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STONE ANALYSIS

& MATCHING REPORT

AP 2898
Cupar Stone and Slate Survey,
Freemason's Hall,
Cupar

Sample SS1

Sandstone Core

SITE	Freemason's Hall
CLIENT	Fife Historic Buildings Trust
DATE SAMPLE RECEIVED	07/07/2016
ANALYSIS/EXAMINATION DATES	23/08/2016
ANALYSIS, INTERPRETATION & REPORT BY	Dr Callum Graham and Roz Artis
CLIENT REQUIREMENTS	Stone Testing & Petrographic Examination for Stone Source Matching
STRUCTURE DATE	Unknown
STRUCTURE TYPE	Freemason's Hall and Scott's clothes shop
STONE TYPE	Blonde sandstone
LOCATION/ FUNCTION IN STRUCTURE	Ashlar building stone
CONDITION OF SAMPLE RECEIVED	The sample received consisted of one core of generally unweathered sandstone Size of largest piece = 44mm diameter x mm length

DETERMINATION OF STONE CHARACTERISTICS

Method of Examination & Test

A sample comprising of one core of relatively un-weathered sandstone was received for examination and determination of its properties. The stone had been cored from the corner of the Freemason's Hall and Scott's clothes shop at No 72-74 Bonnygate, Cupar (Plate 1 and 2) on the 3rd of June, 2016 by Mr Scott MacAskill, stonemason who was joined on site by Dr Callum Graham, Buildings Materials Analyst, with the sample submitted for examination to assist in identifying both a suitable source of replacement stone and the original source quarry of this stone.

Upon receipt in the laboratory the sample was examined with the aid of a stereo-binocular microscope at magnifications up to x 40. Following the initial examination sub-sample were prepared and submitted to a range of physical tests to determine the properties of the stone. In addition a slice was cut through one of the larger intact pieces of stone, with the specimen aligned such that the slice extended through the full thickness of the sample.

The slice was prepared for thin sectioning by washing the soiling from the sample, which was then dried to a constant weight prior to the vacuum impregnation of the sub-sample with an epoxy resin, to which a fluorescent blue dye had

been added. One side of the resin impregnated slice was polished and mounted onto a glass slide (50mm x 75mm), with the mounted sample ground and polished to give an approximate thickness of 30 microns.

The thin section was submitted to a microscopic examination, which was undertaken with the aid of an Olympus POS Polarised Light microscope, fitted with a digital camera, to permit recording of photomicrographs, some of which are included in this report, for reference purposes.

The presence of dyed epoxy resin within the sample enables an assessment of the stone fabric to be made, including an assessment of the visual porosity, void size and distribution along with the evaluation of any crack patterns and physical depositional features apparent in the sample under examination. The sample was examined following standard procedures, and in general accordance with BS EN 12407:2000; Natural Stone Test Methods.

In addition to carrying out a detailed visual and microscopic examination, the physical properties of the stone were also measured. The water absorption was determined by the methods of BS EN 13755:2008, the capillary coefficient by the methods of BS EN 1925:1999, and the apparent density and open porosity determined by the methods of BS EN 1936:1999.

This report presents observations from the microscopic examination along with the results of the physical tests carried out.

The purpose of the examination and testing was to permit a comparison between the sample received and the properties of stone from any visually similar stone, to confirm if these would be suitable matches for the stone submitted.

Plate 1. The sandstone sample was cored from the area highlighted by the red chalk circle. This area was representative of sample 4-type sandstone and was cored from a section of the stone that wasn't directly street facing.

Plate 2. View of the backfilled cored area of the stone.

MACROSCOPIC EXAMINATION

The fresh dry stone had a distinct brown, Fe-mottled appearance and was found to be 10YR 7/6 – 7/7 'yellow' to 10YR 6/6 – 6/7 'brownish yellow' when assessed against the Munsell Soil Colour Charts. It is generally fine to medium grained and predominantly uniform, displaying occasional coarse grained beds, narrow bedding planes, thin discontinuous laminations and cross-beds when observed in-situ within the building. It is hard, cohesive and generally highly compacted sandstone, comprised of mainly sub-rounded to rounded and occasional angular quartz grains, dark indiscernible lithic fragments and minerals and a low proportion of muscovite mica with evidence of point and line contacts in hand specimen. The stone is cemented by a white frosted calcite cement, as indicated by a strong reaction with 10% HCl acid. The main stone matrix is characterised by an orange to brown, uniformly mottled appearance, which is imparted on the stone by Fe-rich clay inclusions and Fe-nodules; occasionally concentrated within narrow bedding planes, which measure up-to 1.5mm in thickness.

Plate 3. Side view of the sandstone core post thin section preparation. The thin section was cut parallel to the length of the core.

Plate 4. End view of the sandstone core post thin section preparation. Distinct Fe-oxide and clay mottling is present, while slight bedding alignment is visible towards the top of the core.

MICROSCOPIC THIN SECTION EXAMINATION

Texture: The stone displays a generally uniform fabric in thin section, with well distributed Fe-oxides and clays throughout and with no distinct spatial concentration or distribution of specific minerals anywhere within the thin section. Narrow diffused bedding planes were evidence in hand specimen, however these could not be distinguished under the microscope. There is a similar alignment of muscovite mica grains throughout the thickness of the sample, however these are in such small numbers as to not significantly influence the visual appearance or moisture transportation pathways in the stone. It is predominantly fine grained, relatively poorly sorted sandstone with grains ranging in size from 70µm to 300µm, and showing a modal grain size value of 140µm, however on average there is a greater relative proportion of coarse than fine grains. The stone is relatively texturally immature, with most grains ranging in shape from angular to sub-rounded and elongate to spherical (average of sub-angular and sub-elongate to sub-spherical). Additionally, there is evidence of small regions characterised by texturally mature, medium to coarse sized grains that are free from authigenic pore filling minerals, with a diffuse grain-size gradient existing between these areas and the remaining stone matrix. Grains are primarily bound by spary calcite cement, with kaolinite and Fe-oxides providing important secondary cements throughout the stone. Grains are moderately well compacted, displaying a majority of point and line contacts, with minor concave-convex contacts present.

Mineralogy: The stone contains a detrital framework mineralogy comprised predominantly of quartz grains, which are found as mainly monocrystalline, unstrained varieties, with minor amounts of polycrystalline and strained varieties found throughout. There is a relatively low proportion of generally unaltered feldspar grains, in the form of plagioclase and microcline, muscovite mica, plus lithic fragments in the form of basic igneous rock. Kaolinite, calcite, opaque minerals (such as Fe-oxides) and other indeterminate clays provide the most abundant cementing authigenic products; which together provide a major proportion of the total stone mineralogical content. Authigenic minerals are those that formed within the rock (either during diagensis or in-situ within the building) after the original sediment was deposited. These commonly form the cementing minerals in the stone, which tend to block and lower the effective porosity. Authigenic clays are generally well dispersed throughout the stone, with the mobilisation of Fe-oxide from Fe-bearing minerals concentrating within layers and isolated regions of the stone imparting the distinct orange mottled colour and texture, and defining the faint diffuse bedding planes.

Detrital Minerals: Quartz, feldspar, muscovite, igneous lithic fragments
Authigenic Minerals: Calcite, Fe-oxide, kaolinite

Porosity: The stone contains a moderate visual porosity and moderate to low permeability owing to the high proportion of pore filling authigenic minerals and intergranular cement. Pores range in their shape, size and connectivity as a consequence of authigenic processes, which provide the stone with a porosity and permeability that varies spatially throughout its thickness. Most pores are primary and intergranular. Physical testing shows that the stone contains an effective and total porosity of 16.7% and 19.5%, respectively, with water absorption, saturation and capillary coefficient values of 6.33%, 0.84 and 43.3gm^2/s, respectively; all of which are classified as moderate to high for sandstones.

Photomicrographs:

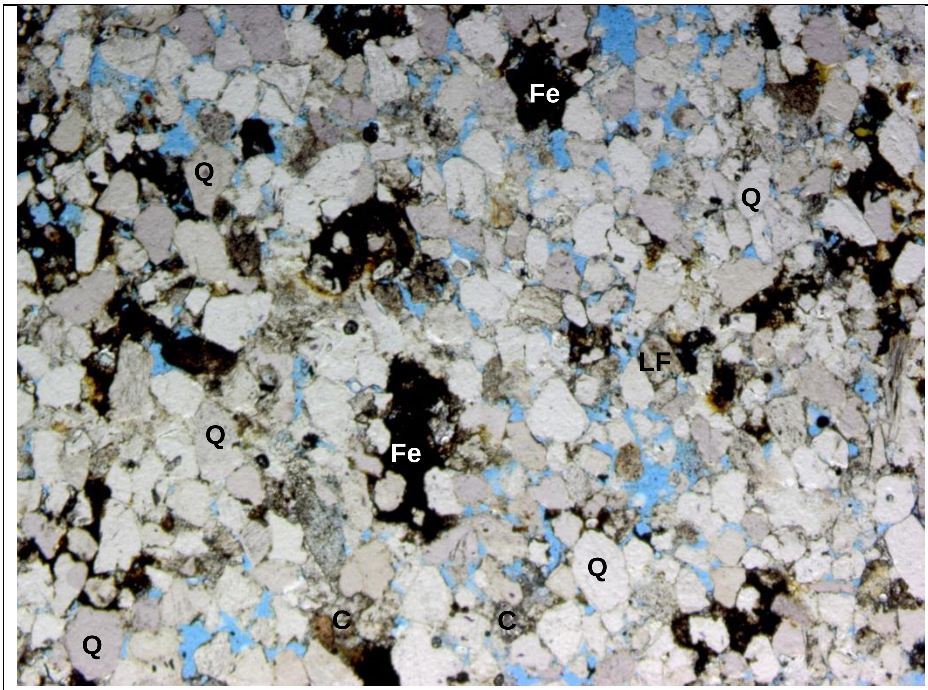


Plate 5. Thin section of the sample under plane polarised light. Pore spaces are highlighted in blue, while areas of very light blue indicate pore filling clays that have absorbed some of the blue dye. The stone is predominantly fine-grained, with most grains being sub-angular to sub-rounded and generally sub-spherical in shape. The high proportion of Fe-oxides and Fe-stained clays provide the stone with its distinctive orange-brown mottled/speckled appearance in hand specimen. Q: quartz, LF: lithic fragment, C: calcite, Fe: Fe-oxide.

Field of view is 3.3mm.

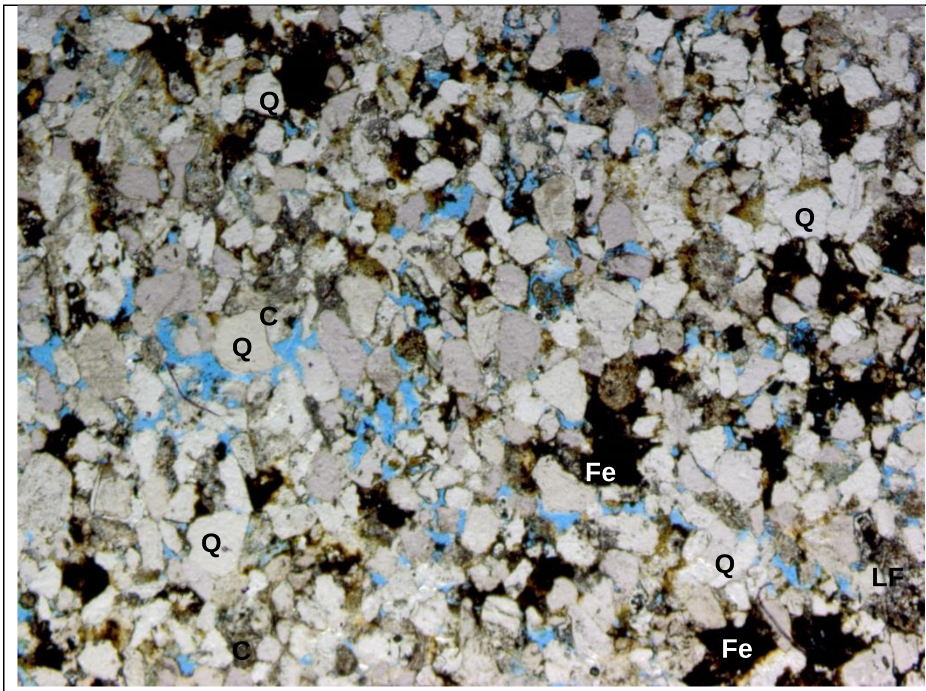


Plate 6. Thin section of the sample under plane polarised light. Pore spaces are highlighted in blue, while areas of very light blue indicate pore filling clays that have absorbed some of the blue dye. The stone contains a high proportion of authigenic minerals (up-to 15% of the stone), in the form of Fe-oxides, clays and calcite cement. This significantly lowers the effective porosity of the stone. The grains are moderately to well compacted, with a mixture of point and line contacts. Q: quartz, LF: lithic fragment, C: calcite, Fe: Fe-oxide.

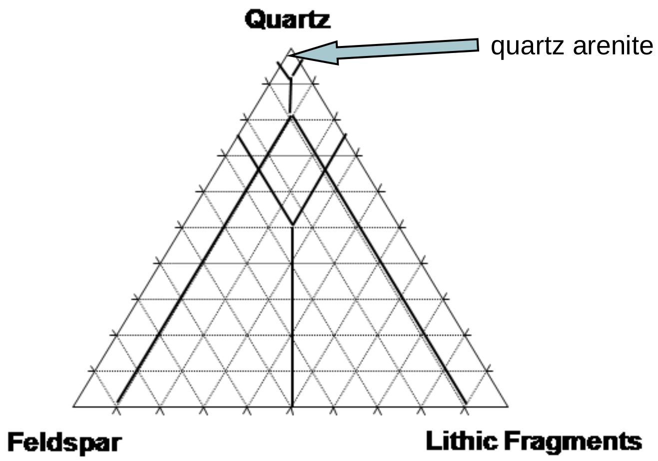
Field of view is 3.3mm.

