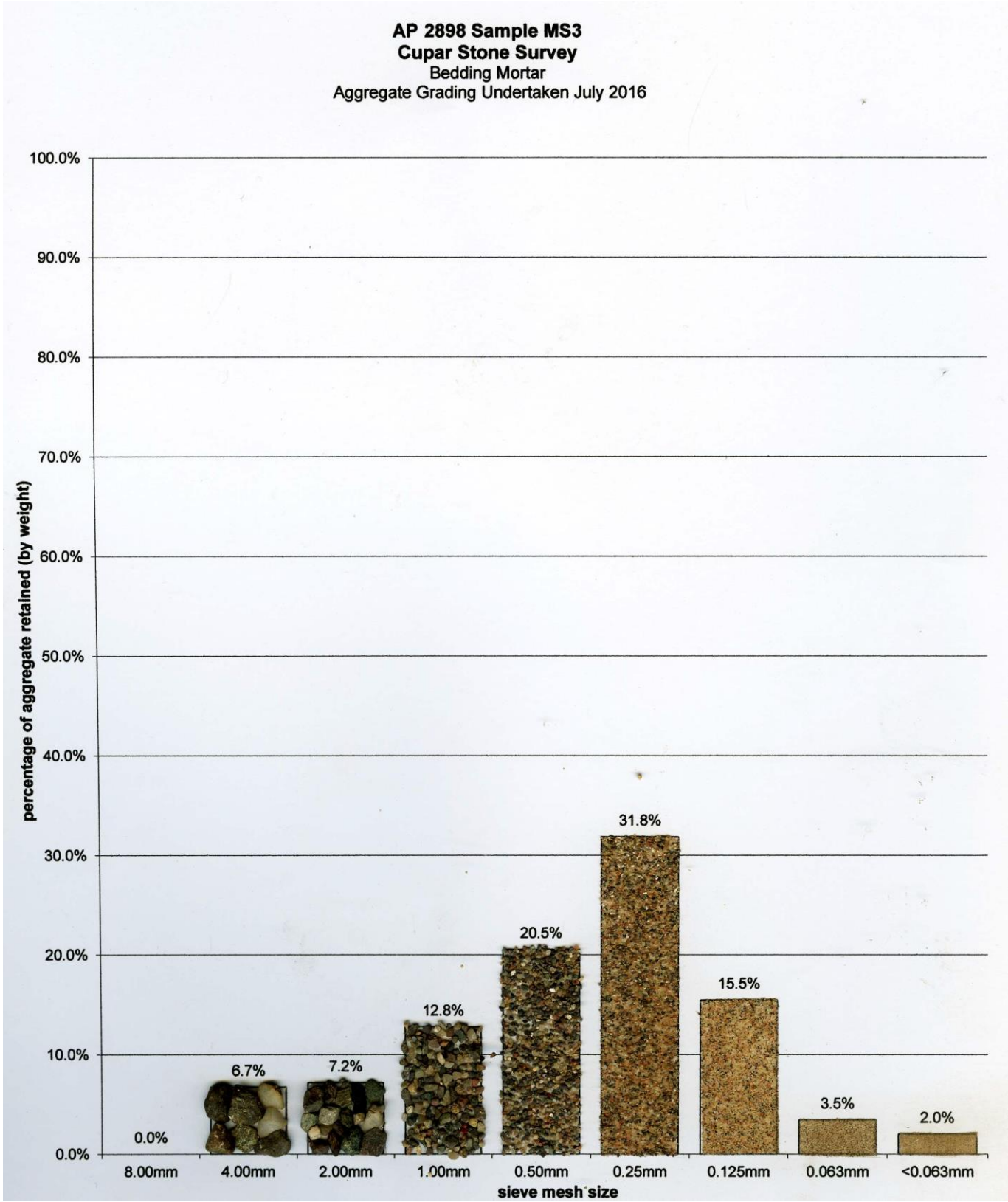
***Sieve perforation sizes correspond to those stated in BS EN 1015.1:1999**

The aggregate isolated from this sample is retained from sieve mesh 4mm down, with the highest percentage of aggregate having been retrieved from sieve mesh size 0.25mm with 31.8%. This sand is generally well graded and predominantly medium grained, showing a normal grain size distribution. The coarse aggregate contains sub-angular, sub-spherical mixed lithic fragments, including mica-schist, red and blonde sandstone and basalt, while the medium to fine grain size fractions comprised a mix of sub-angular to sub-rounded, sub-spherical to spherical grey to light buff coloured quartz and feldspar grains, muscovite mica and similarly dark lithic fragments as found in the coarse fractions. 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 Building Sand from Melville Gates Quarry (see aggregate profile below). This sand has been retained from sieve mesh 4mm down, with the highest percentage of aggregate having been retrieved from sieve mesh size 0.25mm with 41.5%. This sand is moderately to poorly graded (due to the very high 0.25mm fraction) and predominantly medium grained, showing a distinctive uni-modal grain size distribution. It is slightly darker in colour to the analysed sample owing to the slightly darker stained quartz grains and higher proportion of black minerals/lithic fragments in the medium to coarse grain size fractions. It contains a lower proportion of coarse aggregate, very similar fines and a higher proportion of grains within the 0.25mm fraction. The sand show similar mineralogical and textural characteristics to the analysed sample, containing a majority of dark lithic fragments in the coarse fractions and buff quartz grains in the medium to fine fractions. Additionally, Melville Gates Quarry is located extremely close to Cupar, therefore providing locally sourced aggregate, which is likely representative of the original sands used within the mortars of Cupar.

An alternative aggregate match is Concrete Sand from Powmyre Quarry (see aggregate profile below). This sand has been retained from sieve mesh 4mm down, with the highest percentage of aggregate having been retrieved from sieve mesh size 0.25mm with 25.4%. This is a well graded, medium to coarse grained sand that shows a very similar colour and grain size distribution to the analysed sample, albeit displaying a slightly higher proportion of coarse aggregate. It contains a very similar mineralogy, which ultimately influences its colour, while it is also characterised by similar textural characteristics. Powmyre Quarry is located in relatively close proximity to Cupar, near Forfar, Angus.

