SCOTTISH LIME CENTRE TRUST

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

STONE ANALYSIS

& MATCHING REPORT

AP 3480
Inverkeithing Town House,
Inverkeithing Stone and Slate
Audit

Sample 1 - Type SS1

Masonry

SITE	Inverkeithing Town House, Inverkeithing Stone and Slate Audit
CLIENT	Fife Historic Buildings Trust
DATE SAMPLE RECEIVED	18/12/19
ANALYSIS/EXAMINATION DATES	18/12/19 – 10/02/20
ANALYSIS, INTERPRETATION & REPORT BY	Dr Katie Strang and Roz Artis
CLIENT REQUIREMENTS	Petrographic Examination for Stone Source Matching
STRUCTURE DATE	Original building 1770
STRUCTURE TYPE	Town House
STONE TYPE	Sandstone
LOCATION/ FUNCTION IN STRUCTURE	Stone from left hand side of door
CONDITION OF SAMPLE RECEIVED	The sample received consisted of a fresh core of sandstone Total mass of sample received = 287.21 grams

DETERMINATION OF STONE CHARACTERISTICS

Method of Examination & Test

A sample comprising of one core of sandstone, taken from the left hand side of the Town House's main door, by Stacey Rowntree and Dr Katie Strang, with the sample submitted for examination to assist in identifying a suitable source of replacement stone for use in remedial works. This report contains information on the currently available stone matches, information on historic quarries will be provided separately.

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, one dimensioned sub-sample was prepared and submitted to a range of physical tests to determine the properties of the stone. In addition, a slice was cut through the remaining sample 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. Thin section preparation was undertaken by Mr Mike Hall of the Department of Geosciences at The University of Edinburgh.

The thin section was submitted to a microscopic examination, which was undertaken with the aid of a 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.

This report presents observations from the microscopic examination.

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 in the image. This area of masonry was representative of sample SS1-type sandstone and the core was taken from a unit which will need to be replaced. Note the distinct black crust apparent on some masonry units.

MACROSCOPIC EXAMINATION

Plate 2. Core sample post thin section preparation. Note the variability of the orange staining throughout the core. Scale is in mm.

Plate 3. Fresh end of the core (furthest away from environmental exposure) showing significantly less iron oxide staining. Scale is in mm.

Plate 4. End of the core closest to surface – not speckled/mottled appearance in comparison to Plate 3.

The fresh, unweathered dry stone had a distinct blonde colour and was found to be 10YR 8/2 – 7/1 'very pale brown' to 'light grey' when assessed against the Munsell Soil Colour Charts. The weathered end of the core displayed a buff coloured, orange-mottled appearance found to be 10YR 8/3 – 8/4 'very pale brown' to 10YR 8/6 – 7/6 'yellow', with the speckled areas appearing 10YR 6/6 'brownish yellow'. The stone is generally fine to medium grained, and is a relatively heterogeneous sandstone that is variable across each different masonry unit within the building. There is evidence of a wide range of sedimentary structures such as cross bedding, ripple laminations (generally characterised by fine laminations with higher concentrations of Fe-oxides and carbonaceous matter), and massive bedded units throughout the stone used in the building. The fresh, unweathered sandstone is relatively well-compacted, hard, cohesive and is comprised of mainly sub-rounded to rounded and occasional angular quartz grains, 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 silica cement, along with lower proportions of calcite cement (as indicated by a weak reaction with 10% HCl acid). The main matrix of the stone is characterised by a blonde, to orange/brown, mottled appearance, which is imparted on the stone by Fe-rich clay inclusions and Fe-nodules. The abundance of these Fe inclusions is variably throughout the stones thickness, occasionally concentrated within bedding planes, which vary in their thickness and contain a greater proportion of these minerals.

MICROSCOPIC THIN SECTION EXAMINATION

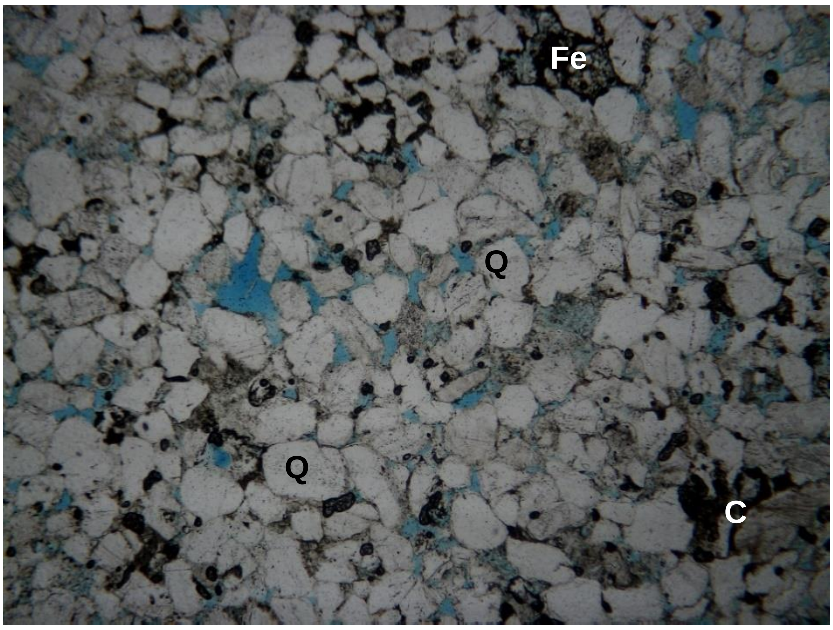
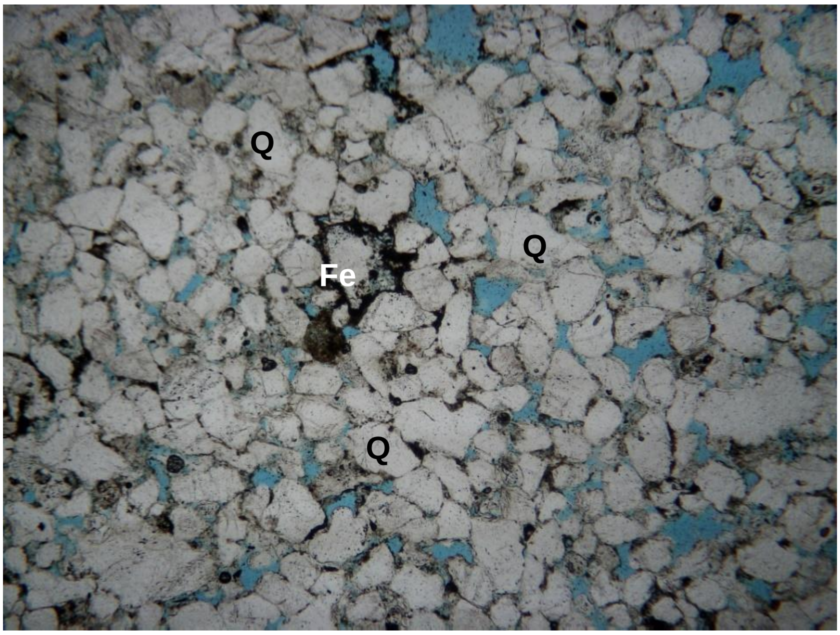
Texture: The stone displays a generally uniform fabric in thin section, with well distributed Fe-oxides and clays throughout and with no distinct spatial concentration or distribution of specific minerals anywhere within the thin section (although this can be seen in hand specimen). The stone is predominantly fine grained, moderately well sorted sandstone with grains ranging in size from 60µm to 250µm. The stone is relatively texturally sub-mature to mature, with most grains ranging in shape from angular to well-rounded and elongate to spherical, (but also some sub-angular to sub-rounded and rounded, and sub-spherical to spherical). Grains are primarily bound by silica cement, with kaolinite and Fe-oxides providing important secondary cements throughout the stone. Grains are moderately compacted, displaying a majority of point and line contacts.