Point Count Data:

Components	Total (%)	Q/F/L (quartz/feldspar/lithic % proportion)
Detrital Components		
Quartz	80	96.4
Feldspar	1	1.2
Lithic fragments	2	2.4
Detrital Clay	2	
Muscovite Mica	<0.5	
Authigenic Minerals		
Quartz Overgrowths	0	
Indeterminate Clay	5	
Calcite	4.5	
Opaque Minerals	5.5	
Total	100	100
Porosity	16 – 19%	

Table 1: Results of modal analysis on the sample received.

Sandstone Classification: This stone is classified using the McBride (1963) classification scheme, as a quartz arenite. The stone contains a majority of quartz grains, a feldspar and lithic fragment content lower than 5%, respectively.



Classification of sandstone after McBride (1963)[1]

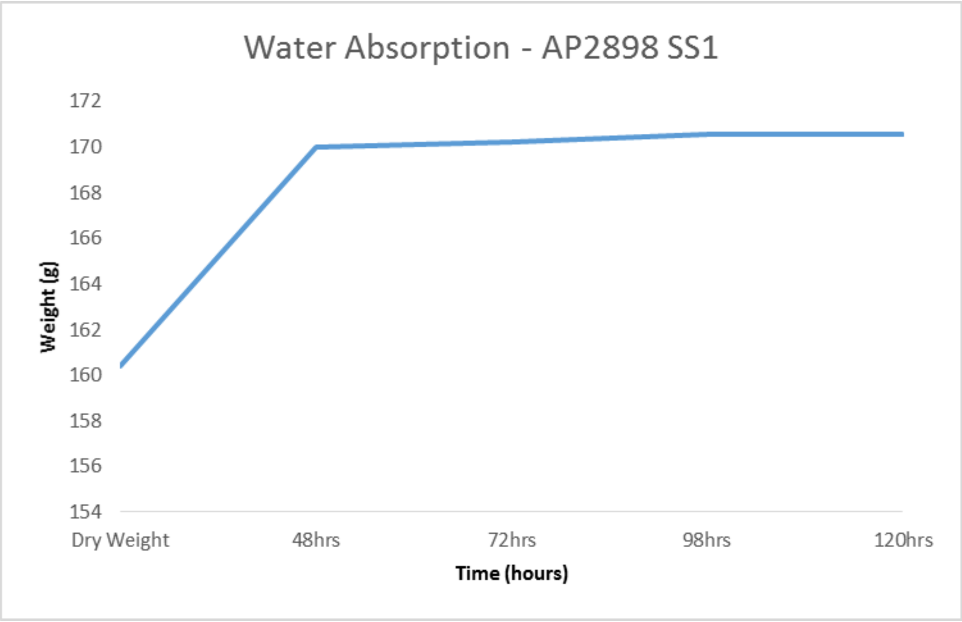
[1] **McBride, E. F. (1963), A classification of common sandstones. Journal of Sedimentary Petrology 33, 664-669**

PHYSICAL PROPERTIES

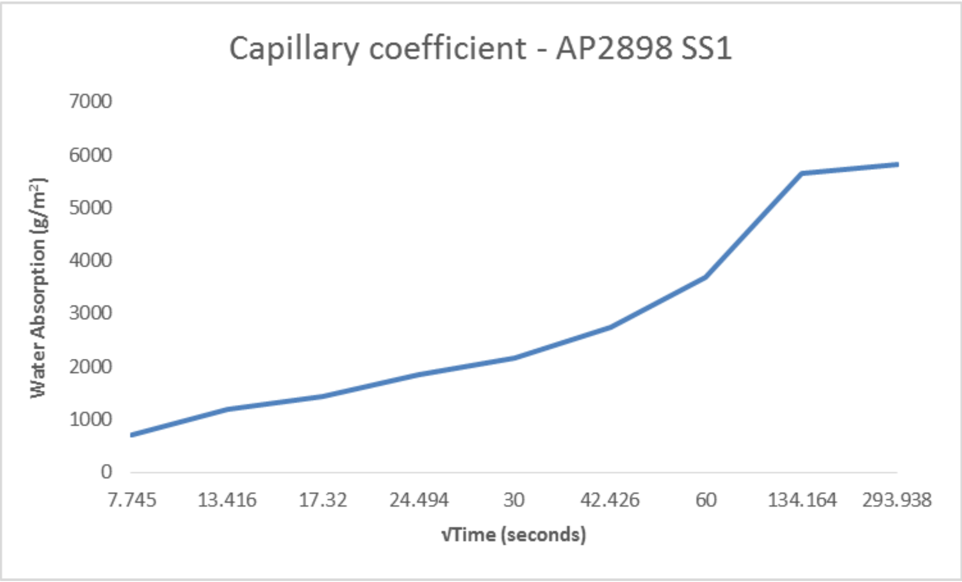
The results obtained from the physical tests are reproduced below, along with the data from stone that may be considered as potential replacements. The data reported for the potential sources was obtained from that held in the laboratory along with data obtained from a range of stone suppliers.

Total (%)	Analysed sample	High Nick sandstone	Blaxter sandstone	Drumhead sandstone	Scotch Buff sandstone
Water Absorption %	6.33	6.00	6.14	6.60	7.02
Apparent Density (Kg/m^{-3})	2456	2140	2069	2150	2115
Total Porosity %	16.7 (effective) – 19.5 (total)	19.7 (open/effective)	13 (effective) – 18 (total)	14 - 19 (open/effective)	14 (effective) – 18 (total)
Saturation Coefficient	0.84	-	0.73	0.72	0.77
Capillary Coefficient (g/m^2/s)	43.3	72	52	-	134
Permeability (mD)	Moderate - High	Moderate - High	~46 (low)	High	~50 (low)
Compressive Strength (MPa)	-	44	38 - 55	74 - 89	75
Acid Immersion Test	High Reaction	Pass	Pass	Pass	Pass

Table 2: Physical properties of sample received and possible matches.



Water Absorption graph for AP2898 SS1



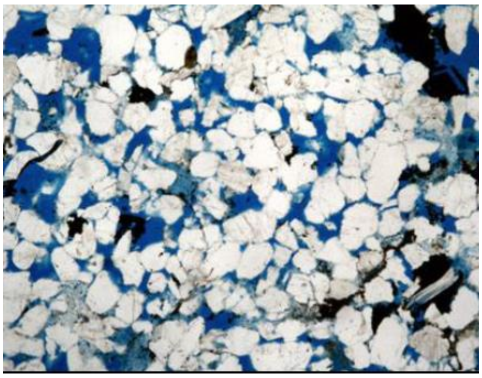
Capillary coefficient graph for AP2898 SS1

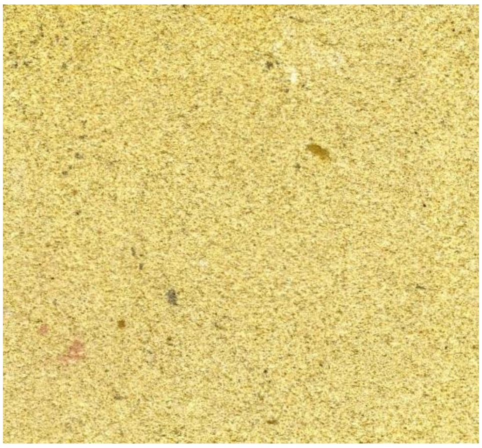
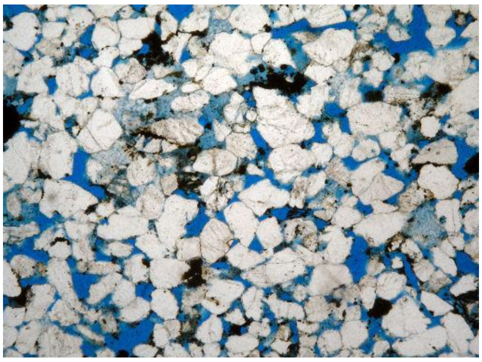
COMMENT

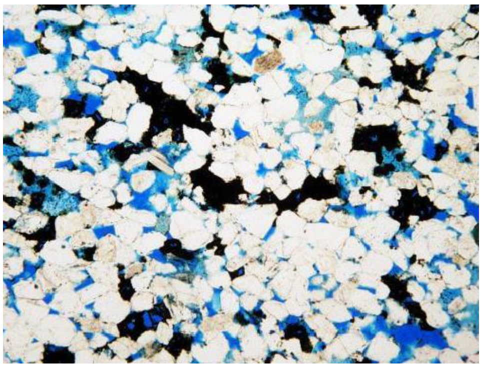
Sample AP2989 SS1 from the Freemason’s Hall at number 72-74 Bonnygate, Cupar is a relatively uniform to slightly diffuse bedded, mineralogically mature, texturally immature, poorly graded quartz arenite sandstone, containing a majority of fine sized, sub-angular to sub-rounded, sub-elongate to sub-spherical quartz grains and lower amounts of feldspar, lithic fragments and muscovite mica comprising the main detrital sandstone matrix. The stone is relatively ‘dirty’, containing a high proportion of authigenic minerals in the form of Fe-oxides and a mixture of clays. This high content of leached Fe-oxide provides the stone with its distinct orange mottled appearance, while the overall proportion of authigenic minerals has likely lowered the effective permeability of the stone, leading to relatively low capillary coefficient values; however the total pore network has likely retained most of its capacity, with measured porosity, water absorption and saturation coefficient values moderate to high for sandstones.

In regards to choosing a suitable matching stone, it must be remembered that because stone is a natural material, it can vary in colour and appearance both over time and spatially within a quarry. It is therefore important to check the colour and appearance/obtain representative samples of the stone with the quarry operator in advance of works. Furthermore, each stone type will vary in its weathering behaviour over a period of years in accordance to weather conditions, the stone extraction process, and it’s functionally within a building. This report is therefore not an endorsement of stone quality, nor does it ensure that the listed matching stones will weather in harmony with the original stone. The matched samples are based on thin section petrographic and physical stone testing analysis, taking into account colour, texture, mineralogy, porosity and permeability.

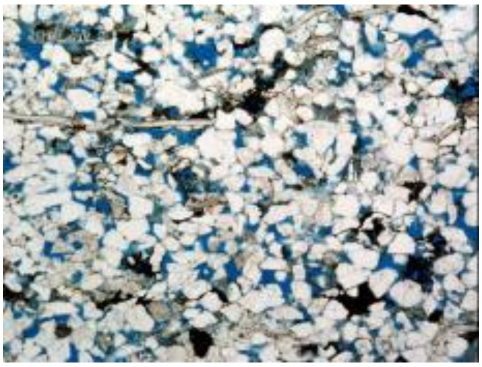
The contact addresses for these quarries are as follows:

High Nick Sandstone **Colour:** Buff coloured, with iron spots and iron-oxide banding. **Fabric:** Mainly uniform, with some aligned grains showing a slight orientation. **Grain size:** Medium grained. **Permeability:** Moderate to high. **Distinctive features:** There is evidence of iron-rich nodules in some stone that is extracted from the quarry. **Comments:** The stone contains distinctive iron-oxide nodules that vary in size from mm's to cm's in diameter. Iron-oxide banding is also common throughout.	**Stancliffe Stone.** **Keypoint Office Village,** **Keys Road,** **Nixs Hill Industrial Estate,** **Alfreton,** **Derbyshire,** **DE55 7FQ** **Tel: 0845 302 0702**  

Blaxter Sandstone	Dunhouse Natural Stone
Colour: Buff **Fabric:** Uniform (with alignment of mica grains occasionally indicating bedding). **Grain size:** Fine to medium grained. **Permeability:** Moderate to High but occasionally low. **Distinctive features:** Blaxter sandstone can commonly show distinct Fe-staining; as either individual nodules or as bands within the stone, and also distinct orange-brown clay inclusions. **Comments:** This stone contains a higher proportion of distinct muscovite grains than the analysed sample.	**Dunhouse Quarry Ltd,** **Darlington,** **County Durham,** **DL2 3QU** **Tel: 01833 660 208**  

Drumhead sandstone **Colour:** Very light buff to buff. **Fabric:** Light buff is uniform, while more buff varieties are irregularly laminated. **Grain size:** Fine to medium grained varieties. **Permeability:** High **Distinctive features:** Occasional Fe-oxide staining. **Comments:** The most buff and laminated varieties would provide the best aesthetic match to the analysed sample; this would be stone quarried from the upper most beds in the quarry.	**David Graham,** **Drumhead Sandstone Ltd,** **Denovan Mains,** **Stirlingshire,** **FK6 6GT** **Tel: 07967 799 253** 

<table>
<tr>
<td>
Scotch Buff Sandstone
Colour: Buff to cream coloured with pervasive brown speckling, occasional brown lines and occasional small to large dark coloured patches.
Fabric: Generally uniform, with some alignment of mica flakes.
Grain Size: Medium grained
Permeability: Moderate to high
Distinctive features: None
Comments: This stone is more buff-coloured than fresh pieces of the analysed sample, but would provide a better visual match to the weathered surfaces of the stone.
</td>
<td>
Real Stone Ltd,
Wingerworth,
Chesterfield,
Derbyshire,
S42 6RG
Tel: 01246 270 244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Sandstone is a natural material and by the nature of its origin, can be extremely variable within and between quarry faces. Ideally, a considered match should be examined in the same manner as the stone to be replaced. Archive sandstone samples of possible quarries may not be equivalent to the currently extracted product.