Contact details for these quarries are listed below.

Angle Park Sand & Gravel Co. Ltd,
Melville Gates Quarry
Ladybank,
Cupar,
Fife
KY7 7RF

Tel: 01337 830 303

Bardon Aggregates,
Powmyre Quarry,
Forfar,
Angus
DD8 1QD

Tel: 01575 509 157

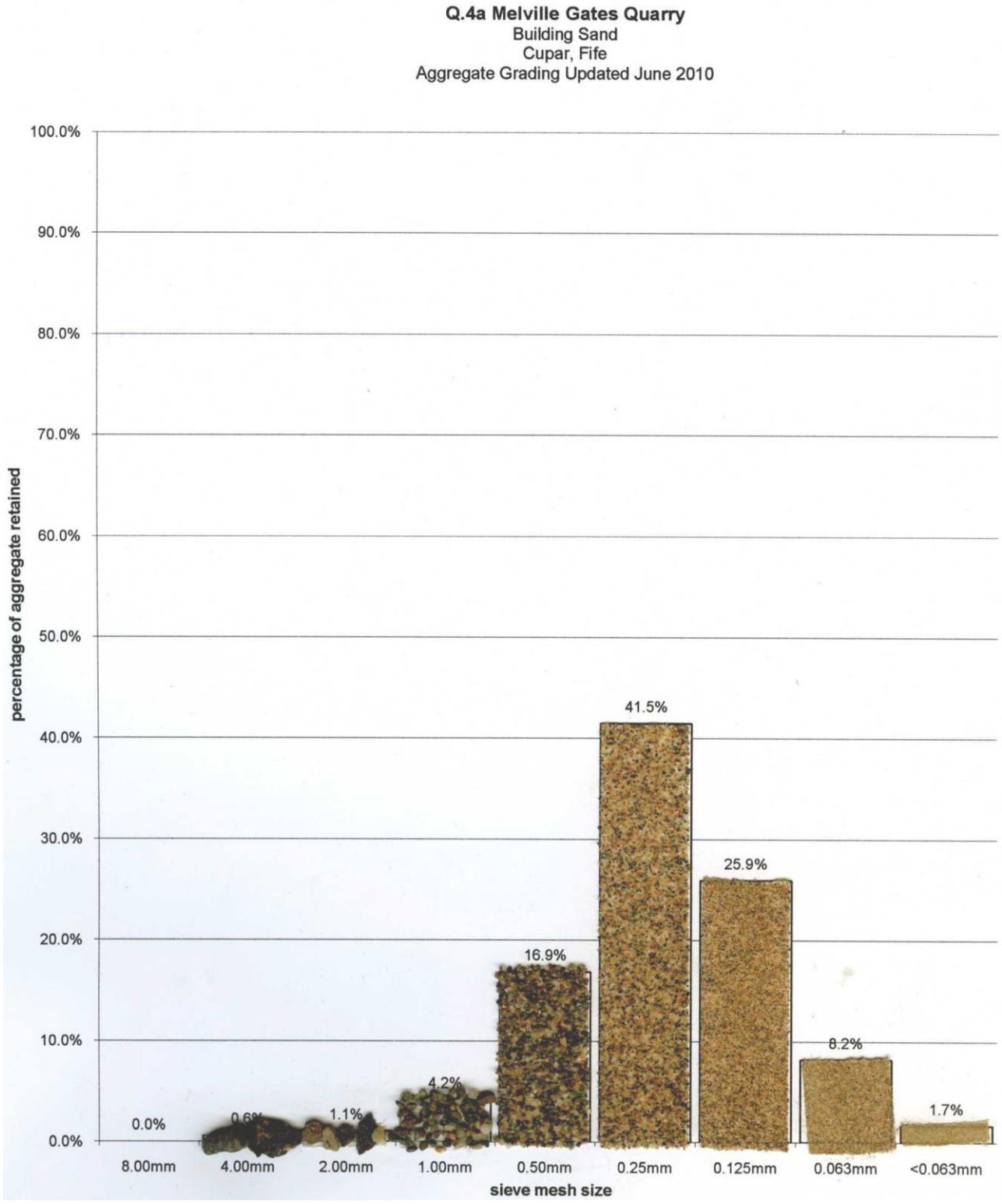
However, the named source(s) is/are not the only potentially suitable source(s) available, but is/are the closest, with respect to visual characteristics and physical properties, on the basis of the work carried out to date, on the sample submitted to examination.

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.