Mineralogy: The stone contains a detrital framework mineralogy comprised predominantly of quartz grains, which are found as mainly monocrystalline, unstrained varieties (most 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. Silica, 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, however it is not completely homogenous.

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

Porosity: The stone contains a moderate visual porosity and moderate permeability (which may be reduced over areas which exhibit higher proportions/concentrations 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 10.04% - 14.27 % respectively.

Photomicrographs:

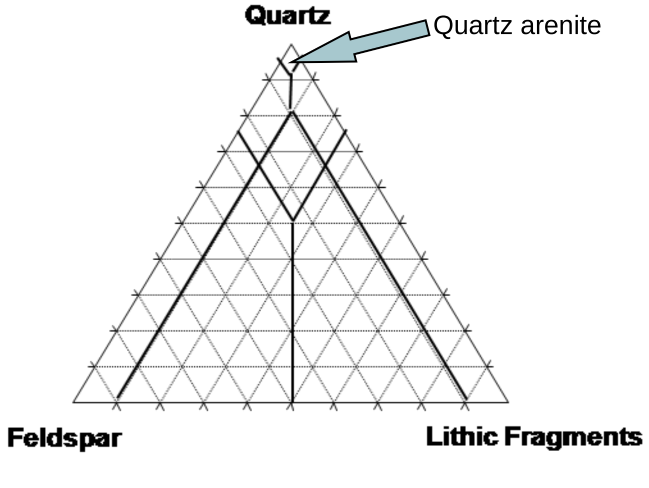
	**Plate 5. Thin section of the sample under plane polarised light. Pore spaces are highlighted in darker blue, while areas of light blue indicate pore filling clays that have absorbed some of the blue dye. The stone contains a high proportion of authigenic minerals, which in some areas may act to fill in and block pores spaces in varying regions throughout the stone. This is what imparts the speckled/mottled appearance to the stone in hand specimen. Q: quartz, Fe: Fe-oxide, C: carbonaceous matter.** **Field of view: 3mm.**
	**Plate 6. Thin section of the sample under plane polarised light. The stone contains a moderate open porosity throughout most of the stone, comprised of similarly sized intergranular pores. Q: quartz, Fe: Fe-oxide.** **Field of view: 3mm.**

Point Count Data:

Components	Total (%)	Q/F/L (quartz/feldspar/lithic % proportion)
Detrital Components		
Quartz	86	96.6
Feldspar	1	1.1
Lithic fragments	2	2.3
Detrital Clay	2	
Muscovite Mica	1	
Authigenic Minerals		
Quartz Overgrowths	0.5	
Indeterminate Clay	1.5	
Calcite	2	
Opaque Minerals	4	
Total	100	100
Porosity	10.04 – 14.27 %	

Table 1: 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 and smaller proportions of feldspar grains and lithic fragments.



Classification of sandstone after McBride (1963)[1]

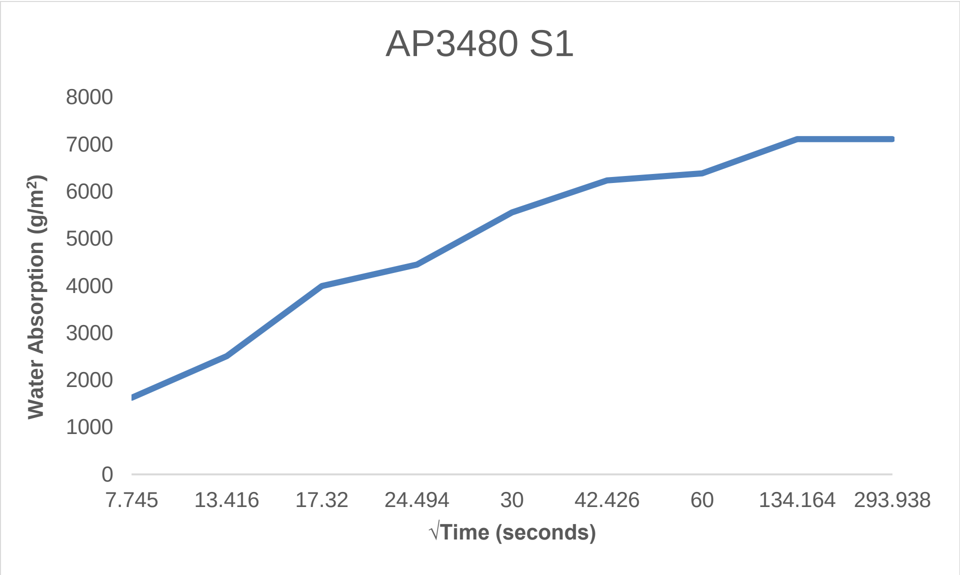
[1] **McBride, E. F. (1963), A classification of common sandstones. Journal of Sedimentary Petrology 33, 664-669**

PHYSICAL PROPERTIES

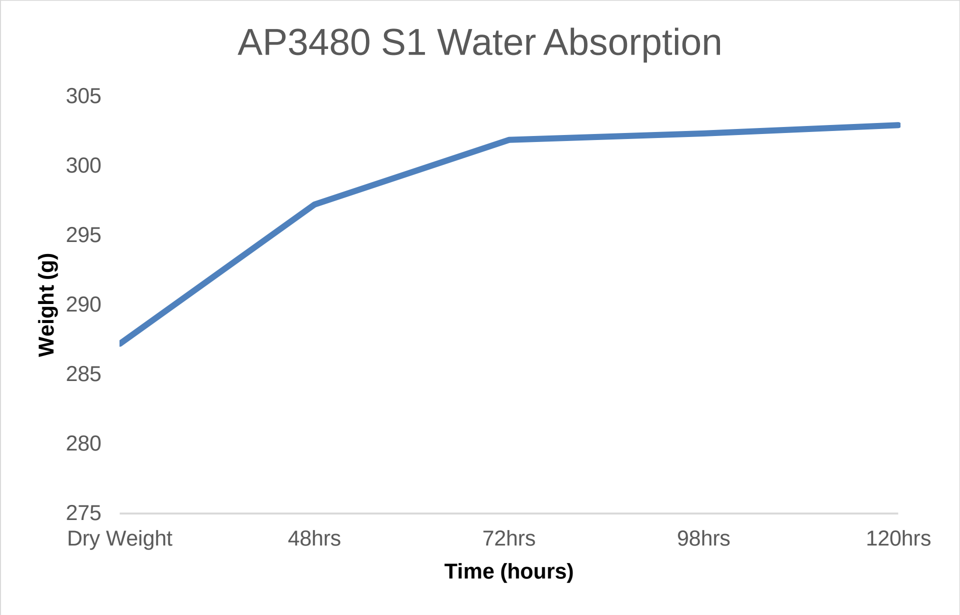
The results obtained from the physical tests are reproduced below, along with the data from stone that may be considered as potential replacements. The data reported for the potential sources was obtained from that held in the laboratory along with that reported in the current edition of the Natural Stone Directory, No. 20, 2016 - 17, and data obtained from a range of stone suppliers.