Some thin section images of replacement sandstones were taken from other British Geological Survey stone reports, as referenced below, with full copyright permission granted for this use. Hand specimen images of replacement sandstones were made in the SLCT Building and Advisory Service lab from representative samples of each sandstone type.

British Geological Survey GeoReport: GR_209056
British Geological Survey GeoReport: GR_210536

British Geological Survey GeoReport: GR_201194/1

As with all quarries the actual properties of the stone available will be dependent on the face, and the bed, being worked at any given time and it is, therefore, always prudent to obtain samples of the current production for comparison with the stone to be matched, prior to ordering supplies for a particular project/application.

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STONE ANALYSIS

& MATCHING REPORT

AP 2898
Cupar Stone and Slate Survey,
Stephen Gethins MP Office,
Cupar

Sample SS2

Sandstone Core

SITE	Stephen Gethins MP Office, Number 68 Bonnygate.
CLIENT	Fife Historic Buildings Trust
DATE SAMPLE RECEIVED	07/07/2016
ANALYSIS/EXAMINATION DATES	23/08/2016
ANALYSIS, INTERPRETATION & REPORT BY	Dr Callum Graham and Roz Artis
CLIENT REQUIREMENTS	Stone Testing & Petrographic Examination for Stone Source Matching
STRUCTURE DATE	Unknown
STRUCTURE TYPE	Offices
STONE TYPE	Blonde sandstone
LOCATION/ FUNCTION IN STRUCTURE	Ashlar building stone
CONDITION OF SAMPLE RECEIVED	The sample received consisted of one core of generally unweathered sandstone Size of largest piece = 44mm diameter x mm length

DETERMINATION OF STONE CHARACTERISTICS

Method of Examination & Test

A sample comprising of one core of relatively un-weathered sandstone was received for examination and determination of its properties. The stone had been cored from the corner Stephen Gethins MP Office at number 68, Bonnygate, Cupar (Plate 1 and 2) on the 3rd of June, 2016 by Mr Scott MacAskill, stonemason who was joined on site by Dr Callum Graham, Buildings Materials Analyst, with the sample submitted for examination to assist in identifying both a suitable source of replacement stone and the original source quarry of this stone.

Upon receipt in the laboratory the sample was examined with the aid of a stereo-binocular microscope at magnifications up to x 40. Following the initial examination sub-sample were prepared and submitted to a range of physical tests to determine the properties of the stone. In addition a slice was cut through one of the larger intact pieces of stone, with the specimen aligned such that the slice extended through the full thickness of the sample.

The slice was prepared for thin sectioning by washing the soiling from the sample, which was then dried to a constant weight prior to the vacuum impregnation of the sub-sample with an epoxy resin, to which a fluorescent blue dye had

been added. One side of the resin impregnated slice was polished and mounted onto a glass slide (50mm x 75mm), with the mounted sample ground and polished to give an approximate thickness of 30 microns.

The thin section was submitted to a microscopic examination, which was undertaken with the aid of an Olympus POS Polarised Light microscope, fitted with a digital camera, to permit recording of photomicrographs, some of which are included in this report, for reference purposes.

The presence of dyed epoxy resin within the sample enables an assessment of the stone fabric to be made, including an assessment of the visual porosity, void size and distribution along with the evaluation of any crack patterns and physical depositional features apparent in the sample under examination. The sample was examined following standard procedures, and in general accordance with BS EN 12407:2000; Natural Stone Test Methods.

In addition to carrying out a detailed visual and microscopic examination, the physical properties of the stone were also measured. The water absorption was determined by the methods of BS EN 13755:2008, the capillary coefficient by the methods of BS EN 1925:1999, and the apparent density and open porosity determined by the methods of BS EN 1936:1999.

This report presents observations from the microscopic examination along with the results of the physical tests carried out.

The purpose of the examination and testing was to permit a comparison between the sample received and the properties of stone from any visually similar stone, to confirm if these would be suitable matches for the stone submitted.

Plate 1. Image of the cored sandstone before removal from the building. This area was representative of sample 4-type sandstone and was cored from a section of the stone that wasn't directly street facing.

MACROSCOPIC EXAMINATION

The fresh dry stone has a distinct brown, Fe-mottled appearance and was found to be 10YR 7/6 – 7/7 ‘yellow’ to 10YR 6/6 – 6/7 ‘brownish yellow’ when assessed against the Munsell Soil Colour Charts. It is generally fine to medium grained and predominantly uniform, displaying occasional coarse grained beds, narrow bedding planes, thin discontinuous laminations and cross-beds when observed in-situ within the building. It is hard, cohesive and generally highly compacted sandstone, comprised of mainly sub-rounded to rounded and occasional angular quartz grains, dark indiscernible lithic fragments and minerals and a low proportion of muscovite mica with evidence of point and line contacts in hand specimen. The stone is cemented by a white frosted calcite cement, as indicated by a moderate reaction with 10% HCl acid. The main stone matrix is characterised by an orange to brown, uniformly mottled appearance, which is imparted on the stone by Fe-rich clay inclusions and Fe-nodules; occasionally concentrated within narrow bedding planes, which measure up-to 1mm in thickness. This sample is very similar to that of sample SS1, but was slightly more coarse-grained when analysed within the building. It represents sandstone type S5, which contains a similar matrix to type S3, and occasionally type S4, but with less coarse grained layers and a higher relative proportion of cross-bedding and narrow laminations in relation to type S3 and S4.

Plate 2. Side view of the sandstone core post thin section preparation. The thin section was cut parallel to the length of the core.

Plate 3. End view of the sandstone core post thin section preparation. Distinct Fe-oxide and clay mottling is present, while slight bedding alignment is visible towards the centre of the core. The alignment of narrow and discontinuous layers indicates that the stone was edge bedded within the building; a common observation throughout most buildings in Cupar.

MICROSCOPIC THIN SECTION EXAMINATION

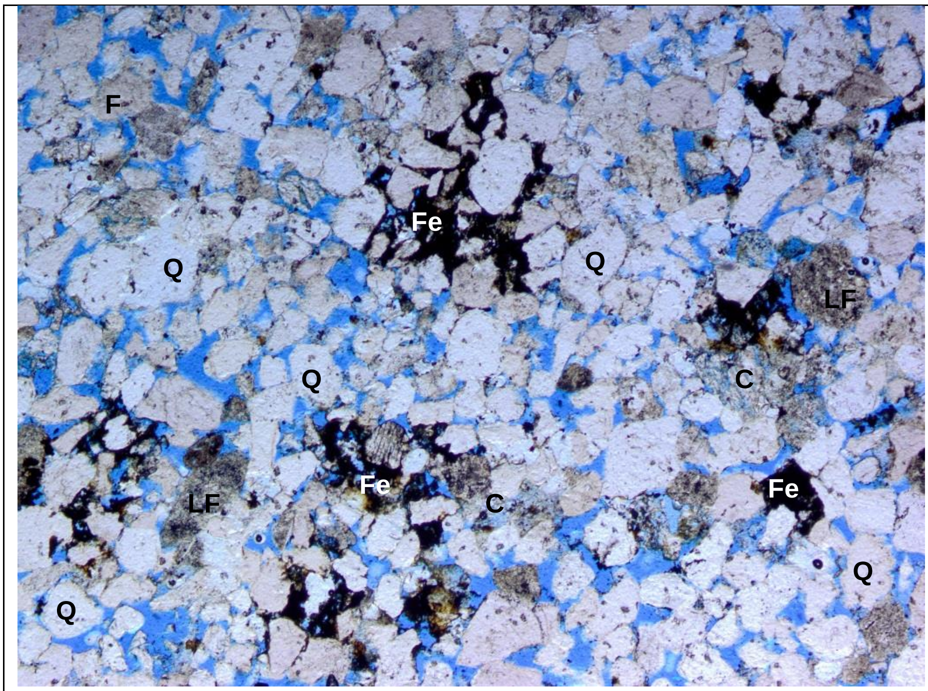
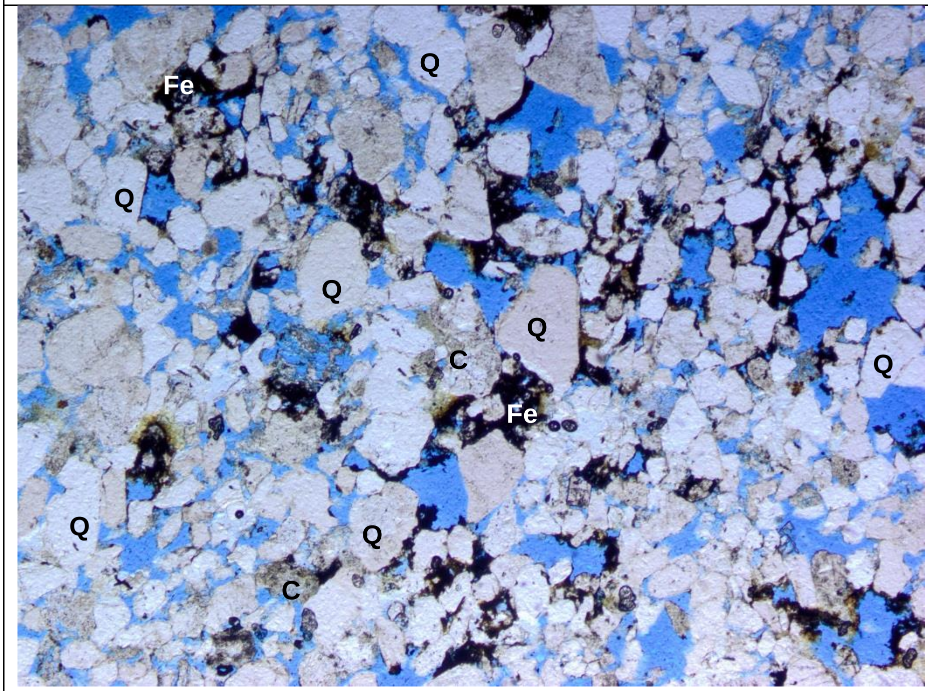
Texture: The stone displays a generally uniform fabric in thin section, with some evidence existing of undulating Fe-oxide and clay-rich layers as well as infrequent and discontinuous fine and coarse grained layers. Narrow diffused bedding planes were evidence in hand specimen, however these could not be accurately distinguished under the microscope. There is a similar alignment of muscovite mica grains throughout the thickness of the sample, however these are in such small numbers as to not significantly influence the visual appearance or moisture transportation pathways in the stone. It is predominantly fine to medium grained, relatively poorly sorted sandstone with grains ranging in size from 60µm to 440µm, and showing a modal grain size value of ~140µm, however on average there is a greater relative proportion of fine than coarse grains. The stone is relatively texturally immature, with most grains ranging in shape from angular to sub-rounded and elongate to spherical (average of sub-angular and sub-elongate to sub-spherical). On average, the smallest grains tend to be more angular, with the coarse grains more rounded in relation to the average grain shape. Additionally, there is evidence of small regions characterised by texturally mature, generally poorly compacted medium to coarse sized and small sized grains, respectively, that are free from authigenic pore filling minerals, with a diffuse grain-size gradient existing between these areas and the remaining stone matrix; these areas are more common and prominent than in sample SS1. Grains are primarily bound by spary calcite silica cement, with the latter found as narrow to thick epitaxial quartz overgrowths that partially to fully enclose grains, and occasionally as small deposits located in narrow pore throats. Kaolinite and Fe-oxides provide additional secondary cements throughout the stone. Grains are moderately to well compacted in regions, displaying a majority of point and line contacts, with lower proportions of concave-convex contacts and minor proportions of dissolution and sutured contacts present.

Mineralogy: The stone contains a detrital framework mineralogy comprised predominantly of quartz grains, which are found as mainly monocrystalline, unstrained varieties, with minor amounts of polycrystalline and strained varieties found throughout. There is a relatively low proportion of generally unaltered feldspar grains, in the form of plagioclase and microcline, muscovite mica, plus lithic fragments in the form of fine-grained sandstone, basic igneous and foliated metamorphic rock. Kaolinite, calcite, opaque minerals (such as Fe-oxides) and other indeterminate clays provide the most abundant cementing authigenic products; which together provide a major proportion of the total stone mineralogical content. Authigenic minerals are those that formed within the rock (either during diagensis or in-situ within the building) after the original sediment was deposited. These commonly form the cementing minerals in the stone, which tend to block and lower the effective porosity. Authigenic clays are generally well dispersed throughout the stone, with the mobilisation of Fe-oxide from Fe-bearing minerals concentrating within layers and isolated regions of the stone imparting the distinct orange mottled colour and texture, and defining the faint diffuse bedding planes.

Detrital Minerals: Quartz, feldspar, muscovite, igneous lithic fragments
Authigenic Minerals: Calcite, quartz overgrowths, Fe-oxide, kaolinite

Porosity: The stone contains a moderate to high visual porosity and moderate to high permeability. Pores range in their shape, size and connectivity as a consequence of authigenic processes, which provide the stone with a porosity and permeability that varies spatially throughout its thickness. Regions characterised by a well sorted and more organised grain compaction (both fine and coarse grained areas) predominantly display a more open and connected pore structure, owing to this organised grain compaction and lower proportion of authigenic minerals. Most pores throughout the stone are primary and intergranular. Physical testing shows that the stone contains an effective and open porosity of 17.5% and 20.4%, respectively, with water absorption, saturation and capillary coefficient values of 7.14%, 0.85 and 135gm^2/s, respectively; all of which are classified as generally high for sandstones.