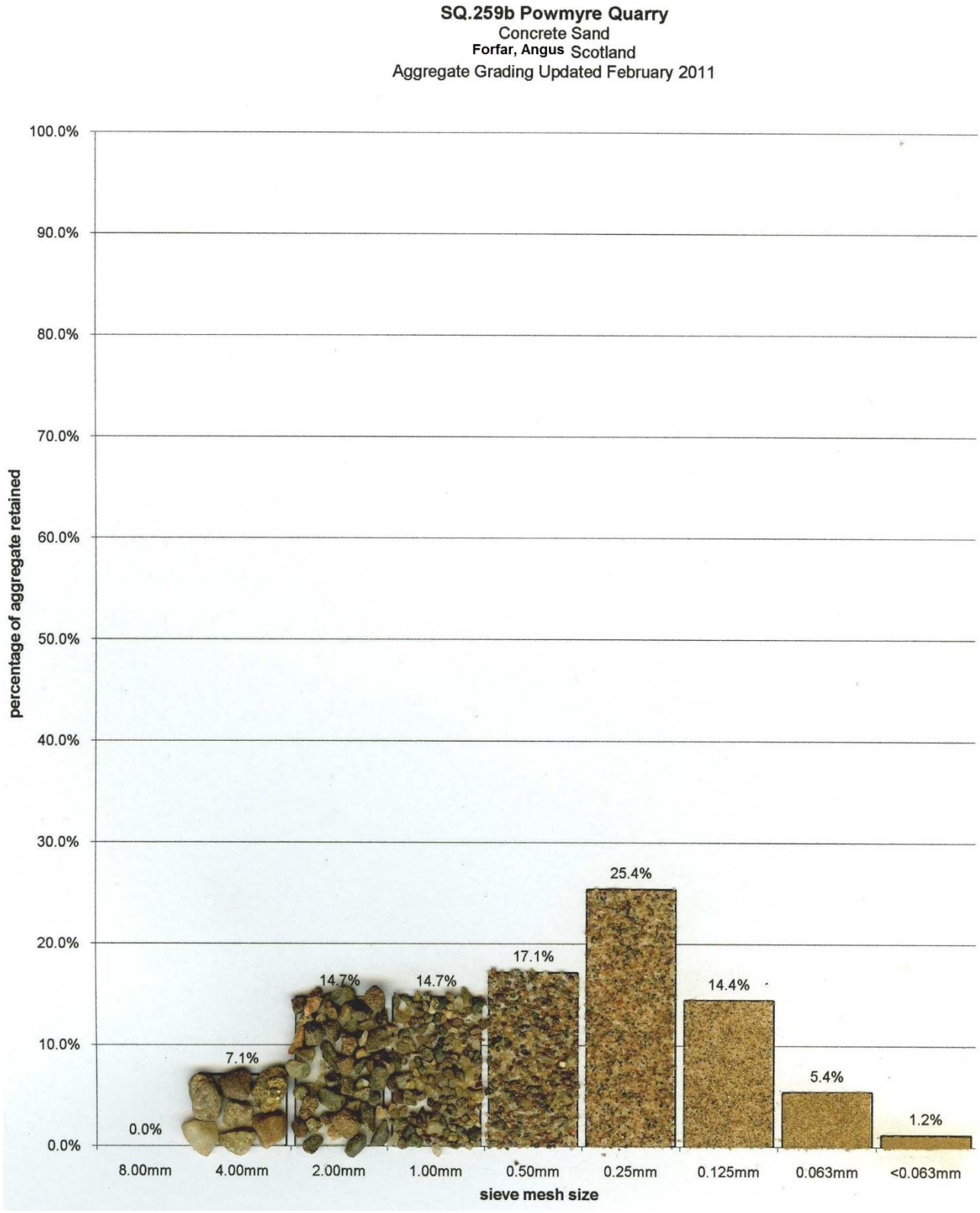
Quarries can change hands, open or close down with a relatively high frequency and therefore the source(s) identified above may become unavailable with no notice. If you are unable to obtain one of the above aggregates within 6 months of us completing this report then we will identify a new source free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



Aggregate Profile of an Alternate Matching Currently Available Aggregate: Concrete Sand, Powmyre 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	:	2.8

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 moderately hydraulic quicklime.

1 PART MODERATELY HYDRAULIC QUICKLIME	**:**	**4.2 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.

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MORTAR ANALYSIS REPORT

AP 2898
Cupar Stone Survey, Cupar

Sample MS4

Bedding Mortar

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And a charitable company limited by guarantee, registered in Scotland no: **SC151481**
www.scotlime.org VAT no 671 2677 22 admin@scotlime.org

SITE	Cupar stone survey
CLIENT	Fife Historic Buildings Trust
DATE SAMPLE RECEIVED	05.07.16
ANALYSIS DATES	11.07.16 – 22.07.16
CLIENT REQUIREMENTS	Standard Mortar Analysis by acid digestion
STRUCTURE DATE	Unknown
STRUCTURE TYPE	Boundary Wall at Castle Field Car Park
MORTAR DATING	Unknown, likely original
LOCATION/ FUNCTION IN BUILDING	Bedding mortar
CONDITION OF SAMPLE RECEIVED	The sample received consisted of a bag containing intact pieces of mortar plus fines. Size of largest piece = 68.74mm x 40.00mm x 21.96mm Total mass of sample received = 136.08 grams

SUMMARY AND INTERPRETATION OF ANALYSIS RESULTS

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

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 8/3 – 10YR 7/3 'very pale brown'.

The mix ratio of the sample is approximately 1 part moderately hydraulic quicklime to 0.62 parts 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).

Plate 2. A freshly broken face of the sample at higher magnification highlighting several clay-rich inclusions.

PROCEDURE	OBSERVATIONS
PRELIMINARY VISUAL ANALYSIS OF SAMPLE	The sample was received as fully carbonated intact pieces of mortar plus fines. The sample varies in strength relative to sample-size, with the smallest sub-samples being soft and friable and the larger samples significantly more firm and non-friable. The mortar contains dark soiled and discoloured surfaces, likely from road-side pollution, with the dark regions likely representing discoloured and polluted gypsum crusts. The mortar contains visible aggregate comprised of large orange to yellow clay inclusions (plate 2), with the largest inclusion measuring ~16mm in length, plus a predominantly medium grained matrix containing a majority of quartz grains, indiscernible dark crystalline rock and locally sourced Fe-stained sandstone fragments, lime inclusions and coal fragments. The sample experienced a range of water absorption rates when subjected to the water droplet test; ranging from slow on discoloured weathered sections to very fast on freshly broken surfaces. This fast internal water absorption rate indicates an interconnected internal pore network that permits the fast and efficient movement of moisture throughout its depth, while slow water absorption rates on weathered surfaces indicate the blocking of surface pores. The total sample weighed 136.08g and the largest intact piece measured 69mm x 40mm x 22mm.
EXAMINATION OF PREPARED SAMPLE BY BINOCULAR MICROSCOPE (X40 MAGNIFICATION)	Once dried the mortar was found to be 10YR 8/3 – 7/3 ‘very pale brown’ when assessed against the Munsell Soil Colour Charts. When assessing the sample by means of binocular microscope it was estimated to contain a moderate proportion of visible aggregate; comprised of a majority of sub-rounded to rounded, sub-spherical to spherical clear and glassy textured to grey and light buff coloured quartz grains which show occasional grain point and line contacts. The aggregate appears to be relatively well distributed throughout the sample. The binder displays a friable and ‘powdery’ texture that shows good binder to aggregate coverage; completely covering and coating grains. There was no evidence of visibly noticeable pores, which would indicate that the mortar must be relatively micro-porous, allowing the mortar to quickly absorb moisture into its fabric.