Total (%)	Analysed Sample	Blaxter sandstone	Swinton Sandstone	High Nick sandstone	Scotch Buff sandstone
Water Absorption %	5.47	6.14	6.4	6.00	5.70
Apparent Density (Kg/m^{-3})	2611	2110	2130	2140	2130
Porosity %	10.04 (effective) – 14.27 (open)	13 (effective) – 18.63 (open)	19.0 (open)	14.7 (effective) – 20.5 (open)	14 (effective) – 19.8 (open)
Saturation Coefficient	0.79	0.63	0.65	-	0.60
Capillary Coefficient (g/m^2/s)	89.76	52	-	72	134
Compressive Strength (MPa)	-	38 - 55	57	44	75
Acid Reaction	Weak reaction	Pass	Pass	Pass	Pass

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



Capillary coefficient graph for AP3480 S1



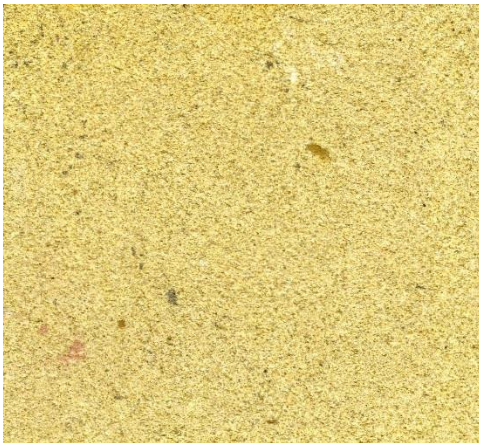
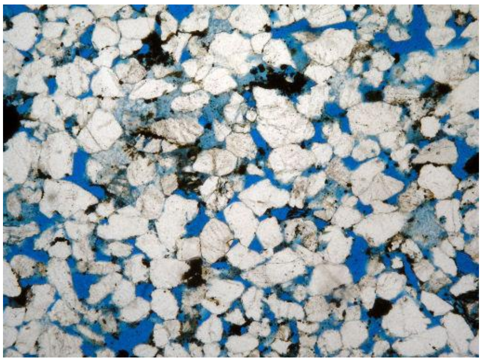
Water absorption graph for AP3480 S1

COMMENT

Sample AP3480 S1 (type SS1) from Inverkeithing Town House is a heterogeneous quartz arenite sandstone, which exhibits varying degrees of Fe-oxide remobilisation within the stone. The stone has experienced considerable supergene changes and undergone significant weathering and alteration, particularly towards the exposed surface, through the precipitation and remobilisation of Fe-oxide within carbonaceous laminations in the stone. Grains are commonly bound by thin silica lenses and some authigenic pore filling clays. This stone resembles common carboniferous stone used throughout the central belt and the below matches are currently available sandstones; historic quarry information will be discussed separately.

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>
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.
</td>
<td>
Dunhouse Natural Stone
Dunhouse Quarry Ltd,
Darlington,
County Durham,
DL2 3QU
Tel: 01833 660 208


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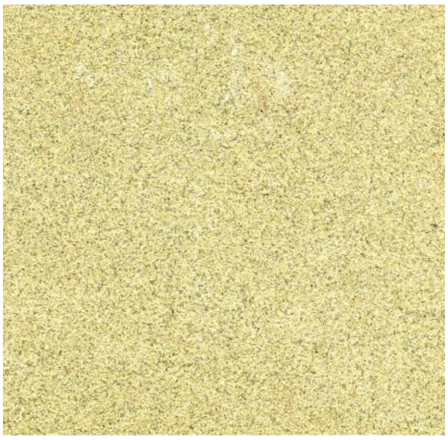
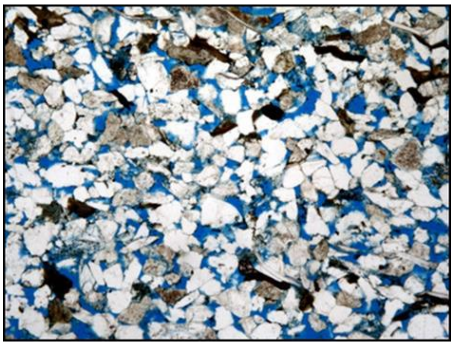
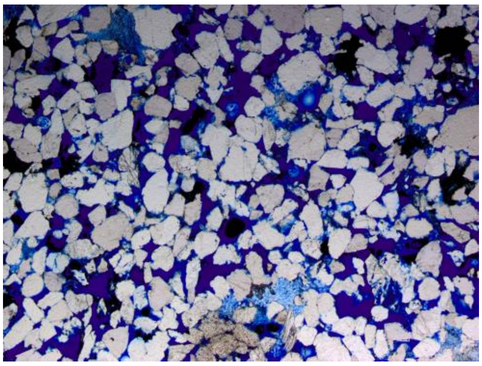
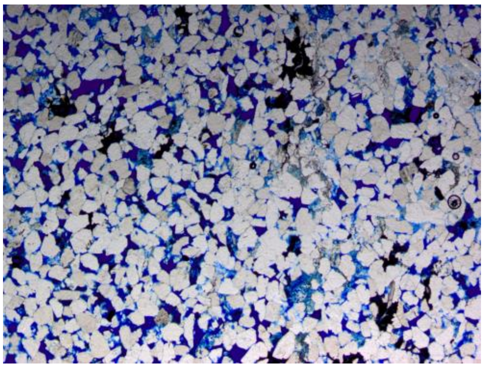
Swinton Sandstone **Colour:** Buff to grey to green **Fabric:** Mainly uniform **Grain size:** Medium grained. **Permeability:** Moderate to high. **Distinctive features:** Swinton sandstone can commonly show tonal colour variation caused by Fe-oxide remobilisation. **Comments:** The more buff coloured variety should be sought.	**Swinton Quarry** **Hutton Stone Co Ltd.** **Masons & Stone Merchants,** **West Fishwick,** **Berwick Upon Tweed,** **TD15 1XQ**  

High Nick Sandstone	Border Stone Quarries,
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.	**Kirkholmedale** **Lanty's Lonnen** **Haltwhistle** **Northumberland** **NE49 0HQ** **Tel: 01434 322140**  

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.	**Blockstone Ltd,** **Gatherly Moor (Scotch Buff Quarry),** **Gilling West,** **Nr Richmond** **DL10 5LL,** **Tel: 01246 927100 (sales)**  

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.

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 3480
Inverkeithing Town Hall,
Inverkeithing Stone and Slate
Audit

Sample 2 - Type SS2

Masonry

SITE	Inverkeithing Town Hall, Inverkeithing Stone and Slate Audit
CLIENT	Fife Historic Buildings Trust
DATE SAMPLE RECEIVED	18/12/19
ANALYSIS/EXAMINATION DATES	18/12/19 – 10/02/20
ANALYSIS, INTERPRETATION & REPORT BY	Dr Katie Strang and Roz Artis
CLIENT REQUIREMENTS	Petrographic Examination for Stone Source Matching
STRUCTURE DATE	Original building 1770
STRUCTURE TYPE	Town Hall
STONE TYPE	Sandstone
LOCATION/ FUNCTION IN STRUCTURE	Stone from right hand side of door
CONDITION OF SAMPLE RECEIVED	The sample received consisted of a fresh core of sandstone Total mass of sample received = 298.74 grams

DETERMINATION OF STONE CHARACTERISTICS

Method of Examination & Test

A sample comprising of one core of sandstone, taken from the right hand side of the Town Hall's main door, by Stacey Rowntree and Dr Katie Strang, with the sample submitted for examination to assist in identifying a suitable source of replacement stone for use in remedial works. This report contains information on currently available sandstone sources; details of historic quarries will be provided separately.

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, one dimensioned sub-sample was prepared and submitted to a range of physical tests to determine the properties of the stone. In addition, a slice was cut through the remaining sample 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. Thin section preparation was undertaken by Mr Mike Hall of the Department of Geosciences at The University of Edinburgh.

The thin section was submitted to a microscopic examination, which was undertaken with the aid of a 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.

This report presents observations from the microscopic examination.

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 in the image (right of door where SS1 was taken). This area of masonry was representative of sample SS2-type sandstone and the core was taken from a unit which will need to be replaced. Note the distinct black crust apparent on some masonry units.

MACROSCOPIC EXAMINATION

Plate 2. Core sample post thin section preparation. Note the variability of the orange staining throughout the core, similar to that in S1. Scale is in mm.

Plate 3. The weathered end of the core. Scale is in mm.