Photomicrographs:

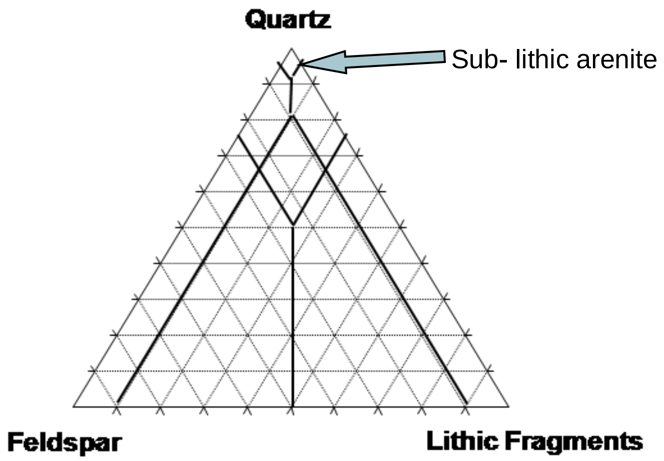
	Plate 4. Thin section of the sample under plane polarised light. Pore spaces are highlighted in blue, while areas of very light blue indicate pore filling clays that have absorbed some of the blue dye. The stone is predominantly fine grained and comprised of a majority of sub-rounded, sub-spherical quartz grains, lithic fragments and authigenic minerals, which contribute 15% of the overall stone mineralogy. Q: quartz, F: feldspar LF: lithic fragment, C: calcite, Fe: Fe-oxide. Field of view is 3.3mm.
	Plate 5. Thin section of the sample under plane polarised light. Pore spaces are highlighted in blue, while areas of very light blue indicate pore filling clays that have absorbed some of the blue dye. The stone contains a relatively high open porosity, comprised of primary intergranular pores and larger secondary mouldic pores where unstable grains have undergone dissolution. Q: quartz, LF: lithic fragment, C: calcite, Fe: Fe-oxide. Field of view is 3.3mm.

Point Count Data:

Components	Total (%)	Q/F/L (quartz/feldspar/lithic % proportion)
Detrital Components		
Quartz	77.5	94
Feldspar	1	1
Lithic fragments	4	5
Detrital Clay	1	
Muscovite Mica	<0.2	
Authigenic Minerals		
Quartz Overgrowths	1.5	
Indeterminate Clay	4.5	
Calcite	2	
Opaque Minerals	8.5	
Total	100	100
Porosity	17.5 – 20.4	

Table 3: Results of modal analysis on the sample received.

Sandstone Classification: This stone is classified using the McBride (1963) classification scheme, as a sub-lithic arenite. The stone contains a majority of quartz grains, a feldspar content of 2% and a lithic fragment content of 5%.



Classification of sandstone after McBride (1963)[1]

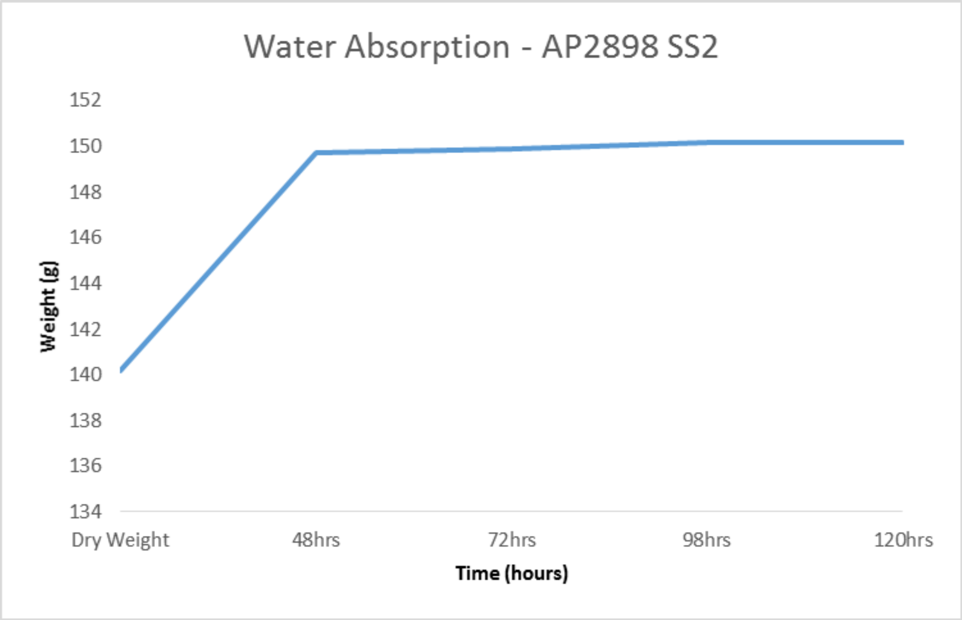
[1] **McBride, E. F. (1963), A classification of common sandstones. Journal of Sedimentary Petrology 33, 664-669**

PHYSICAL PROPERTIES

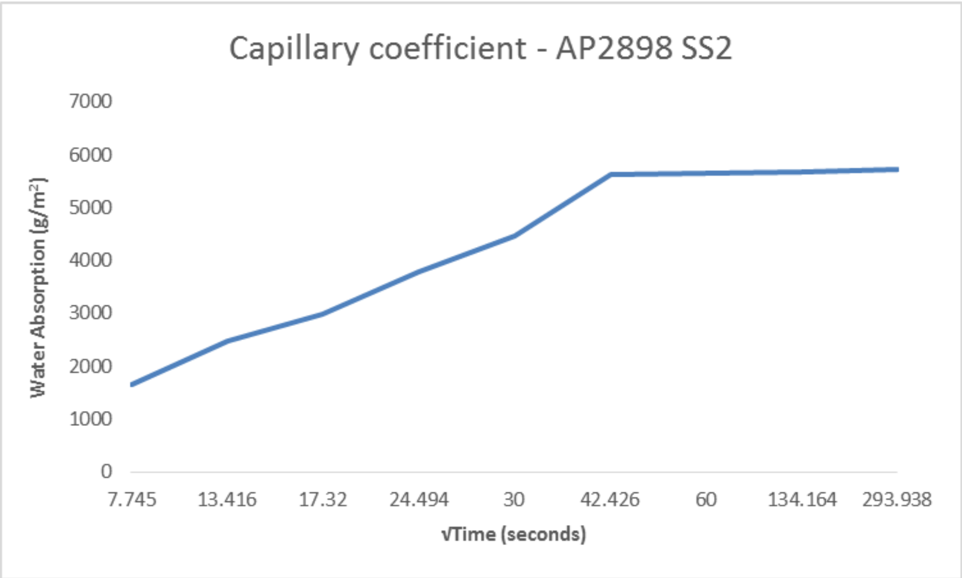
The results obtained from the physical tests are reproduced below, along with the data from stone that may be considered as potential replacements. The data reported for the potential sources was obtained from that held in the laboratory along with data obtained from a range of stone suppliers.

Total (%)	Analysed sample	High Nick sandstone	Blaxter sandstone	Drumhead sandstone	Scotch Buff sandstone
Water Absorption %	7.14	6.00	6.14	6.60	7.02
Apparent Density (Kg/m^{-3})	2328	2140	2069	2150	2115
Total Porosity %	17.5 (effective) – 20.4 (total)	19.7 (open/effective)	13 (effective) – 18 (total)	14 - 19 (open/effective)	14 (effective) – 18 (total)
Saturation Coefficient	0.85	-	0.73	0.72	0.77
Capillary Coefficient ($g/m^2/s$)	135	72	52	-	134
Permeability (mD)	Moderate - High	Moderate - High	~46 (low)	High	~50 (low)
Compressive Strength (MPa)	-	44	38 - 55	74 - 89	75
Acid Immersion Test	Moderate Reaction	Pass	Pass	Pass	Pass

Table 4: Physical properties of sample received and possible matches.



Water Absorption graph for AP2898 SS2



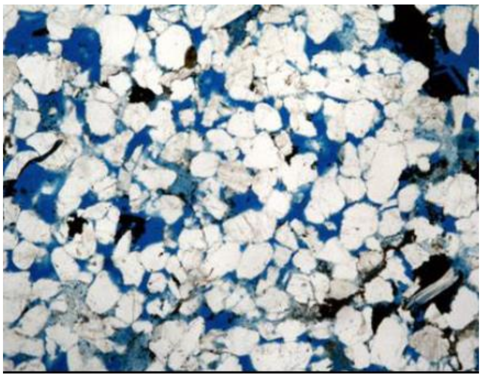
Capillary coefficient graph for AP2898 SS2

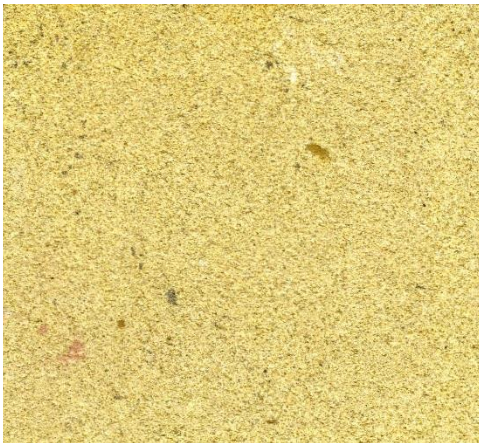
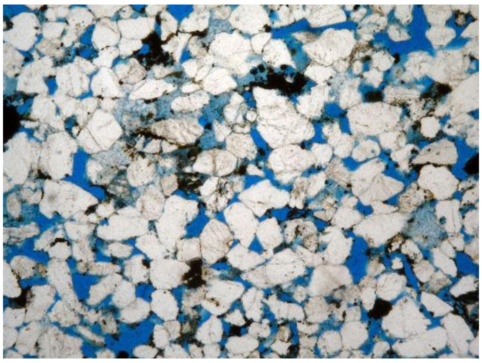
COMMENT

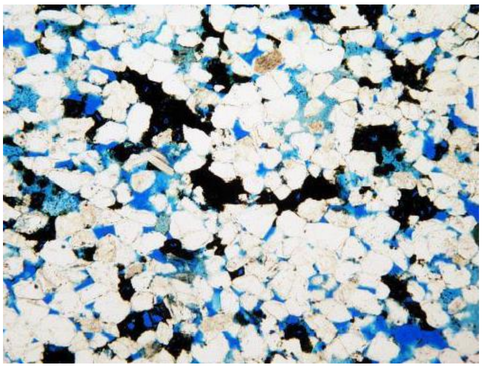
Sample AP2989 SS2 from Stephen Gethins MP Office at number 68 Bonnygate, Cupar is a relatively uniform to slightly diffuse bedded, texturally and mineralogically immature, poorly graded arenite sandstone, containing a majority of fine to medium sized, sub-angular to sub-rounded, sub-elongate to sub-spherical quartz grains with lower amounts of feldspar, lithic fragments and muscovite mica comprising the main detrital sandstone matrix. The stone is relatively 'dirty', containing a high proportion of authigenic minerals in the form of Fe-oxides and a mixture of clays. This high content of leached Fe-oxide provides the stone with its distinct orange mottled appearance, while the overall proportion of authigenic minerals hasn't necessarily affected the internal pore network to a great extent, with the total pore network retaining most of its capacity, with the measured porosity, water absorption, capillary coefficient and saturation coefficient values being generally high for sandstones.

In regards to choosing a suitable matching stone, it must be remembered that because stone is a natural material, it can vary in colour and appearance both over time and spatially within a quarry. It is therefore important to check the colour and appearance/obtain representative samples of the stone with the quarry operator in advance of works. Furthermore, each stone type will vary in its weathering behaviour over a period of years in accordance to weather conditions, the stone extraction process, and it's functionally within a building. This report is therefore not an endorsement of stone quality, nor does it ensure that the listed matching stones will weather in harmony with the original stone. The matched samples are based on thin section petrographic and physical stone testing analysis, taking into account colour, texture, mineralogy, porosity and permeability.