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 with steam, bubbling, a high rise in temperature and quickly fading episodes of foaming. This reaction lasted up to 15-20 minutes in the same intensity.	
FILTRATION	GRADE: 20	PAPER TYPE: Whatman Type 41

CONSTITUENTS OF ANALYSIS SAMPLE

MATERIAL	WEIGHT (g)	COMMENTS
A: DRY WEIGHT OF ANALYSIS SAMPLE	131.87	Mass of sample analysed (before acid digestion).
B: DRY WEIGHT OF ALL INSOLUBLES	98.50	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	98.50	Corrected for retention of hydraulic components or other non-soluble reaction products.
E: (A-D) DRY WEIGHT OF LIME	33.37	Including insoluble binder where present.
MOISTURE CONTENT (%)	2.93	Based on mass of sample before and after drying.
OTHER	-	Gypsum and other non-binder related contaminants or reaction products.

AGGREGATE GRADING & CHARACTERISATION

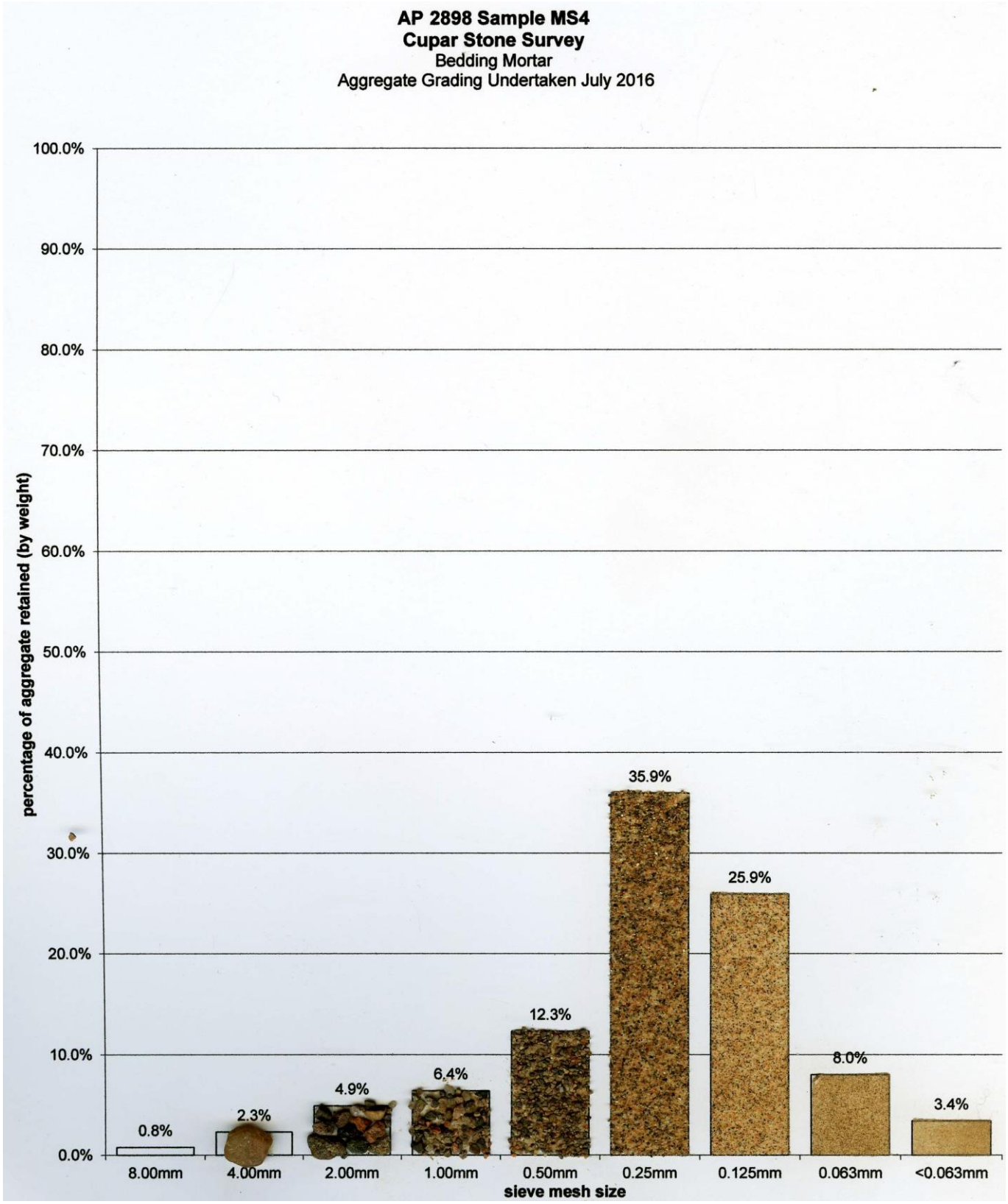
SIEVE PERFORATION SIZE*	AGGREGATE RETAINED (g)	UNDISSOLVED BINDER (%)	CORRECTED AGGREGATE WEIGHT (g)	% OF AGGREGATE	COMMENTS
8mm	0.78	0.00	0.78	0.80	Rounded fragments of quartz.
4mm	2.29	0.00	2.29	2.30	Rounded quartz grains and weathered stone.
2mm	4.86	0.00	4.86	4.90	Sub-angular to rounded quartz grains, weathered igneous rock and clay inclusions.
1mm	6.32	0.00	6.32	6.40	Same as above.
500µm	12.17	0.00	12.17	12.30	Same as above.
250µm	35.42	0.00	35.42	35.90	Same as above.
125µm	25.54	0.00	25.54	25.90	Same as above plus mica flakes.
63µm	7.90	0.00	7.90	8.00	Indiscernible.
< 63µm including filter residue	3.38	0.00	3.38	3.40	Indiscernible clay.