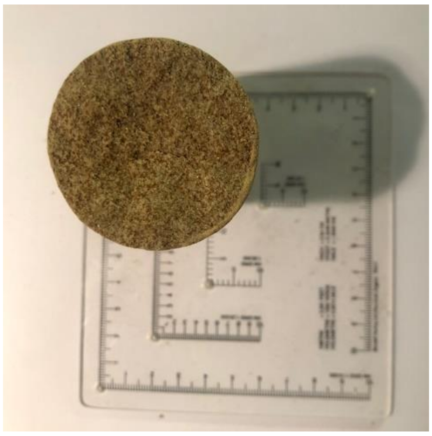


Plate 4. Fresh end of core– note speckled/mottled appearance in comparison to Plate 3. Scale is in mm

The fresh, unweathered dry stone was found to be 10YR 8/3 – 6/4 'very pale brown' to 'light yellowish brown' when assessed against the Munsell Soil Colour Charts. The weathered end of the core displayed an orange-mottled appearance found to be 10YR 8/4 'very pale brown' to 10YR 8/6 – 7/6 'yellow', with the speckled areas appearing 10YR 6/6 'brownish yellow'. The stone is generally fine to medium grained, and is a relatively heterogeneous sandstone that is variable across each different masonry unit within the building, most likely due to varying levels of Fe-oxide remobilisation. The fresh, unweathered sandstone is relatively well-compacted, hard and cohesive. The weathered surface is very friable and individual grains can be picked from the sandstone matrix with ease. The stone is predominately cemented by white frosted silica cement and Fe-oxides. The main matrix of the stone is characterised by a blonde, to orange/brown, mottled appearance, which is imparted on the stone by Fe-rich clay inclusions and Fe-nodules. The abundance of these Fe inclusions is variably throughout the stones thickness, occasionally concentrated within bedding planes, which vary in their thickness and contain a greater proportion of these minerals. The stone appears to be of poor building stone quality, owing to the inherent fabric/texture of the stone.

MICROSCOPIC THIN SECTION EXAMINATION

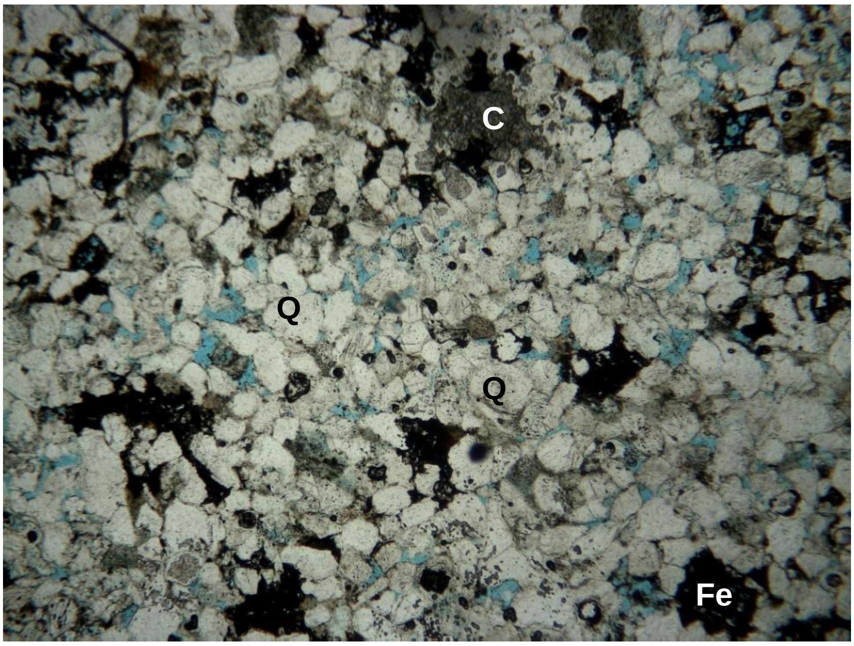
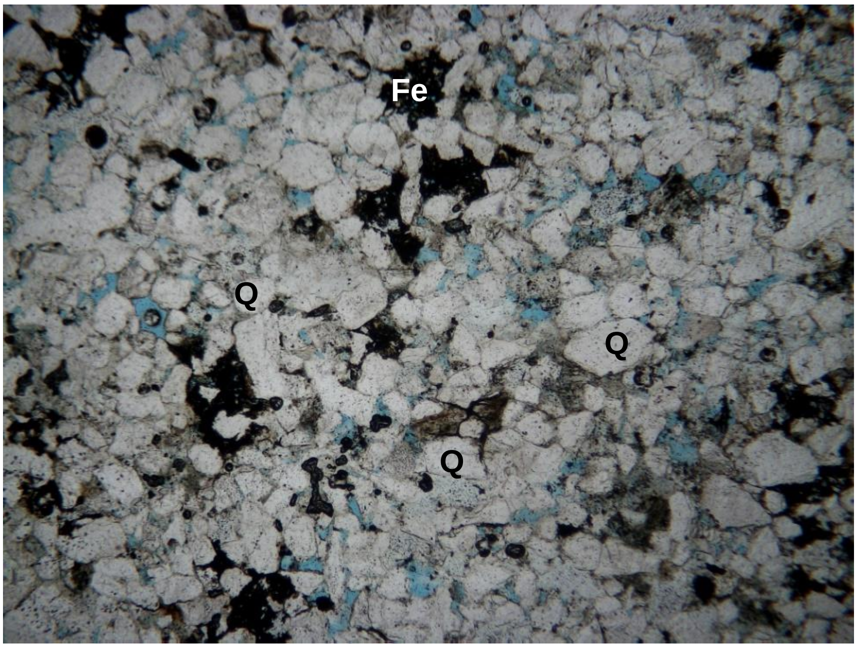
Texture: The stone displays a generally uniform fabric in thin section, with well distributed Fe-oxides and clays throughout and with no distinct spatial concentration or distribution of specific minerals anywhere within the thin section (although this can be seen in hand specimen). The stone is predominantly fine grained, moderately well sorted sandstone. The stone is relatively texturally sub-mature to mature, with most grains ranging in shape from angular to well-rounded and elongate to spherical. Grains are primarily bound by silica cement, with kaolinite and Fe-oxides providing important secondary cements throughout the stone. Grains are moderately compacted, displaying a majority of point and line contacts.

Mineralogy: The stone contains a detrital framework mineralogy comprised predominantly of quartz grains, which are found as mainly monocrystalline, unstrained varieties (most 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. Silica, 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, which is variable across masonry units.

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

Porosity: The stone contains a moderate visual porosity and moderate permeability (which may be reduced over areas which exhibit higher proportions/concentrations 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 9.49 – 14.98% respectively.

Photomicrographs:

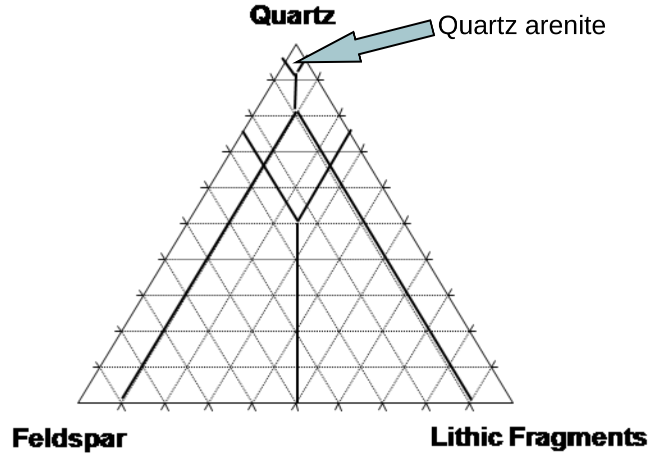
	**Plate 5. Thin section of the sample under plane polarised light. Pore spaces are highlighted in darker blue, while areas of light blue indicate pore filling clays that have absorbed some of the blue dye. The stone contains a high proportion of authigenic minerals, which in some areas may act to fill in and block pores spaces in varying regions throughout the stone. This is what imparts the speckled/mottled appearance to the stone in hand specimen. Q: quartz, Fe: Fe-oxide, C: carbonaceous matter.** **Field of view: 3mm.**
	**Plate 6. Thin section of the sample under plane polarised light. The. Q: quartz, Fe: Fe-oxide.** **Field of view: 3mm.**

Point Count Data:

Components	Total (%)	Q/F/L (quartz/feldspar/lithic % proportion)
Detrital Components		
Quartz	85	96.5
Feldspar	2	2.3
Lithic fragments	1	1.2
Detrital Clay	2	
Muscovite Mica	0.5	
Authigenic Minerals		
Quartz Overgrowths	1	
Indeterminate Clay	1.5	
Calcite	1	
Opaque Minerals	6	
Total	100	100
Porosity	9.49 – 14.98%	

Table 1: 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 and smaller proportions of feldspar grains and lithic fragments.