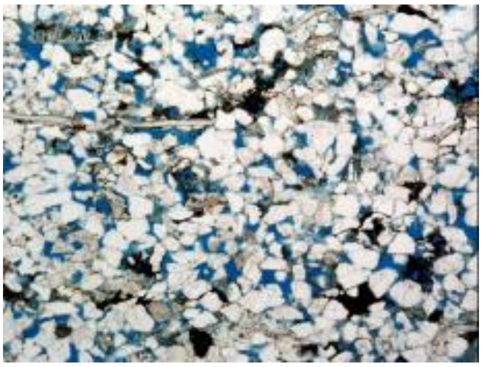
The contact addresses for these quarries are as follows:

High Nick Sandstone **Colour:** Buff coloured, with iron spots and iron-oxide banding, and 'Tiger Stripes' banded varieties of strong ochreous Fe-oxides. **Fabric:** Mainly uniform, with some aligned grains showing a slight orientation. **Grain size:** Medium grained. **Permeability:** Moderate to high. **Distinctive features:** There is evidence of iron-rich nodules in some stone that is extracted from the quarry. **Comments:** The stone contains distinctive iron-oxide nodules that vary in size from mm's to cm's in diameter. Iron-oxide banding is also common throughout. The 'tiger stripes' variety of bedded ion-oxides will likely provide the best aesthetic match for the most banded blocks of stone.	**Stancliffe Stone.** **Keypoint Office Village,** **Keys Road,** **Nixs Hill Industrial Estate,** **Alfreton,** **Derbyshire,** **DE55 7FQ** **Tel: 0845 302 0702**  

Blaxter Sandstone **Colour:** Buff **Fabric:** Uniform (with alignment of mica grains occasionally indicating bedding). **Grain size:** Fine to medium grained. **Permeability:** Moderate to High but occasionally low. **Distinctive features:** Blaxter sandstone can commonly show distinct Fe-staining; as either individual nodules or as bands within the stone, and also distinct orange-brown clay inclusions. **Comments:** This stone contains a higher proportion of distinct muscovite grains than the analysed sample.	**Dunhouse Natural Stone** **Dunhouse Quarry Ltd,** **Darlington,** **County Durham,** **DL2 3QU** **Tel: 01833 660 208**  

Drumhead sandstone **Colour:** Very light buff to buff. **Fabric:** Light buff is uniform, while more buff varieties are irregularly laminated. **Grain size:** Fine to medium grained varieties. **Permeability:** High **Distinctive features:** Occasional Fe-oxide staining. **Comments:** The most buff and laminated varieties would provide the best aesthetic match to the analysed sample; this would be stone quarried from the upper most beds in the quarry.	**David Graham,** **Drumhead Sandstone Ltd,** **Denovan Mains,** **Stirlingshire,** **FK6 6GT** **Tel: 07967 799 253** 

<table>
<tr>
<td>
Scotch Buff Sandstone
Colour: Buff to cream coloured with pervasive brown speckling, occasional brown lines and occasional small to large dark coloured patches.
Fabric: Generally uniform, with some alignment of mica flakes.
Grain Size: Medium grained
Permeability: Moderate to high
Distinctive features: None
Comments: This stone is more buff-coloured than fresh pieces of the analysed sample, but would provide a better visual match to the weathered surfaces of the stone.
</td>
<td>
Real Stone Ltd,
Wingerworth,
Chesterfield,
Derbyshire,
S42 6RG
Tel: 01246 270 244


</td>
</tr>
</table>

Sandstone is a natural material and by the nature of its origin, can be extremely variable within and between quarry faces. Ideally, a considered match should be examined in the same manner as the stone to be replaced. Archive sandstone samples of possible quarries may not be equivalent to the currently extracted product.

Some images of replacement sandstones were taken from other British Geological Survey stone reports, as referenced below, with full copyright permission granted for this use. Hand specimen images of replacement sandstones were made in the SLCT Building and Advisory Service lab from representative samples of each sandstone type.

British Geological Survey GeoReport: GR_209056
British Geological Survey GeoReport: GR_210536

British Geological Survey GeoReport: GR_201194/1
Albornoz-Parra, LJ, Tracey, EA and Gillespie, MR, 2014. A Building Stone Assessment of The Engine Shed, Stirling. British Geological Survey Commissioned Report, CR/14/088. 29pp

As with all quarries the actual properties of the stone available will be dependent on the face, and the bed, being worked at any given time and it is, therefore, always prudent to obtain samples of the current production for comparison with the stone to be matched, prior to ordering supplies for a particular project/application.

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

STONE ANALYSIS

& MATCHING REPORT

AP 2898
Cupar Stone and Slate Survey,
Watts Pub,
Cupar

Sample SS3

Sandstone Core

SITE	Watts Pub
CLIENT	Fife Historic Buildings Trust
DATE SAMPLE RECEIVED	07/07/2016
ANALYSIS/EXAMINATION DATES	23/08/2016
ANALYSIS, INTERPRETATION & REPORT BY	Dr Callum Graham and Roz Artis
CLIENT REQUIREMENTS	Stone Testing & Petrographic Examination for Stone Source Matching
STRUCTURE DATE	Unknown
STRUCTURE TYPE	Watts Pub
STONE TYPE	Blonde sandstone
LOCATION/ FUNCTION IN STRUCTURE	Ashlar building stone
CONDITION OF SAMPLE RECEIVED	The sample received consisted of one core of slightly weathered sandstone Size of largest piece = 44mm diameter x mm length

DETERMINATION OF STONE CHARACTERISTICS

Method of Examination & Test

A sample comprising of one core of relatively un-weathered sandstone was received for examination and determination of its properties. The stone had been cored from the bottom of the front façade of Watts Pub, Station Road, Cupar (Plate 1 and 2) on the 3rd of June, 2016 by Mr Scott MacAskill, stonemason who was joined on site by Dr Callum Graham, Buildings Materials Analyst, with the sample submitted for examination to assist in identifying both a suitable source of replacement stone and the original source quarry of this stone.

Upon receipt in the laboratory the sample was examined with the aid of a stereo-binocular microscope at magnifications up to x 40. Following the initial examination sub-sample were prepared and submitted to a range of physical tests to determine the properties of the stone. In addition a slice was cut through one of the larger intact pieces of stone, with the specimen aligned such that the slice extended through the full thickness of the sample.

The slice was prepared for thin sectioning by washing the soiling from the sample, which was then dried to a constant weight prior to the vacuum impregnation of the sub-sample with an epoxy resin, to which a fluorescent blue dye had

been added. One side of the resin impregnated slice was polished and mounted onto a glass slide (50mm x 75mm), with the mounted sample ground and polished to give an approximate thickness of 30 microns.

The thin section was submitted to a microscopic examination, which was undertaken with the aid of an Olympus POS Polarised Light microscope, fitted with a digital camera, to permit recording of photomicrographs, some of which are included in this report, for reference purposes.

The presence of dyed epoxy resin within the sample enables an assessment of the stone fabric to be made, including an assessment of the visual porosity, void size and distribution along with the evaluation of any crack patterns and physical depositional features apparent in the sample under examination. The sample was examined following standard procedures, and in general accordance with BS EN 12407:2000; Natural Stone Test Methods.

In addition to carrying out a detailed visual and microscopic examination, the physical properties of the stone were also measured. The water absorption was determined by the methods of BS EN 13755:2008, the capillary coefficient by the methods of BS EN 1925:1999, and the apparent density and open porosity determined by the methods of BS EN 1936:1999.

This report presents observations from the microscopic examination along with the results of the physical tests carried out.

The purpose of the examination and testing was to permit a comparison between the sample received and the properties of stone from any visually similar stone, to confirm if these would be suitable matches for the stone submitted.

Plate 1. The sandstone sample was cored from the area highlighted by the red circle. This area was representative of sample 1-type sandstone and was cored from a section of the building not obviously noticeable from the seated area in front of the building.

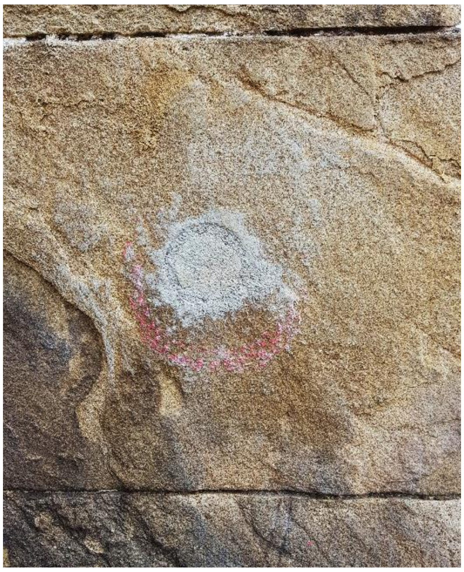


Plate 2. View of the backfilled cored area of the stone.

MACROSCOPIC EXAMINATION

The fresh dry stone had a distinct blonde to light cream and yellow to buff coloured, orange-mottled appearance and was found to be 10YR 7/6 – 7/7 'yellow' to 10YR 6/6 – 6/7 'brownish yellow' when assessed against the Munsell Soil Colour Charts. It is generally fine to medium grained, relatively heterogeneous sandstone that is variable across each different block of stone used in the building. There is evidence of a range of sedimentary structures throughout different sandstone blocks, including fine laminations, ripple beds, cross beds and uniform bedding planes. The fresh, unweathered sandstone is hard, cohesive and generally highly compact, comprised of mainly sub-rounded to rounded and occasional angular quartz grains, dark indiscernible lithic fragments and minerals and a low proportion of muscovite mica with evidence of point and line contacts in hand specimen. The stone is cemented by a white frosted calcite cement, as indicated by a strong reaction with 10% HCl acid. The main stone matrix is characterised by an orange to brown, uniformly mottled appearance, which is imparted on the stone by Fe-rich clay inclusions and Fe-nodules; occasionally concentrated within narrow bedding planes, which vary in their thickness. The stone is of relatively poor building stone quality, owing to the inherent fabric/texture of the stone, with the bottom courses of buildings that use this stone suffering from: (i) delamination, (ii) granular decay, (iii) bursting, (iv) bubbling, (v) flaking, (vi) scaling and contour scaling, (vii) salt bursting, (viii) black gypsum crusts, (ix) salt efflorescence, (x) impact damage, (xi) fracturing, (xii) cracking.

Plate 3. Side view of the sandstone core post thin section preparation. The thin section was cut parallel to the length of the core.

Plate 4. End view of the sandstone core post thin section preparation. A dark discoloured surface crust is evident on the exposed weathered surface of the core. The area from where the stone was cored had suffered from delamination, with the presence of salt efflorescence on the stone surface.

MICROSCOPIC THIN SECTION EXAMINATION

The sample of stone analysed by the method of petrographic microscopy is representative of the underlying 'uniform' stone matrix and therefore does not consider the larger sedimentary structures present within the stone. It is considered that this analysis is the most representative of the stone, especially in relation of the field of view under the microscope compared to the larger-scaled textural features evident across full sized building blocks.

Texture: The stone displays a generally uniform fabric in thin section, with well distributed Fe-oxides and clays throughout and with no distinct spatial concentration or distribution of specific minerals anywhere within the thin section. There is a similar alignment of muscovite mica grains throughout the thickness of the sample, however these are in such small numbers as to not significantly influence the visual appearance or moisture transportation pathways in the stone. It is predominantly fine grained, moderately well sorted sandstone with grains ranging in size from 65µm to 240µm, and showing a modal grain size value of ~120µm. The stone is relatively texturally sub-mature, with most grains ranging in shape from angular to well-rounded and elongate to spherical (average of sub-angular to sub-rounded and rounded, and sub-spherical to spherical). Grains are primarily bound by spary calcite cement, with kaolinite and Fe-oxides providing important secondary cements throughout the stone. Grains are moderately to poorly compacted, displaying a majority of point and line contacts, with calcite generally cementing grains together in the absence of compacted grains.

Mineralogy: The stone contains a detrital framework mineralogy comprised predominantly of quartz grains, which are found as mainly monocrystalline (>95%), unstrained varieties (likely igneous in origin), with minor amounts of polycrystalline and strained varieties found throughout. There is a relatively low proportion of feldspar grains, in the form of plagioclase and microcline, muscovite mica, plus lithic fragments in the form of basic igneous and foliated metamorphic rock. Feldspar and lithic fragments show a moderate to high degree of alteration and dissolution, forming pitted, fractured and micro-porous surfaces. Kaolinite, calcite, opaque minerals (such as Fe-oxides) and other indeterminate clays provide the most abundant cementing authigenic products; which together provide a major proportion of the total stone mineralogical content. Authigenic minerals are those that formed within the rock (either during diagenesis or in-situ within the building) after the original sediment was deposited. These commonly form the cementing minerals in the stone, which tend to block and lower the effective porosity. Authigenic clays are generally well dispersed throughout the stone, with the mobilisation of Fe-oxide from Fe-bearing minerals concentrating within isolated regions of the stone imparting the distinct orange mottled colour and texture.

Detrital Minerals: Quartz, feldspar, muscovite, igneous lithic fragments
Authigenic Minerals: Calcite, Fe-oxide, kaolinite

Porosity: The stone contains a moderate visual porosity and moderate to low permeability owing to the high proportion of pore filling authigenic minerals and intergranular cement. Pores range in their shape, size and connectivity as a consequence of authigenic processes, which provide the stone with a porosity and permeability that varies spatially throughout its thickness. Most pores are primary and intergranular. Physical testing shows that the stone contains an effective and open porosity of 12.9% and 14.8%, respectively, with water absorption, saturation and capillary coefficient values of 7.18%, 0.87 and 73gm^2/s, respectively; the former two of which are classified as moderate to high for sandstones.

Photomicrographs:

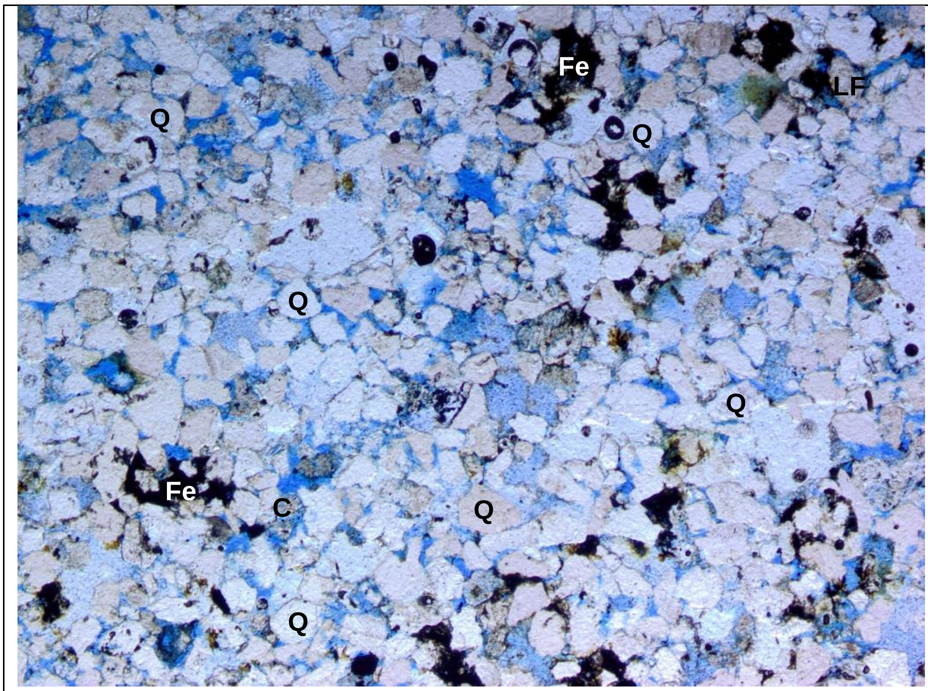


Plate 5. Thin section of the sample under plane polarised light. Pore spaces are highlighted in blue, while areas of very light blue indicate pore filling clays that have absorbed some of the blue dye. The stone contains a moderately open porosity throughout most of the stone, comprised of similarly small sized intergranular pores. Q: quartz, LF: lithic fragment, C: calcite, Fe: Fe-oxide.