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

The aggregate isolated from this sample is retained from sieve mesh 8mm down, with the highest percentage of aggregate having been retrieved from sieve mesh size 0.25mm with 35.9%. It is moderately to poorly graded and predominantly medium grained sand that displays a negatively skewed uni-modal grain size distribution. The coarse fractions contain sub-angular to sub-rounded, sub-spherical grains of quartz and weathered mixed lithic fragments. The medium to fine grain size fractions comprise a higher relative proportion of quartz and feldspar grains, imparting the overall light buff colour to the sand. 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 Building Sand from Melville Gates Quarry (see aggregate profile below). This sand has been retained from sieve mesh 4mm down with the largest percentage of aggregate retained at sieve mesh size 0.25mm with 41.50%. This sand is moderately to poorly graded (due to the very high 0.25mm fraction) and predominantly medium grained, showing a distinctive uni-modal grain size distribution. It is slightly darker in colour to the analysed sample owing to the slightly darker stained quartz grains and higher proportion of black minerals/lithic fragments in the medium to coarse grain size fractions. It contains a lower proportion of coarse aggregate, very similar fines and a higher proportion of grains within the 0.25mm fraction. The sand show similar mineralogical and textural characteristics to the analysed sample, containing a majority of dark lithic fragments in the coarse fractions and buff quartz grains in the medium to fine fractions. Additionally, Melville Gates Quarry is located extremely close to Cupar, therefore providing locally sourced aggregate, which is likely representative of the original sands used within the mortars of Cupar.

An alternative aggregate match is 0/4mm Washed Concrete Sand from Snabe Quarry (see aggregate profile below). This sand has been retained from sieve mesh 4mm down with the largest percentage of aggregate retained at sieve mesh size 0.25mm with 30.8%. It is predominantly medium to coarse grained, moderately to well graded sand that shows a similar grain size distribution to the analysed sample. It contains a slightly higher proportion of coarse grained aggregate, which imparts a slightly darker overall colour to the sand. It shares similar textural and mineralogical characteristics to the analysed sample, comprises a mixture of sub-angular to sub-rounded dark lithic fragments and grey quartz grains.

Contact details for these quarries are listed below.

Angle Park Sand & Gravel Co. Ltd,	Tarmac,
Melville Gates Quarry,	Snabe Quarry
Ladybank,	Strathaven Road,
Cupar,	Drumclog,
Fife	South Lanarkshire
KY7 7RF	ML10 6QF
Tel: 01337 830 303	Tel: 01357 440 070

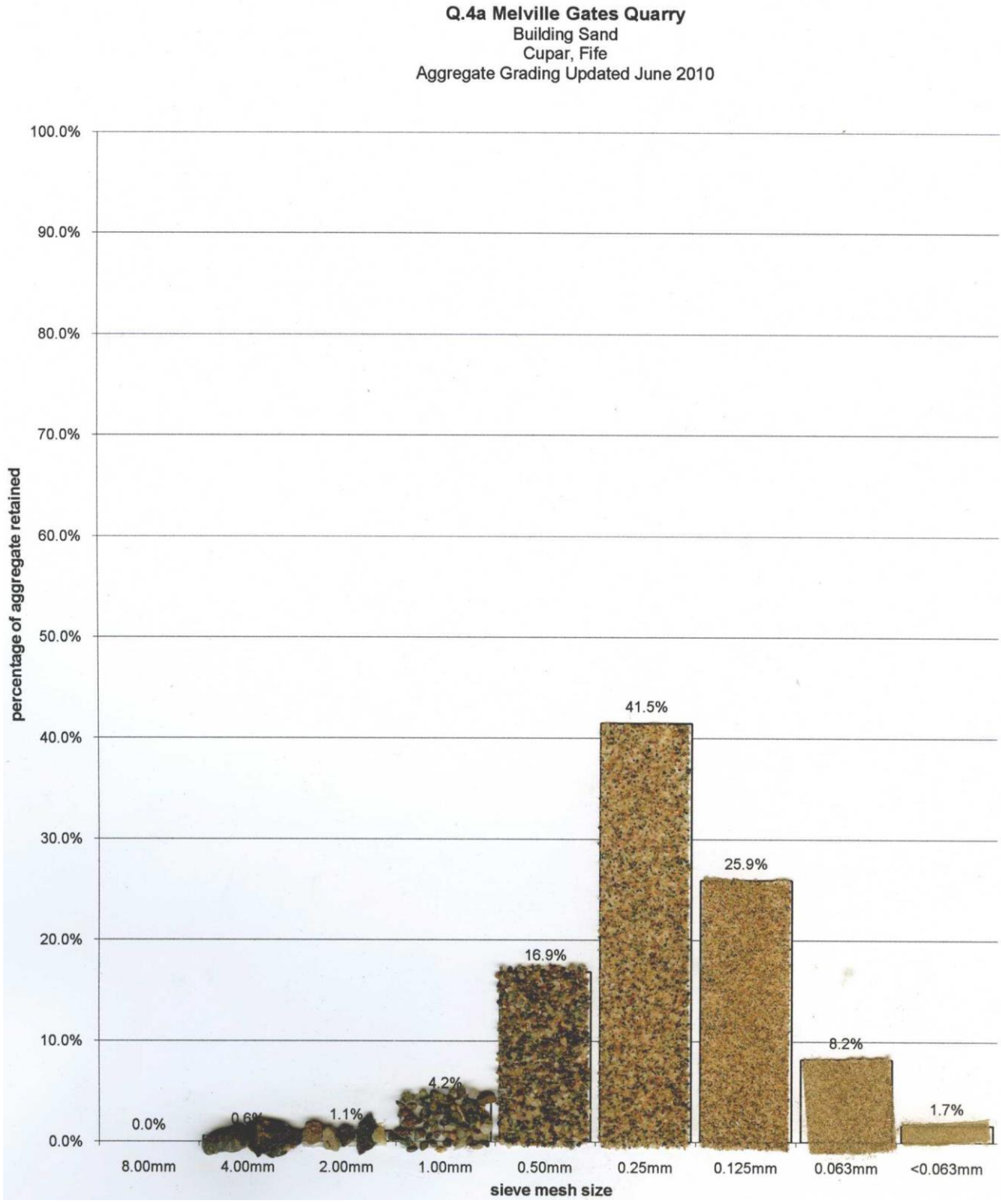
However, the named source(s) is/are not the only potentially suitable source(s) available, but is/are the closest, with respect to visual characteristics and physical properties, on the basis of the work carried out to date, on the sample submitted to examination.