Classification of sandstone after McBride (1963)[1]

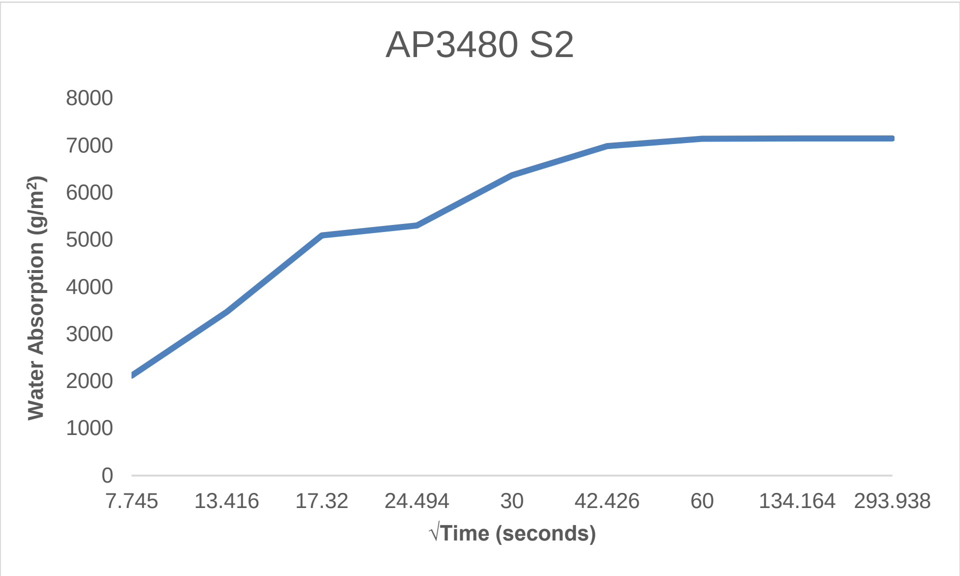
[1] McBride, E. F. (1963), A classification of common sandstones. Journal of Sedimentary Petrology 33, 664-669

PHYSICAL PROPERTIES

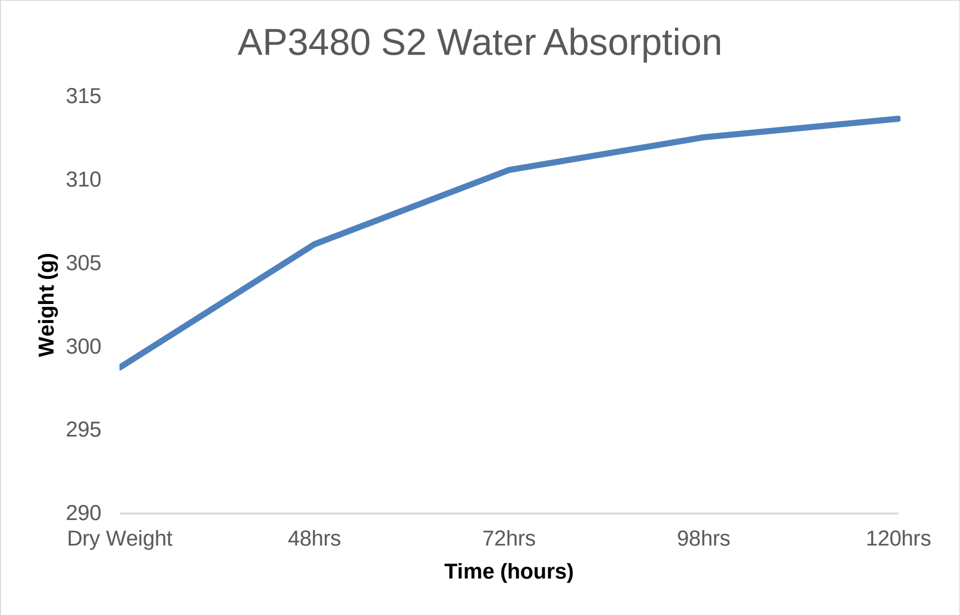
The results obtained from the physical tests are reproduced below, along with the data from stone that may be considered as potential replacements. The data reported for the potential sources was obtained from that held in the laboratory along with that reported in the current edition of the Natural Stone Directory, No. 20, 2016 - 17, and data obtained from a range of stone suppliers.

Total (%)	Analysed Sample	Blaxter sandstone	Stainton sandstone	High Nick sandstone	Scotch Buff sandstone
Water Absorption %	4.99	6.14	4.8	6.00	5.70
Apparent Density (Kg/m^{-3})	2480	2110	2190	2140	2130
Total Porosity %	9.49 (effective) - 14.98 (open)	13 (effective) – 18.63 (open)	- 17.3 (open)	14.7 (effective) – 20.5 (open)	14 (effective) – 19.8 (total)
Saturation Coefficient	0.99	0.63	0.64	-	0.60
Capillary Coefficient (g/m^2/s)	116.78	52	-	72	134
Compressive Strength (MPa)	-	38 - 55	48.0 – 55.3	44	75
Acid Reaction	No reaction	Pass	Pass	Pass	Pass

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



Capillary coefficient graph for AP3480 S2



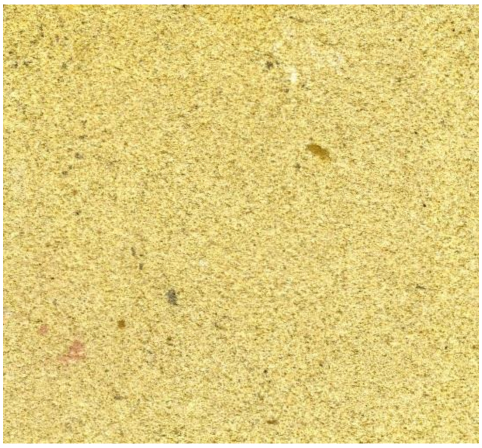
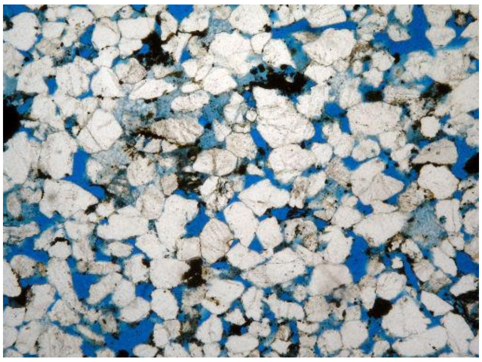
Water absorption graph for AP3480 S2

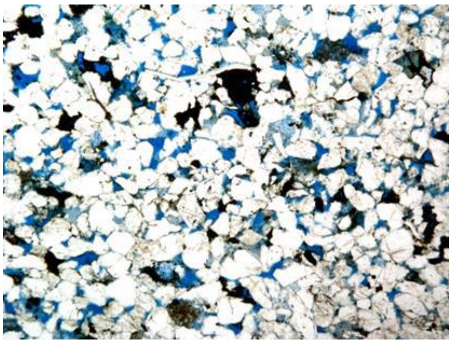
COMMENT

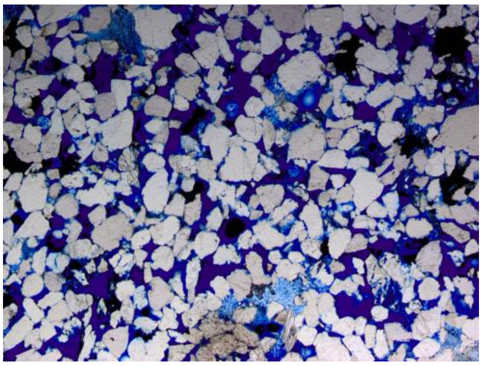
Sample AP3480 S2 (type SS2) from Inverkeithing Town House is a heterogeneous quartz arenite sandstone, which exhibits extensive and varying degrees of Fe-oxide remobilisation within the stone. The stone has experienced considerable supergene changes and undergone significant weathering and alteration, particularly towards the exposed surface, through the precipitation and remobilisation of Fe-oxide in the stone. Grains are commonly bound by thin silica lenses and some authigenic pore filling clays. This stone resembles common carboniferous stone used throughout the central belt and details of historic quarries will be provided separately. The below contains information on currently available matching stones.