Field of view is 3.3mm.

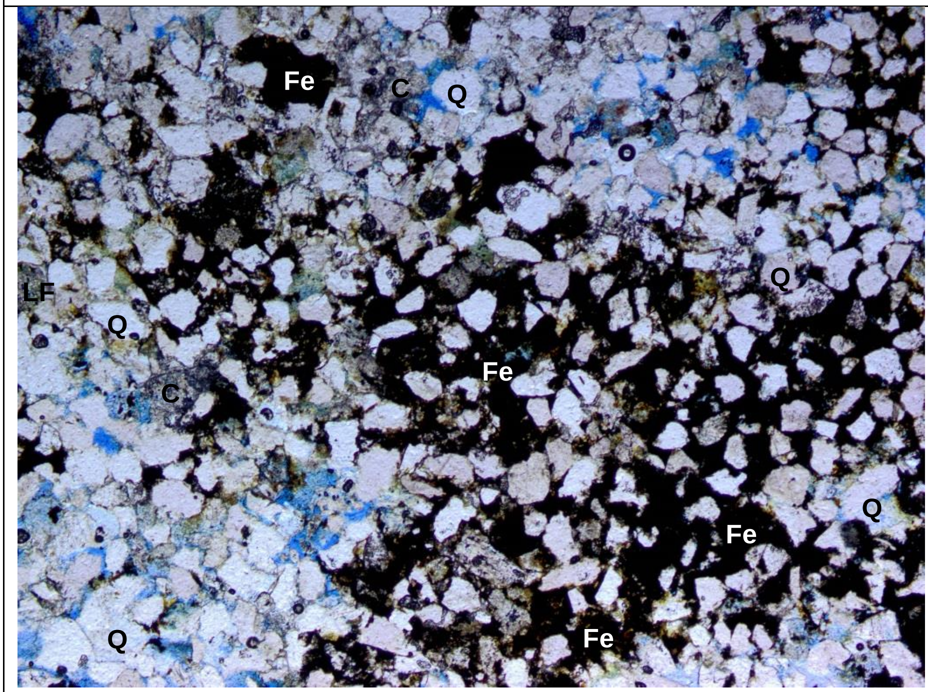


Plate 6. Thin section of the sample under plane polarised light. Pore spaces are highlighted in blue, while areas of very light blue indicate pore filling clays that have absorbed some of the blue dye. The stone contains an extremely high proportion of authigenic minerals, with ~9% Fe-oxides evident, completely infilling and blocking pores spaces in small regions throughout the stone. This area appears as a large orange-brown inclusion/speckle in hand specimen.

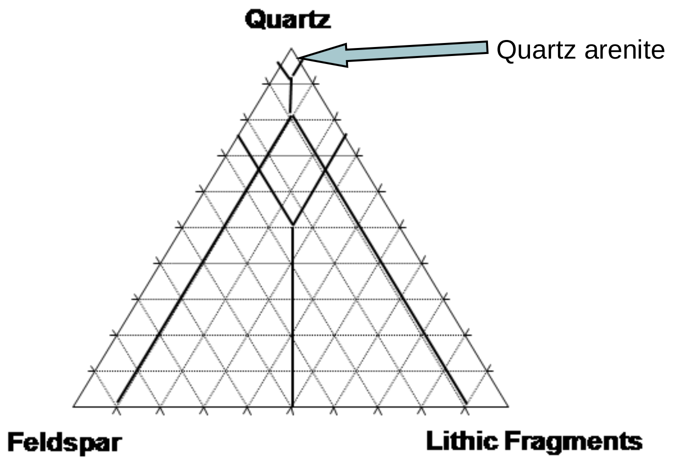
Field of view is 3.3mm.

Point Count Data:

Components	Total (%)	Q/F/L (quartz/feldspar/lithic % proportion)
Detrital Components		
Quartz	76.5	97.5
Feldspar	0.5	0.5
Lithic fragments	1.5	2
Detrital Clay	3	
Muscovite Mica	<0.1	
Authigenic Minerals		
Quartz Overgrowths	0.5	
Indeterminate Clay	7	
Calcite	2	
Opaque Minerals	9	
Total	100	100
Porosity	12.9 – 14.8	

Table 5: Results of modal analysis on the sample received.

Sandstone Classification: This stone is classified using the McBride (1963) classification scheme, as a quartz arenite. The stone contains a majority of quartz grains, a feldspar content of 0.5% and a lithic fragment content of less than 5%.



Classification of sandstone after McBride (1963)[1]

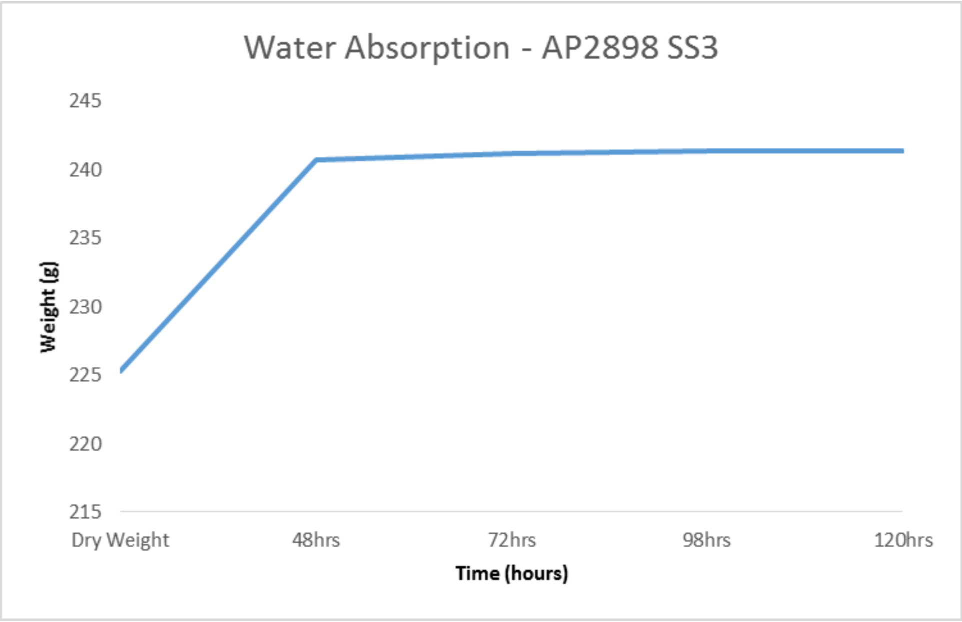
[1] McBride, E. F. (1963), A classification of common sandstones. Journal of Sedimentary Petrology 33, 664-669

PHYSICAL PROPERTIES

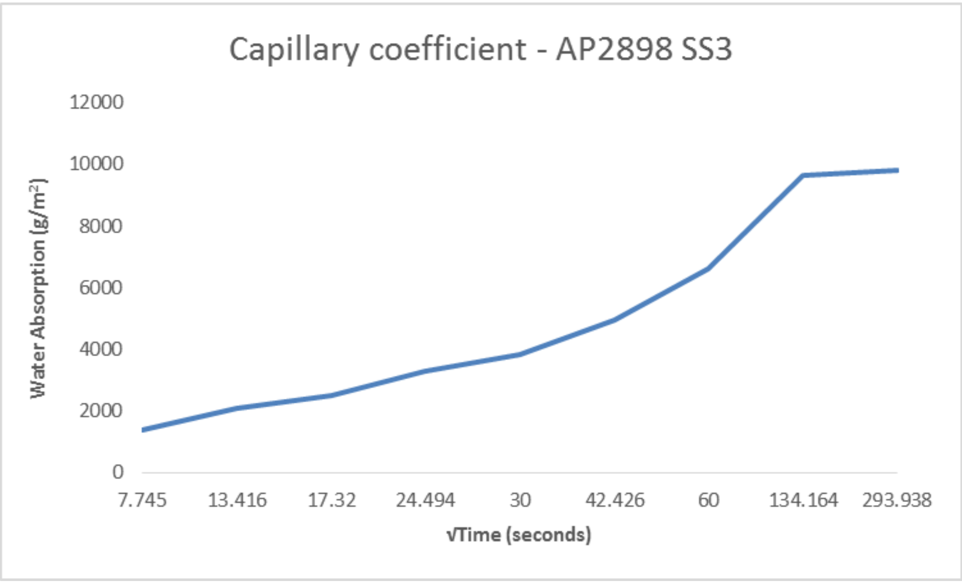
The results obtained from the physical tests are reproduced below, along with the data from stone that may be considered as potential replacements. The data reported for the potential sources was obtained from that held in the laboratory along with data obtained from a range of stone suppliers.

Total (%)	Analysed sample	High Nick sandstone	Blaxter sandstone	Drumhead sandstone	Scotch Buff sandstone
Water Absorption %	7.18	6.00	6.14	6.60	7.02
Apparent Density (Kg/m^{-3})	1802	2140	2069	2150	2115
Total Porosity %	12.9 (effective) – 14.8 (total)	19.7 (open/effective)	13 (effective) – 18 (total)	14 - 19 (open/effective)	14 (effective) – 18 (total)
Saturation Coefficient	0.87	-	0.73	0.72	0.77
Capillary Coefficient (g/m^2/s)	73.27	72	52	-	134
Permeability (mD)	Low - Moderate	Moderate - High	~46 (low)	High	~50 (low)
Compressive Strength (MPa)	-	44	38 - 55	74 - 89	75
Acid Immersion Test	High Reaction	Pass	Pass	Pass	Pass

Table 6: Physical properties of sample received and possible matches.



Water Absorption graph for AP2898 SS3



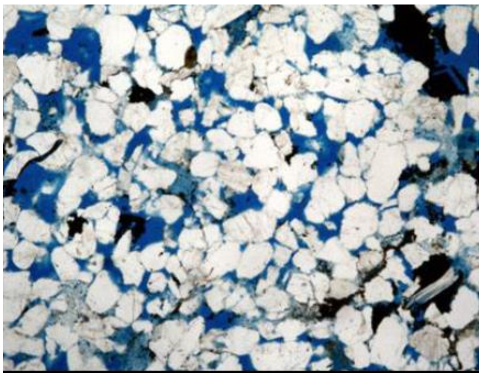
Capillary coefficient graph for AP2898 SS3

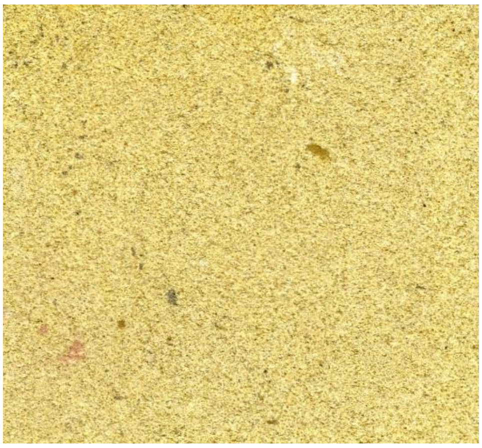
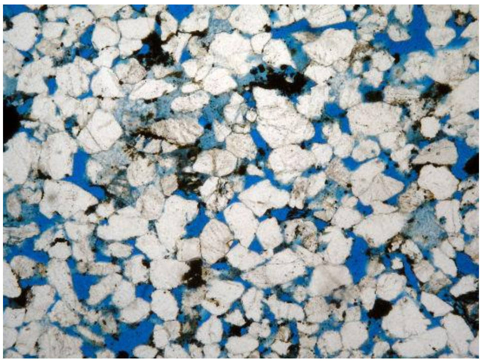
COMMENT

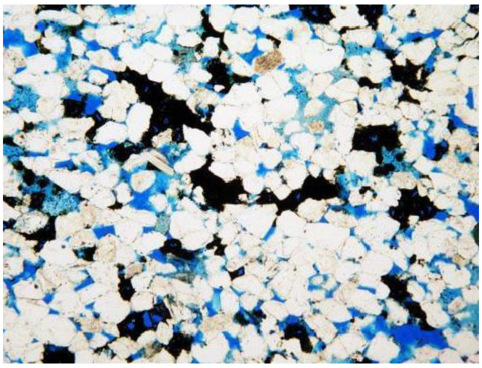
Sample AP2989 SS3 from Watts Pub and Restaurant at Station Road, Cupar is heterogeneous, texturally sub-mature and mineralogically mature, moderately to well graded quartz arenite sandstone, containing a majority of fine, sub-angular to sub-rounded, sub-spherical to spherical quartz grains with lower amounts of feldspar, lithic fragments and muscovite mica comprising the main detrital sandstone matrix. The stone is relatively ‘dirty’, containing a high proportion of authigenic minerals in the form of Fe-oxides and a mixture of clays. This high content of leached Fe-oxide provides the stone with its distinct orange mottled appearance, while the overall proportion of authigenic minerals has likely lowered the effective permeability of the stone, leading to relatively low capillary coefficient values; however the total pore network has likely retained most of its capacity, with water absorption and saturation coefficient values being moderate to high for sandstones.