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.

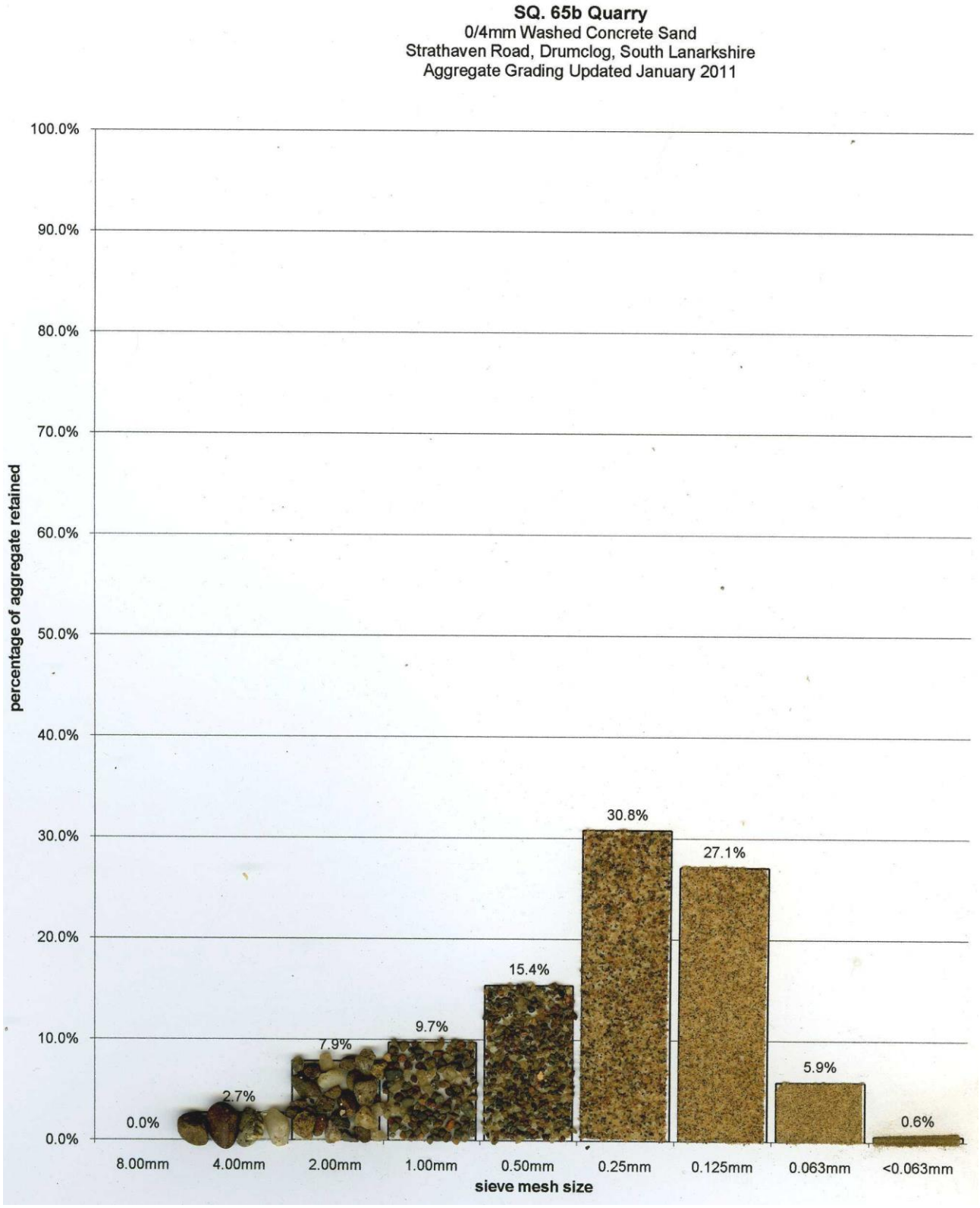
Quarries can change hands, open or close down with a relatively high frequency and therefore the source(s) identified above may become unavailable with no notice. If you are unable to obtain one of the above aggregates within 6 months of us completing this report then we will identify a new source free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



Aggregate Profile of an Alternate Matching Currently Available Aggregate: 0/4mm Washed Concrete Sand, Snabe 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	:	3.0

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 moderately hydraulic quicklime.

1 PART MODERATELY HYDRAULIC QUICKLIME	**:**	**4.4 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.

SCOTTISH LIME CENTRE TRUST

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Fife
KY11 3EN
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F: + 44 (0)1383 872744

MORTAR ANALYSIS REPORT

AP 2898
Cupar Stone Survey, Sand grading

Sample MS5

River Sand

SITE	River Sand from River Eden, Cupar
CLIENT	Fife Historic Buildings Trust
DATE SAMPLE RECEIVED	05/07/2016
ANALYSIS DATES	22/07/2016
CLIENT REQUIREMENTS	Aggregate Grading
CONDITION OF SAMPLE RECEIVED	The sample received consisted of wet river sand.