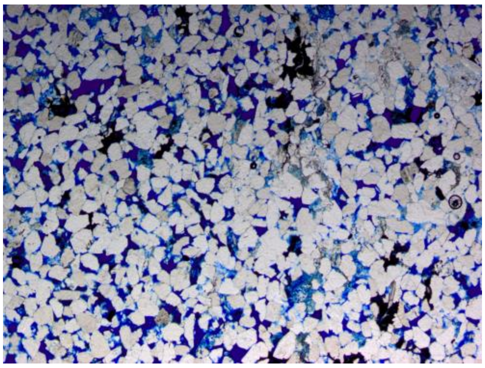
In regards to choosing a suitable matching stone, it must be remembered that because stone is a natural material, it can vary in colour and appearance both over time and spatially within a quarry. It is therefore important to check the colour and appearance/obtain representative samples of the stone 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:

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**  

Stainton Sandstone **Colour:** Buff to light greyish buff **Fabric:** Mainly uniform **Grain size:** Fine to medium grained. **Permeability:** Moderate to high. **Distinctive features:** Stainton sandstone commonly exhibits a speckled appearance due to Fe-oxide content. **Comments:** The medium grained, buff coloured variety should be sought.	**Stainton Quarry,** **Natural Stone Products Ltd** **Barnard Castle,** **Durham,** **DL12 8RB** **Tel: 01833 690444**  

High Nick Sandstone	Border Stone Quarries,
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.	**Kirkholmedale** **Lanty's Lonnen** **Haltwhistle** **Northumberland** **NE49 0HQ** **Tel: 01434 322140**  

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.	**Blockstone Ltd,** **Gatherly Moor (Scotch Buff Quarry),** **Gilling West,** **Nr Richmond** **DL10 5LL,** **Tel: 01246 927100 (sales)**  

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.

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.

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

STONE ANALYSIS

& MATCHING REPORT

AP 3480
Inverkeithing Town House,
Inverkeithing Stone and Slate
Audit

Sample 3 - Type SS3

Flagstone

SITE	Inverkeithing Town House, Inverkeithing Stone and Slate Audit
CLIENT	Fife Historic Buildings Trust
DATE SAMPLE RECEIVED	18/12/19
ANALYSIS/EXAMINATION DATES	18/12/19 – 10/02/20
ANALYSIS, INTERPRETATION & REPORT BY	Dr Katie Strang and Roz Artis
CLIENT REQUIREMENTS	Petrographic Examination for Stone Source Matching
STRUCTURE DATE	Original building 1770
STRUCTURE TYPE	Town House/Hall
STONE TYPE	Sandstone
LOCATION/ FUNCTION IN STRUCTURE	Stone from the bothy floor
CONDITION OF SAMPLE RECEIVED	The sample received consisted of a fresh core of sandstone Total mass of sample received = 347.28 grams

DETERMINATION OF STONE CHARACTERISTICS

Method of Examination & Test

A sample comprising of one core of sandstone, taken from the flagstone floor of the Town House Bothy, by Stacey Rowntree and Dr Katie Strang, with the sample submitted for examination to assist in identifying a suitable source of replacement stone for use in remedial works.

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, one dimensioned sub-sample was prepared and submitted to a range of physical tests to determine the properties of the stone. In addition, a slice was cut through the remaining sample 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. Thin section preparation was undertaken by Mr Mike Hall of the Department of Geosciences at The University of Edinburgh.

The thin section was submitted to a microscopic examination, which was undertaken with the aid of a 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.

This report presents observations from the microscopic examination.

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.

MACROSCOPIC EXAMINATION

In hand specimen the fresh, unweathered sample was found to be 7.5YR 8/1 'white' to 7.5YR 8/2 'pinkish white' and 10YR 7/2 'light grey' when assessed against the Munsell Soil Colour Charts. The sandstone is predominantly fine grained throughout. The sample is coherent and well cemented, however does show slight alteration on the upper surface. The stone is characterised by distinct narrow and generally discontinuous 'wispy' laminations that are present throughout the thickness of the sample; ranging in thickness from ~0.5mm to a maximum of 0.9mm. The stone appears to be semi-texturally immature, mineralogically sub-mature to mature in the most, with moderately sorted grains; with two main grain size classes visually identified under binocular microscope. The stone is composed of sub-angular to sub-rounded, sub-spherical, grey coloured quartz grains, with a relatively low proportion of Fe-oxides, clay inclusions, muscovite mica and lithic fragments within the main matrix mineralogy. Fe-oxides, carbonaceous matter, clays and mica are accumulated in high concentrations within the distinct laminations in the stone. The layers appear to vary in thickness throughout the depth of the sample and show a generally 'wispy' texture.

Plate 1. Sample as received pre thin section preparation. Scale is in mm.

MICROSCOPIC THIN SECTION EXAMINATION

Texture: The stone contains a microscopic laminated texture that is prevalent throughout the thickness of the sample. Most layers comprise accumulated Fe-oxides, clays, muscovite, biotite and carbonaceous matter and are regularly very narrow. These laminations are very common on the microscopic scale, infilling pore spaces and as narrow veins that infill pore throats. The stone is predominantly fine grained, with some coarser grained regions and layers evident between laminations throughout the stone. The sample is relatively texturally immature and moderately to poorly sorted, containing a range of sub-angular to sub-rounded and sub-elongate to sub-spherical grains throughout. Most grains are fine grained and sub-angular to sub-rounded and sub-spherical in shape and are well compacted and cemented. Grains show a range of grain contact types and are bound by silica cement along grain point contacts (as quartz overgrowths).

Mineralogy: The main framework mineralogy is composed of a majority of fine to medium grained, sub-rounded, sub-spherical quartz grains, found as both mono-crystalline and to a significantly lower proportion poly-crystalline varieties and as unstrained and strained grains that show an undulose texture. The sandstone is relatively mineralogically mature, containing a low relative proportion of mainly similar sized and shaped (in relation to quartz) feldspar grains, found as both microcline (orthoclase) and plagioclase feldspar, dolomite cement, authigenic and detrital clays, a range of different sized muscovite and biotite mica grains, Fe-oxides and carbonaceous matter; the latter three of which are found concentrated within narrow laminations in the stone. Feldspar and muscovite grains show a relatively high degree of decomposition and alteration into kaolinite and chlorite clays. Some areas of the stone, where there are laminations containing mica/Fe oxides and carbonaceous matter, have undergone alteration and dissolution. This significantly decreases the strength of the stone affects the porosity in these regions, and it likely why the sample is spalling and very friable. Muscovite grains show a similar orientation to the Fe-rich laminations and generally poorly distributed throughout the stone.

Porosity: The stone contains a moderate porosity, measured as between 11.42 - 15.47%, with permeability being significantly lower across regions of the stone with higher concentrations of Fe oxides and carbonaceous matter.