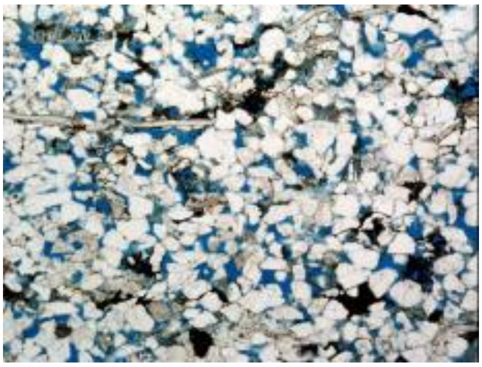
In regards to choosing a suitable matching stone, it must be remembered that because stone is a natural material, it can vary in colour and appearance both over time and spatially within a quarry. It is therefore important to check the colour and appearance/obtain representative samples of the stone with the quarry operator in advance of works. Furthermore, each stone type will vary in its weathering behaviour over a period of years in accordance to weather conditions, the stone extraction process, and it’s functionally within a building. This report is therefore not an endorsement of stone quality, nor does it ensure that the listed matching stones will weather in harmony with the original stone. The matched samples are based on thin section petrographic and physical stone testing analysis, taking into account colour, texture, mineralogy, porosity and permeability.

The contact addresses for these quarries are as follows:

High Nick Sandstone **Colour:** Buff coloured, with iron spots and iron-oxide banding. **Fabric:** Mainly uniform, with some aligned grains showing a slight orientation. **Grain size:** Medium grained. **Permeability:** Moderate to high. **Distinctive features:** There is evidence of iron-rich nodules in some stone that is extracted from the quarry. **Comments:** The stone contains distinctive iron-oxide nodules that vary in size from mm's to cm's in diameter. Iron-oxide banding is also common throughout.	**Stancliffe Stone.** **Keypoint Office Village,** **Keys Road,** **Nixs Hill Industrial Estate,** **Alfreton,** **Derbyshire,** **DE55 7FQ** **Tel: 0845 302 0702**  

Blaxter Sandstone **Colour:** Buff **Fabric:** Uniform (with alignment of mica grains occasionally indicating bedding). **Grain size:** Fine to medium grained. **Permeability:** Moderate to High but occasionally low. **Distinctive features:** Blaxter sandstone can commonly show distinct Fe-staining; as either individual nodules or as bands within the stone, and also distinct orange-brown clay inclusions. **Comments:** This stone contains a higher proportion of distinct muscovite grains than the analysed sample.	**Dunhouse Natural Stone** **Dunhouse Quarry Ltd,** **Darlington,** **County Durham,** **DL2 3QU** **Tel: 01833 660 208**  

Drumhead sandstone **Colour:** Very light buff to buff. **Fabric:** Light buff is uniform, while more buff varieties are irregularly laminated. **Grain size:** Fine to medium grained varieties. **Permeability:** High **Distinctive features:** Occasional Fe-oxide staining. **Comments:** The most buff and laminated varieties would provide the best aesthetic match to the analysed sample; this would be stone quarried from the upper most beds in the quarry.	**David Graham,** **Drumhead Sandstone Ltd,** **Denovan Mains,** **Stirlingshire,** **FK6 6GT** **Tel: 07967 799 253** 

Scotch Buff Sandstone	**Real Stone Ltd,**
Colour: Buff to cream coloured with pervasive brown speckling, occasional brown lines and occasional small to large dark coloured patches. **Fabric:** Generally uniform, with some alignment of mica flakes. **Grain Size:** Medium grained **Permeability:** Moderate to high **Distinctive features:** None **Comments:** This stone is more buff-coloured than fresh pieces of the analysed sample, but would provide a better visual match to the weathered surfaces of the stone.	**Wingerworth,** **Chesterfield,** **Derbyshire,** **S42 6RG** **Tel: 01246 270 244**  

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British Geological Survey GeoReport: GR_209056
British Geological Survey GeoReport: GR_210536

British Geological Survey GeoReport: GR_201194/1

As with all quarries the actual properties of the stone available will be dependent on the face, and the bed, being worked at any given time and it is, therefore, always prudent to obtain samples of the current production for comparison with the stone to be matched, prior to ordering supplies for a particular project/application.

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STONE ANALYSIS

& MATCHING REPORT

AP 2898
Cupar Stone and Slate Survey,
Pagan Osbourne,
Cupar

Sample SS4

Sandstone Core

SITE	Pagan Osbourne
CLIENT	Fife Historic Buildings Trust
DATE SAMPLE RECEIVED	07/07/2016
ANALYSIS/EXAMINATION DATES	23/08/2016
ANALYSIS, INTERPRETATION & REPORT BY	Dr Callum Graham and Roz Artis
CLIENT REQUIREMENTS	Stone Testing & Petrographic Examination for Stone Source Matching
STRUCTURE DATE	Unknown
STRUCTURE TYPE	Lawyers offices
STONE TYPE	Blonde sandstone
LOCATION/ FUNCTION IN STRUCTURE	Ashlar building stone
CONDITION OF SAMPLE RECEIVED	The sample received consisted of one core of generally unweathered sandstone. Size of largest piece post thin section preparation = 44mm diameter x mm length.

DETERMINATION OF STONE CHARACTERISTICS

Method of Examination & Test

A sample comprising of one core of relatively un-weathered sandstone was received for examination and determination of its properties. The stone had been cored from the corner of the offices of Pagan Osbourne at number 14, St Catherine Street, Cupar (Plate 1 and 2) on the 3rd of June, 2016 by Mr Scott MacAskill, stonemason who was joined on site by Dr Callum Graham, Buildings Materials Analyst, with the sample submitted for examination to assist in identifying both a suitable source of replacement stone and the original source quarry of this stone.

Upon receipt in the laboratory the sample was examined with the aid of a stereo-binocular microscope at magnifications up to x 40. Following the initial examination sub-sample were prepared and submitted to a range of physical tests to determine the properties of the stone. In addition a slice was cut through one of the larger intact pieces of stone, with the specimen aligned such that the slice extended through the full thickness of the sample.

The slice was prepared for thin sectioning by washing the soiling from the sample, which was then dried to a constant weight prior to the vacuum impregnation of the sub-sample with an epoxy resin, to which a fluorescent blue dye had

been added. One side of the resin impregnated slice was polished and mounted onto a glass slide (50mm x 75mm), with the mounted sample ground and polished to give an approximate thickness of 30 microns.

The thin section was submitted to a microscopic examination, which was undertaken with the aid of an Olympus POS Polarised Light microscope, fitted with a digital camera, to permit recording of photomicrographs, some of which are included in this report, for reference purposes.

The presence of dyed epoxy resin within the sample enables an assessment of the stone fabric to be made, including an assessment of the visual porosity, void size and distribution along with the evaluation of any crack patterns and physical depositional features apparent in the sample under examination. The sample was examined following standard procedures, and in general accordance with BS EN 12407:2000; Natural Stone Test Methods.

In addition to carrying out a detailed visual and microscopic examination, the physical properties of the stone were also measured. The water absorption was determined by the methods of BS EN 13755:2008, the capillary coefficient by the methods of BS EN 1925:1999, and the apparent density and open porosity determined by the methods of BS EN 1936:1999.

This report presents observations from the microscopic examination along with the results of the physical tests carried out.

The purpose of the examination and testing was to permit a comparison between the sample received and the properties of stone from any visually similar stone, to confirm if these would be suitable matches for the stone submitted.

Plate 1. The sandstone sample was cored from the area highlighted by the red box. This area had suffered very slight surface scaling decay and was located in an inconspicuous area of the building that won't affect its aesthetic value.

Plate 2. View of the backfilled cored area of the stone. The mortar used for backfilling provides a similar surface colour to the stone.

MACROSCOPIC EXAMINATION

The dry, fresh stone was found to be 7.5YR 8/1 to 10YR 8/1 ‘white’ in hand specimen when assessed against the Munsell Soil Colour Charts. The sandstone is predominantly fine to medium grained and locally coarse grained throughout the building, with surfaces being cohesive and non-friable. Within the building, this type of stone displays shallow pitted surfaces (plate 1), minor shallow surface scaling decay (plate 2) and infrequent biological growth. The stone is composed of a majority of well compacted sub-rounded to well rounded, sub-spherical to spherical clear and glassy textured quartz grains, with minor proportions of Fe-oxides and discreet clay inclusions also present; only evident as mobilised clay from when the stone was cut. Grains are strong and cohesive and therefore likely cemented by thin silica rims, while grains show a high proportion of point and line grain contacts throughout. Fresh internal surfaces of the stone experience fast water absorption rates when subjected to the water droplet test, indicating an interconnected and permeable internal pore network.

Plate 3. Side view of the cored section of sandstone post thin section preparation. There are no visible textural features evident in hand specimen.

Plate 4. End view of the sandstone core post thin section preparation.

MICROSCOPIC THIN SECTION EXAMINATION

Texture: The stone is completely uniform throughout, containing well distributed and uniformly compacted grains. The stone is predominantly fine to medium grained, well sorted and texturally mature, characterised by sub-rounded to rounded, sub-spherical to spherical grains, with occasional sub-elongate and sub-angular grains also present. Grains are generally well compacted throughout, showing a majority of point and line contacts, with minor proportions of concave-convex, dissolution and sutured contacts also present. Pore spaces remain relatively unaltered and clean owing to the low proportion of authigenic minerals. Grains are predominantly bound by patchy silica cement, with limited quartz overgrowths present.

Mineralogy: The stone contains a mature detrital framework mineralogy composed of a majority of well sorted, rounded to sub-rounded, spherical to sub-spherical quartz grains which are found as mainly mono-crystalline, strained and unstrained varieties, with trace polycrystalline grains found throughout. There is a low proportion of similarly sized and shaped lithic fragments of metamorphic origin, as well as trace proportions of clean and unaltered plagioclase feldspar grains, clay and Fe-oxides.

Detrital Minerals: *Quartz, Feldspar*
Authigenic Minerals: *Kaolinite, Fe-oxides*

Porosity: The stone has a high visual porosity (estimated as roughly 15 – 20%) that appears to be well connected in thin section. Most pores are of a very similar size, owing to the organised and well sorted grain compaction; this provides the stone with a generally uni-modal pore size distribution and relatively high permeability. These properties are generally very important, as they allow the stone to be both moisture and vapour permeable; essentially allowing it to 'breathe'.

Photomicrographs:

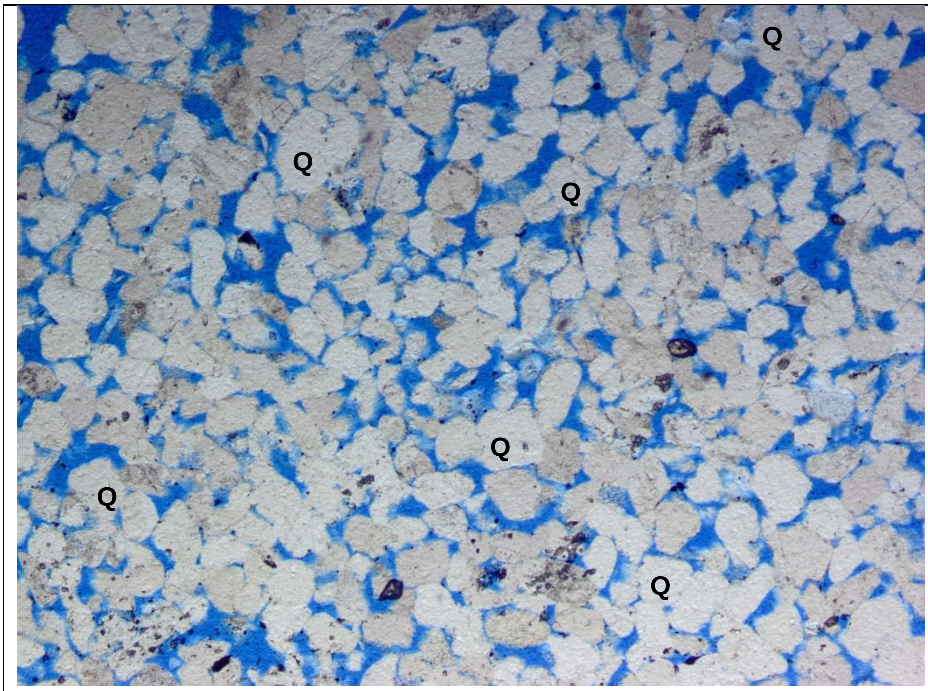


Plate 5. Thin section of the sample under plane polarised light. Pore spaces appear as light blue. The stone is predominantly fine to medium grained, texturally mature and well graded. Grains are mainly sub-rounded and sub-spherical in shape and show a stable compaction configuration, whereby the stone is characterised by a majority of point and line grain contacts, and a well-connected internal pore network. Q: quartz.

Field of view is 3.3mm.