ANALYTICAL PROCEDURES

The selected sample of material was dried to a constant weight at 120ºC for 24 hours and then separated into separate batches and analysed for its void ratio and grading. Grading was undertaken using British Standard Sieves and following the BS EN 933-1:1997 standard for the physical testing of aggregates. The grain constituents of each grading interval were then analysed under binocular microscope in order to characterise their mineralogy and shape, and the full batch of mixed sand colour matched using the Munsell Soil Colour Charts.

RESULTS

Sample	Void Ratio (%)	Colour
MS5 River Sand	38.0	10YR 5/4 'yellowish brown' to 10YR 4/4 'dark yellowish brown'
Melville Gates Quarry Building Sand	38.9	5YR 5/4 'reddish brown'

AGGREGATE GRADING & CHARACTERISATION

MS5a: as received

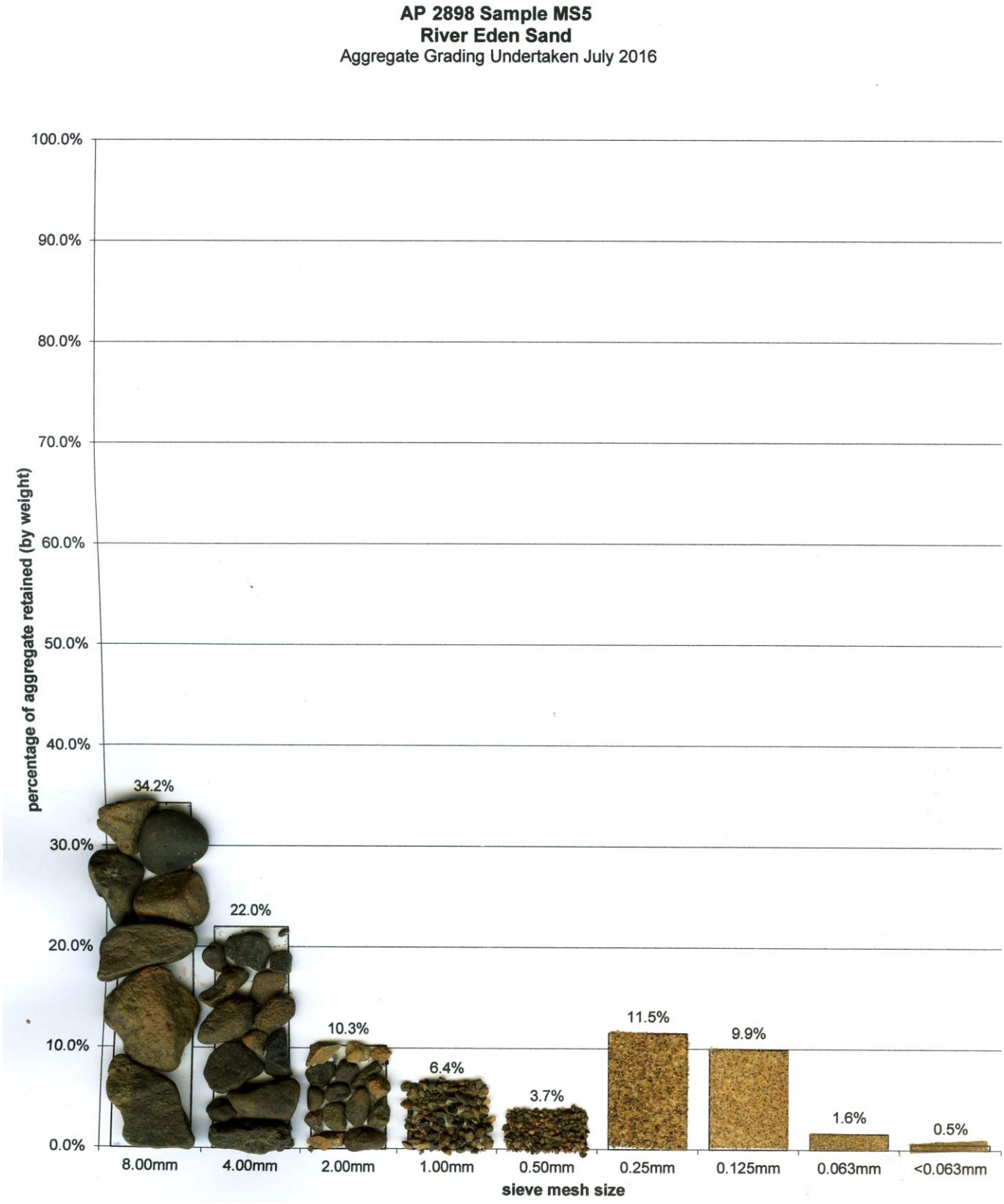
SIEVE PERFORATION SIZE*	AGGREGATE RETAINED (g)	% OF AGGREGATE	COMMENTS
8mm	186.20	34.20	Sub-rounded to well-rounded, elongate-spherical dark weathered crystalline rock – likely weathered basic igneous and metamorphic.
4mm	119.59	22.00	Generally sub-angular to rounded, but occasionally angular, ranging from elongate to spherical, mixed lithic fragments including fine to medium grained red and blonde sandstone. Basic igneous rock including vesicular basalt and mixed metamorphic rock. A low percentage of quartz and dark indiscernible minerals.
2mm	55.81	10.30	As above, but also including feldspar, mudstone and medium to coarse grain crystalline rock (possible granite).
1mm	34.84	6.40	As above. About 30% quartz and feldspar, 70% mixed lithic fragments.
500µm	19.92	3.70	Angular-rounded (generally sub-angular to sub-rounded), sub-spherical to spherical quartz and low percentage feldspar and 40-50% mixed lithic fragments (generally mixed finely crystalline igneous and mudstone).
250µm	62.64	11.50	Sub-angular to rounded sub-spherical to spherical quartz (90%) and 10% dark lithic fragments.
125µm	53.98	9.90	As above.
63µm	8.66	1.60	Indiscernible.
< 63µm	2.83	0.50	Indiscernible clay.