Photomicrographs:

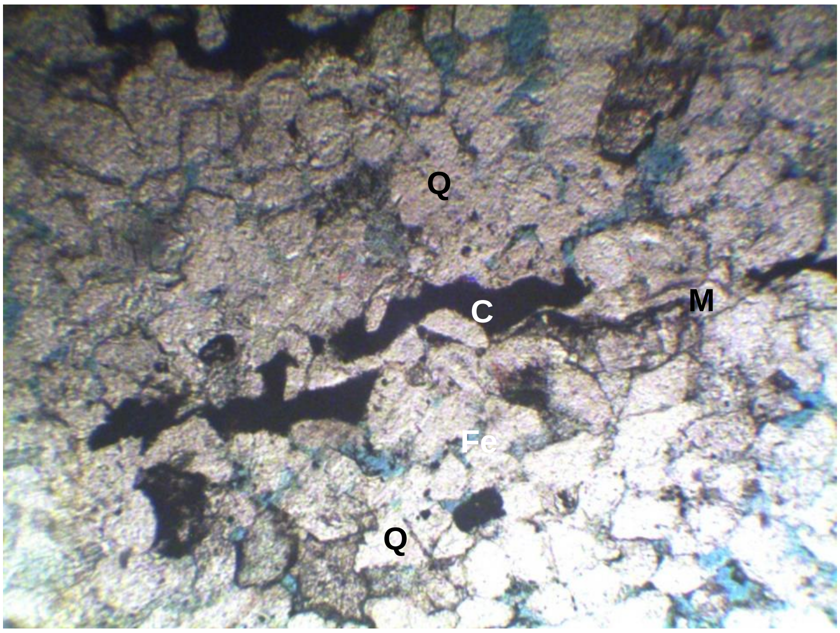


Plate 2. Thin section of the sample under plane polarised light. Pore spaces are highlighted in darker blue, while areas of light blue indicate pore filling clays that have absorbed some of the blue dye. Narrow carbonaceous and mica-rich laminations are evident throughout the sample, completely blocking pores and creating barriers to flow in these regions. Q: quartz, M: mica, Fe: Fe-oxide, C: carbonaceous matter.

Field of view: 3mm.

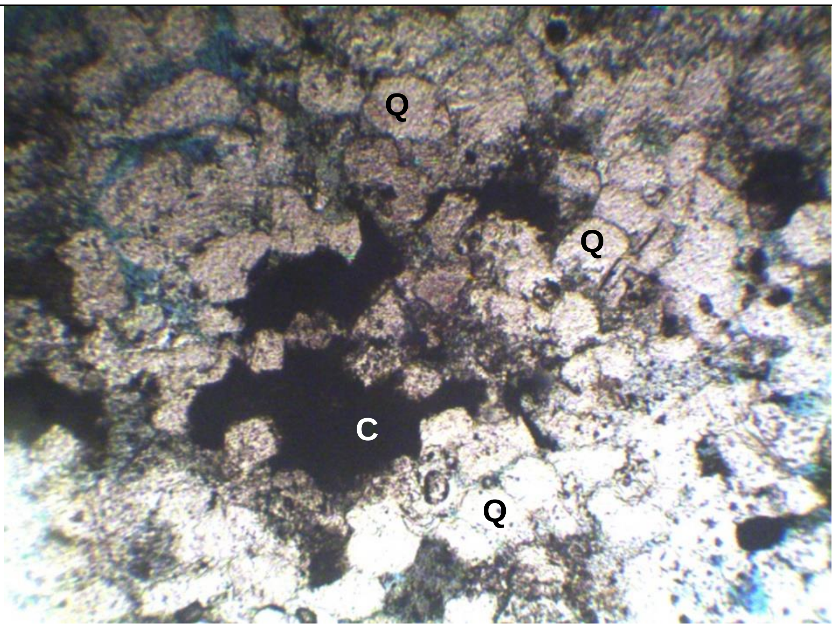


Plate 3. Thin section of the sample under plane polarised light. The stone contains an extremely high proportion of authigenic minerals, mainly Fe oxides, infilling and blocking pores spaces in small regions throughout the stone. Q: quartz, C: carbonaceous matter

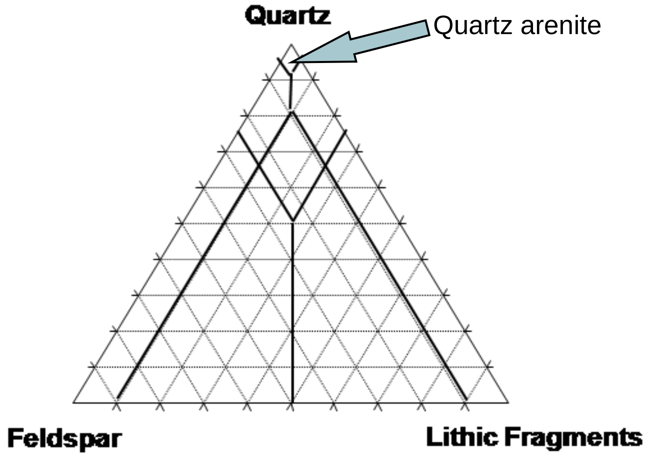
Field of view: 3mm.

Point Count Data:

Components	Total (%)	Q/F/L (quartz/feldspar/lithic % proportion)
Detrital Components		
Quartz	81	94
Feldspar	3	3.4
Lithic fragments	2	2.6
Detrital Clay	3	
Muscovite Mica	2	
Authigenic Minerals		
Quartz Overgrowths	0.5	
Indeterminate Clay	3.5	
Calcite	0	
Opaque Minerals	5	
Total	100	100
Porosity	11.42 - 15.47%	

Table 1: 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 and smaller proportions of feldspar grains and lithic fragments.



Classification of sandstone after McBride (1963)[1]

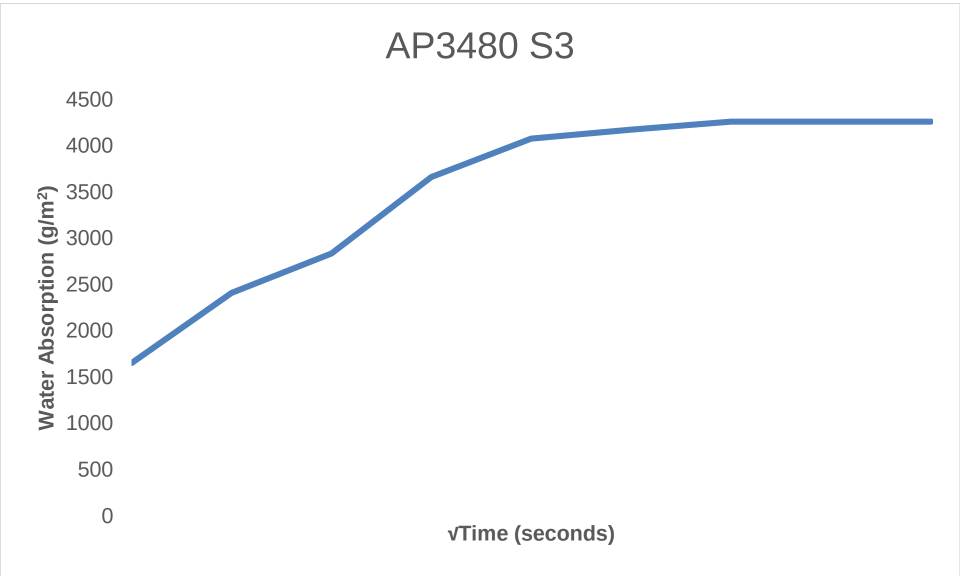
[1] **McBride, E. F. (1963), A classification of common sandstones. Journal of Sedimentary Petrology 33, 664-669**