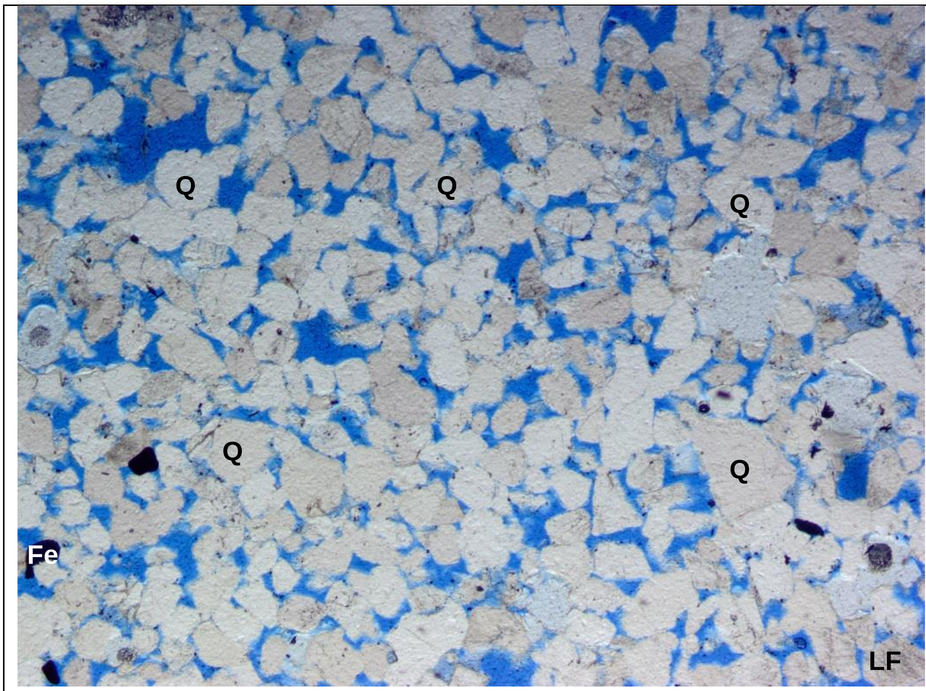


Plate 6. Thin section of the sample under plane polarised light. Pore spaces are highlighted in blue. The stone is composed of a majority of sub-rounded, sub-spherical to spherical quartz grains and a lower proportion of lithic fragments, feldspar grains and Fe-oxides. Q: quartz, Fe: Fe-oxide.

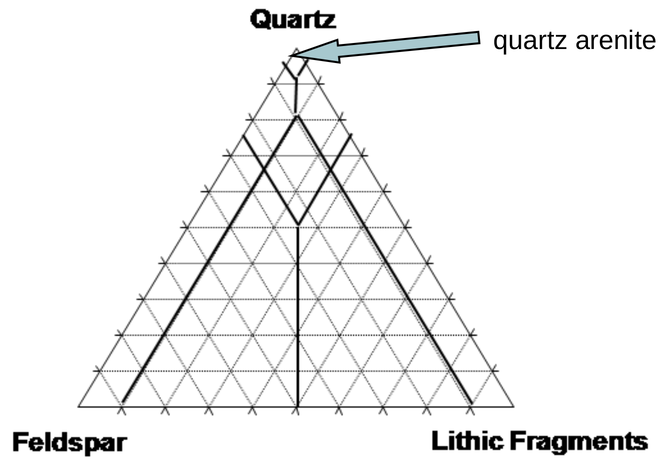
Field of view is 0.5mm.

Point Count Data:

Components	Total (%)	Q/F/L (quartz/feldspar/lithic % proportion)
Detrital Components		
Quartz	97	98
Feldspar	1	1.5
Lithic fragments	0.5	0.5
Detrital Clay	0	
Muscovite Mica	0	
Authigenic Minerals		
Quartz Overgrowths	<1.0	
Indeterminate Clay	1	
Calcite	0	
Opaque Minerals	0.5	
Total	100	100
Porosity	12.9 – 16.6	

Table 7: Results of modal analysis on the sample received.

Sandstone Classification: The stone is classified using the McBride (1963) classification scheme, as a quartz arenite. The stone contains a majority of quartz grains, a feldspar content lower than 5% and a similar small proportion of lithic fragments (<5%).



Classification of sandstone after McBride (1963)[1]

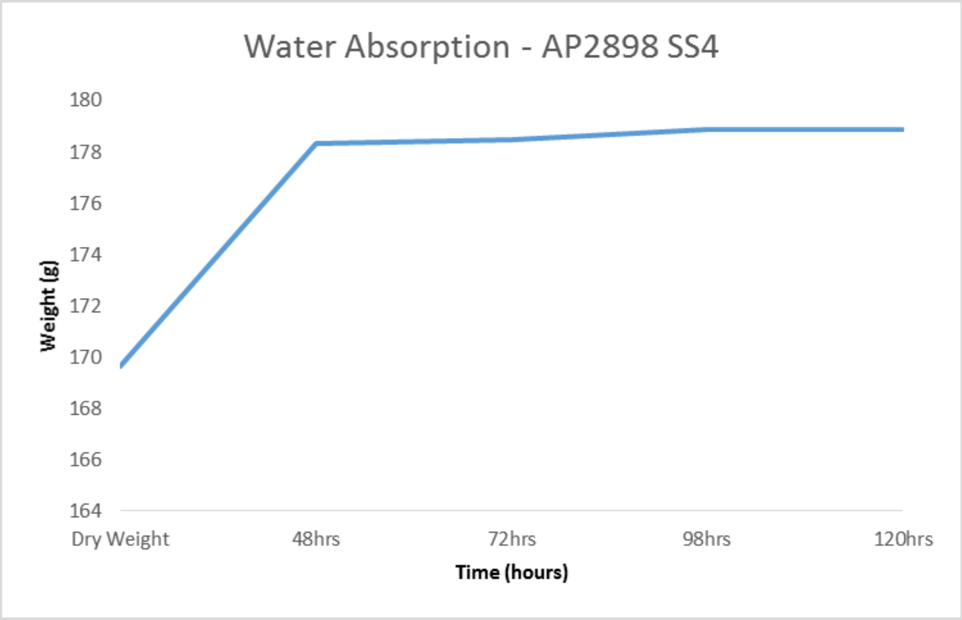
[1] **McBride, E. F. (1963), A classification of common sandstones. Journal of Sedimentary Petrology 33, 664-669**

PHYSICAL PROPERTIES

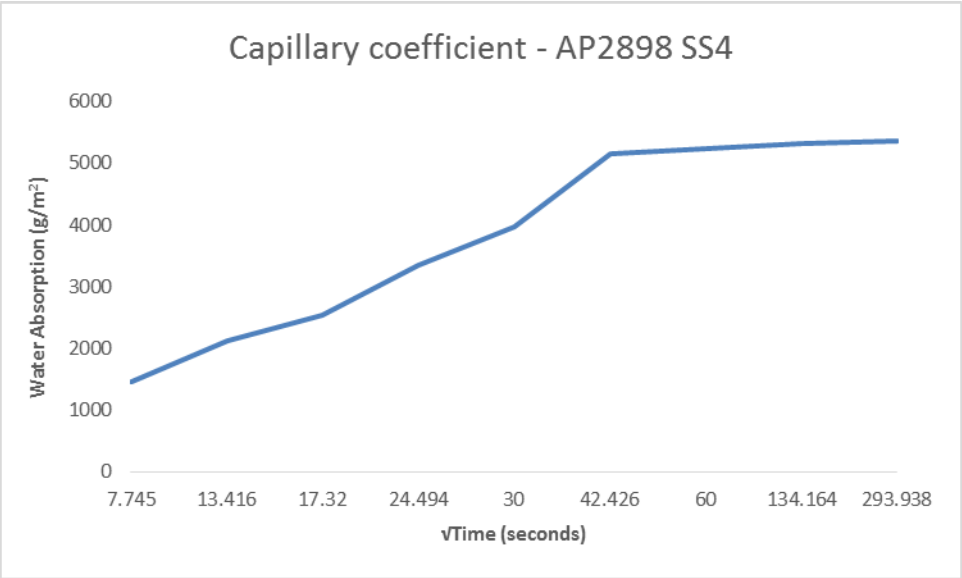
The results obtained from the physical tests are reproduced below, along with the data from stone that may be considered as potential replacements. The data reported for the potential sources was obtained from that held in the laboratory along with data obtained from a range of stone suppliers.

Total (%)	Analysed sample	Cullalo sandstone	Hazeldean sandstone	Clashach sandstone
Water Absorption %	5.45	~5.87	~4.45	~2.97
Apparent Density (Kg/m^{-3})	2350	~2100	~2200	~2180
Total Porosity %	12.9 (effective) - 16.6 (total)	14 (effective) - 20 (total)	10 (effective) – 16 (total)	6 (effective) – 10 (total)
Saturation Coefficient	0.75	0.69	0.67	0.62
Capillary Coefficient (g/m^2)	126	~108	~51	~28
Permeability (mD)	Moderate - High	~600 (High)	~300 (Moderate)	~80 (Low)
Compressive Strength (MPa)	-	35 - 43	84	132
Acid Immersion Test	Pass	Pass	Pass	Pass

Table 8: Physical properties of possible matches.



Water absorption graph for AP2898 SS4



Capillary coefficient graph for AP2898 SS4

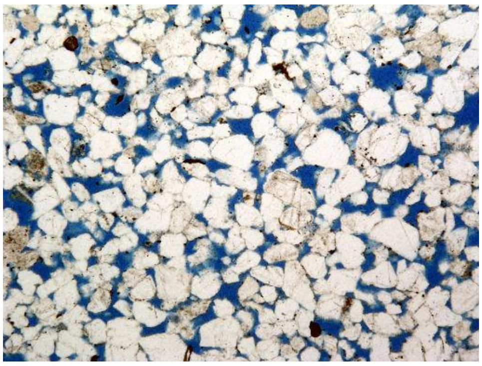
COMMENT

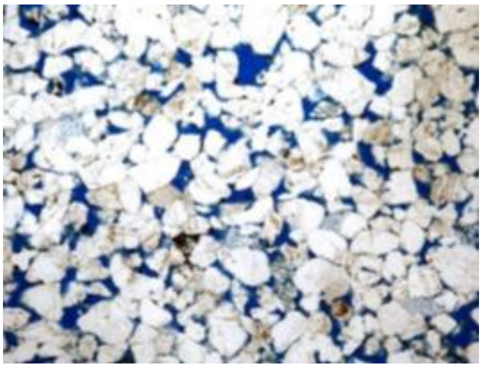
Sample AP2898 SS4 from the Pagan Osbourne office in Cupar is a uniform, texturally and mineralogically mature, fine to medium grained quartz arenite sandstone containing a majority of sub-rounded, sub-spherical quartz grains. It is ‘clean’ sandstone, containing a very low proportion of authigenic minerals, which has led to the preservation of an open and permeable pore network; an important property that much be matched in replacement sandstone. From its location in Cupar, it’s thought that stone obtained from Carboniferous rock in Fife was likely used in its construction, with the stone showing parallels with Cullalo sandstone from Burntisland.

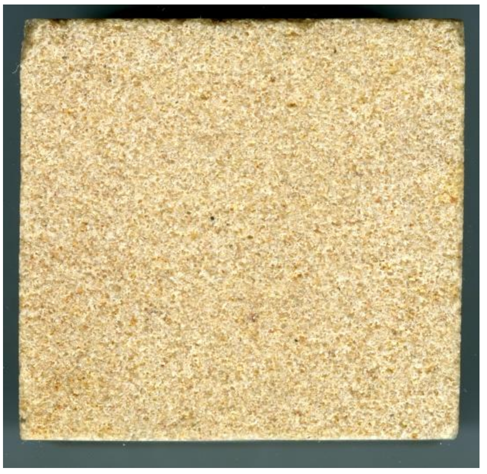
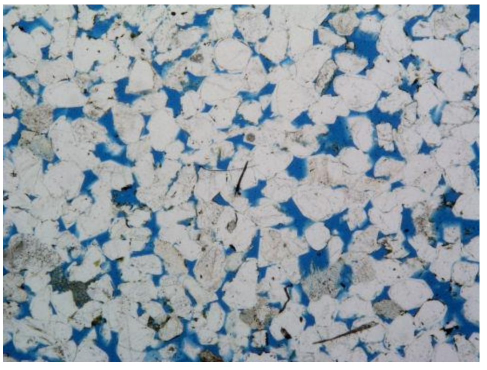
In regards to choosing a suitable matching stone, it must be remembered that because stone is a natural material, it can vary in colour and appearance both over time and spatially within a quarry. It is therefore important to check the colour and appearance/obtain representative samples of the stone with the quarry operator in advance of works. Furthermore, each stone type will vary in its weathering behaviour over a period of years in accordance to weather conditions, the stone extraction process, and it’s functionally within a building. This report is therefore not an endorsement of stone quality, nor does it ensure that the listed matching stones will weather in harmony with the original stone. The matched samples are based on thin section petrographic and physical stone testing analysis, taking into account colour, texture, mineralogy, porosity and permeability.

The contact addresses for these quarries are as follows:

<table>
<tr>
<td>Cullalo sandstone
Colour: Light grey to light buff.
Fabric: Uniform.
Grain size: Fine to medium grained varieties.
Permeability: High
Distinctive features: None.
Comments: None.</td>
<td>Tradstocks,
Dunaverig,
Thornhill,
Stirling,
FK8 3QW
Tel: 01786 850 400

</td>
</tr>
</table>

Hazeldean Sandstone **Colour:** White to light grey and buff varieties. **Fabric:** Mainly uniform, with evidence of slight bedding. **Grain size:** Fine to medium grained. **Permeability:** Moderate to High. **Distinctive features:** None. **Comments:** The white to grey varieties will provide the best visual match.	**Hutton Stone Co. Ltd.** **Masons & Stone Merchants,** **West Fishwick,** **Berwick-upon-Tweed,** **TD15 1XQ** **Tel: 01289 386 056**  

Clashach sandstone **Colour:** Light grey. **Fabric:** Uniform. **Grain size:** Fine to medium grained varieties. **Permeability:** Low to high. **Distinctive features:** None. **Comments:** None.	**Tennants (Elgin) Ltd,** **Brumley Brae,** **Elgin,** **Moray,** **IV30 5PP** **Tel: 01343 552 767**  

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British Geological Survey GeoReport: GR_210536

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