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

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



AGGREGATE GRADING & CHARACTERISATION

MS5b: corrected fractions

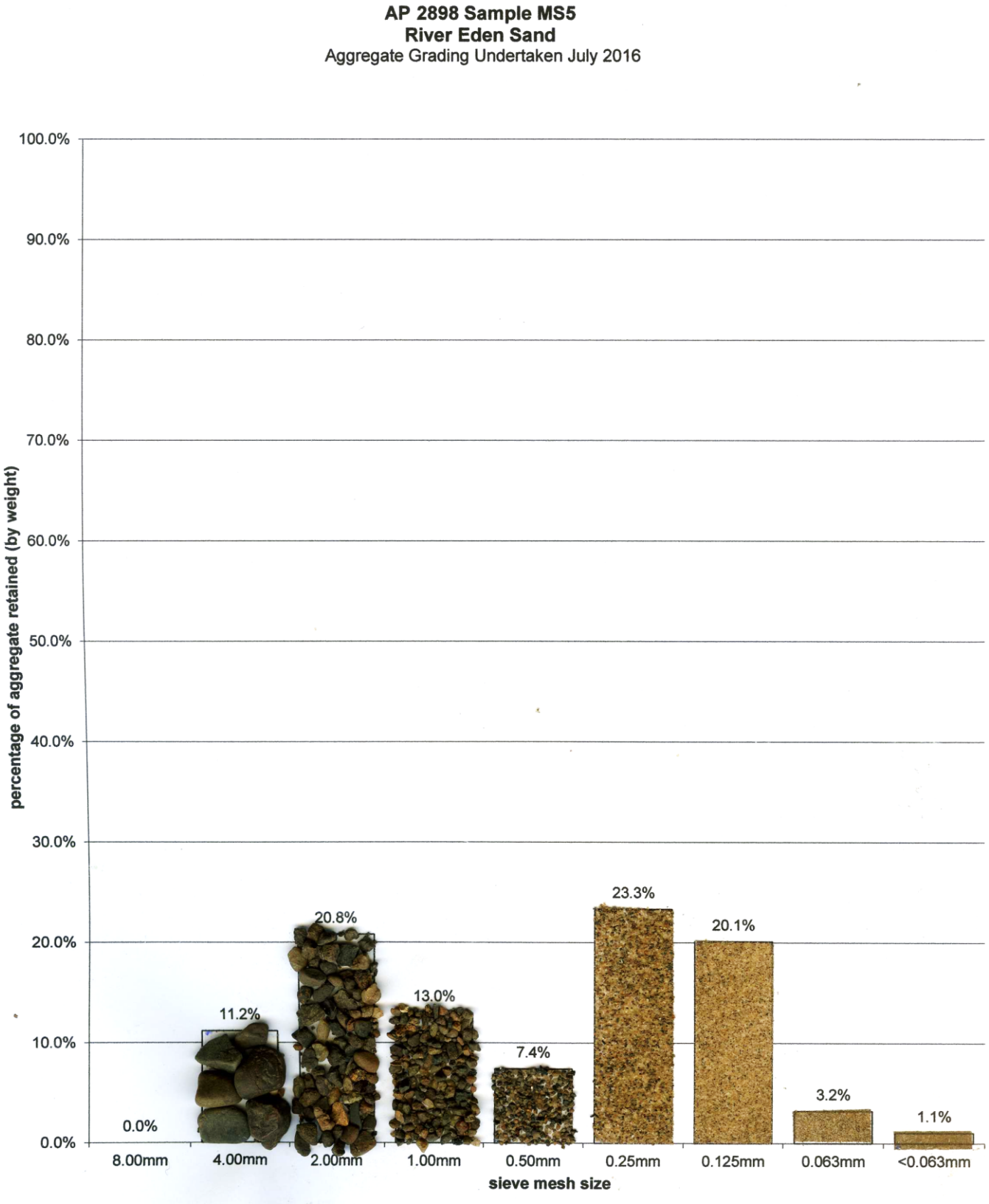
SIEVE PERFORATION SIZE*	AGGREGATE RETAINED (g)	% OF AGGREGATE	COMMENTS
8mm	0	0	
4mm	30.00	11.20	Generally sub-angular to rounded, but occasionally angular, ranging from elongate to spherical, mixed lithic fragments including fine to medium grained red and blonde sandstone. Basic igneous rock including vesicular basalt and mixed metamorphic rock. A low percentage of quartz and dark indiscernible minerals.
2mm	55.81	20.80	As above, but also including feldspar, mudstone and medium to coarse grain crystalline rock (possible granite).
1mm	34.84	13.00	As above. About 30% quartz and feldspar, 70% mixed lithic fragments.
500µm	19.92	7.40	Angular-rounded (generally sub-angular to sub-rounded), sub-spherical to spherical quartz and low percentage feldspar and 40-50% mixed lithic fragments (generally mixed finely crystalline igneous and mudstone).
250µm	62.64	23.30	Sub-angular to rounded sub-spherical to spherical quartz (90%) and 10% dark lithic fragments.
125µm	53.98	20.10	As above.
63µm	8.66	3.20	Indiscernible.
< 63µm	2.83	1.10	Indiscernible clay.

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

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



AGGREGATE GRADING & CHARACTERISATION

Building Sand from Melville Gates Quarry

SIEVE PERFORATION SIZE*	AGGREGATE RETAINED (g)	% OF AGGREGATE
8mm	0	0
4mm	0.55	0.60
2mm	1.00	1.10
1mm	3.95	4.2
500µm	16.00	16.90
250µm	39.35	41.50
125µm	24.60	25.90
63µm	7.80	8.20
< 63µm	1.60	1.70

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

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