PHYSICAL PROPERTIES

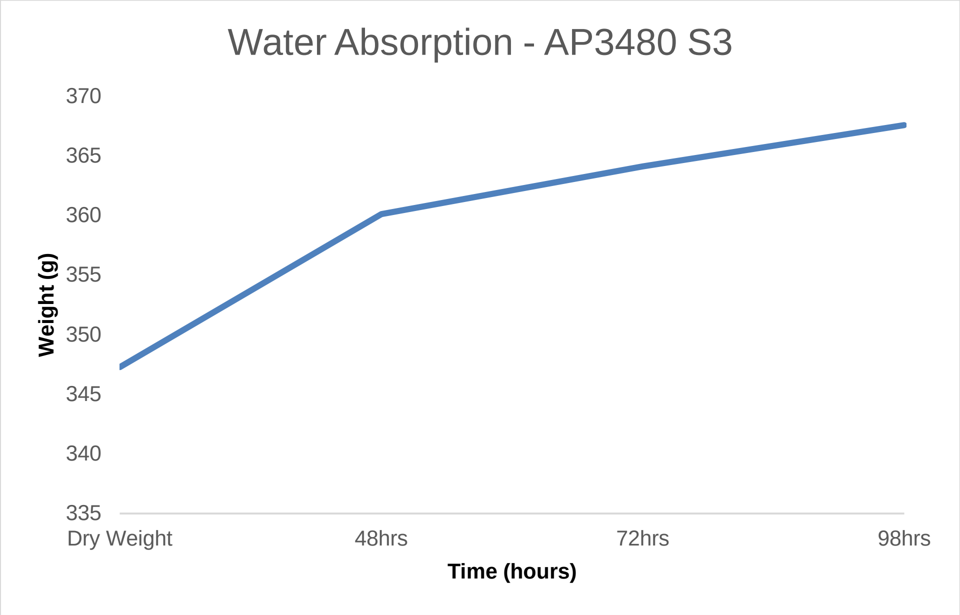
The results obtained from the physical tests are reproduced below, along with the data from stone that may be considered as potential replacements. The data reported for the potential sources was obtained from that held in the laboratory along with that reported in the current edition of the Natural Stone Directory, No. 20, 2016 – 2017, and data obtained from a range of stone suppliers.

Total (%)	Analysed Sample	Scotch Buff sandstone
Water Absorption %	5.85	5.70
Apparent Density (Kg/m^{-3})	2340	2130
Total Porosity %	11.42 (effective) - 15.47 (open)	14 (effective) – 19.8 (total)
Saturation Coefficient	0.89	0.60
Capillary Coefficient (g/m^2/s)	173.96	134
Compressive Strength (MPa)	-	75
Acid Reaction	No Reaction	Pass

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



Capillary coefficient graph for AP3480 S3



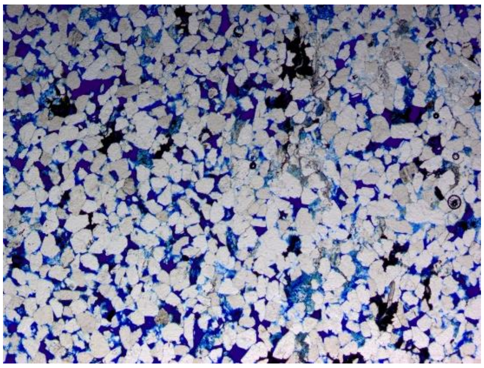
Water absorption graph for AP3480 S3

COMMENT

Sample AP3480 S3 (type SS3) from Inverkeithing Town House is an irregularly laminated, quartz arenite sandstone that is relatively texturally immature and relatively mineralogically mature. The stone contains a majority of sub-angular to sub-rounded, sub-spherical, fine grained quartz, with high relative proportions of mica and low proportions of feldspar and lithic fragments. The stone has experienced considerable supergene changes and undergone significant weathering and alteration, through the precipitation and remobilisation of Fe-oxide within carbonaceous laminations in the stone. Grains are commonly bound by thin silica lenses and some authigenic pore filling clays. This stone resembles common carboniferous stone used throughout the central belt. For example, it is known that certain beds within the carboniferous Craigleith quarry contained ripple bedded sandstone (commonly referred to as “feak” rock) similar to, and this bedded Craigleith stone is seen in many buildings throughout Edinburgh (e.g. National Monument, Calton Hill). This Craigleith feak rock is recorded as having been used for rubble work, foundations, steps, plats and paving and is essentially indistinguishable from Hailes sandstone. It is therefore likely that that this material is from a similar deposit.

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:

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.	**Blockstone Ltd,** **Gatherly Moor (Scotch Buff Quarry),** **Gilling West,** **Nr Richmond** **DL10 5LL,** **Tel: 01246 927100 (sales)**  

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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.

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

STONE ANALYSIS

& MATCHING REPORT

AP 3480
Hill Street Boundary Wall,
Inverkeithing Stone and Slate
Audit

Sample 7 - Type W1

Whinstone/dolerite

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www.scotlime.org VAT no 671 2677 22 admin@scotlime.org

SITE	Hill Street Boundary Wall, Inverkeithing Stone and Slate Audit
CLIENT	Fife Historic Buildings Trust
DATE SAMPLE RECEIVED	18/12/19
ANALYSIS/EXAMINATION DATES	18/12/19 – 23/02/20
ANALYSIS, INTERPRETATION & REPORT BY	Dr Katie Strang and Roz Artis
CLIENT REQUIREMENTS	Petrographic Examination for Stone Source Matching
STRUCTURE DATE	? Mid 19th century or earlier
STRUCTURE TYPE	Boundary Wall
STONE TYPE	Whinstone / dolerite
LOCATION/ FUNCTION IN STRUCTURE	Stone from right side of boundary wall
CONDITION OF SAMPLE RECEIVED	The sample received consisted of an intact piece of rubble masonry Total mass of sample received = 688.54 grams

DETERMINATION OF STONE CHARACTERISTICS

Method of Examination & Test

A sample comprising of one block of whinstone rubble masonry, taken from the Boundary Wall at Hill Street, Inverkeithing, by Stacey Rowntree and Dr Katie Strang, with the sample submitted for examination to assist in identifying a suitable source of replacement stone for use in remedial works.

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, one dimensioned sub-sample was prepared and submitted to a range of physical tests to determine the properties of the stone. In addition, a slice was cut through the remaining sample 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. Thin section preparation was undertaken by Mr Mike Hall of the Department of Geosciences at The University of Edinburgh.

The thin section was submitted to a microscopic examination, which was undertaken with the aid of a 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.

This report presents observations from the microscopic examination.

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.

MACROSCOPIC EXAMINATION

In hand specimen the weathered surface of the sample was found to be 10YR 5/3 'brown' to 10YR 4/3 'brown', while the fresh, un-weathered surface was found to be GLEY1 4/1 'dark greenish grey' to GLEY2 3/1 'very dark greenish grey' when assessed against the Munsell Soil Colour Charts. The sample was removed as an intact piece of rubble masonry from a boundary wall. Rubble whinstone commonly displays an irregular shape; a consequence of its high strength, low friability, low porosity and crystalline structure. The stone is known as a whinstone; which is a general term that describes any hard, dark crystalline rock. This sample is an extremely hard, medium to finely-crystalline rock composed of tightly interlocking crystals that can be seen in hand specimen. The sample contains a dark groundmass/underlying matrix composed mainly from pyroxene and plagioclase feldspar that are generally elongated and display a lath shape, with the largest crystals measuring ~1-2mm in diameter. The surface of the sample is heavily weathered, with signs of onion skin weathering noted. The weathering front extends to a depth of around 3-10mm into the stone, and is characterised by a lighter colour than the fresh stone. These lighter red/brown coloured areas are due to weathering of Fe-bearing minerals such as olivine and pyroxene within the stone. The sample experienced an extremely low water absorption capacity when subjected to the water droplet test. This lack of water absorption is indicative of a low porosity and low permeability stone, due to the interlocking crystalline nature of the pores.

Plate 1. Sample as received pre thin section preparation. Showing heavily weathered surface and signs of "onion skin" weathering. Scale is in mm.

MICROSCOPIC THIN SECTION EXAMINATION

Texture:

The sample displays an ophytic texture, with slender to broad plagioclase laths wrapped or moulded by anhedral to subhedral pyroxene. It is generally medium-crystalline, uniform and equigranular throughout. Crystals are visible in hand specimen, placing the stone texture on the side of phaneritic (visible), however dolerite sills are typically shallow intrusive bodies and often exhibit fine grained to aphanitic chilled margins which may contain tachylite (dark mafic glass) and the appearance of a finer grained aphantic (non-visible) texture in some regions.

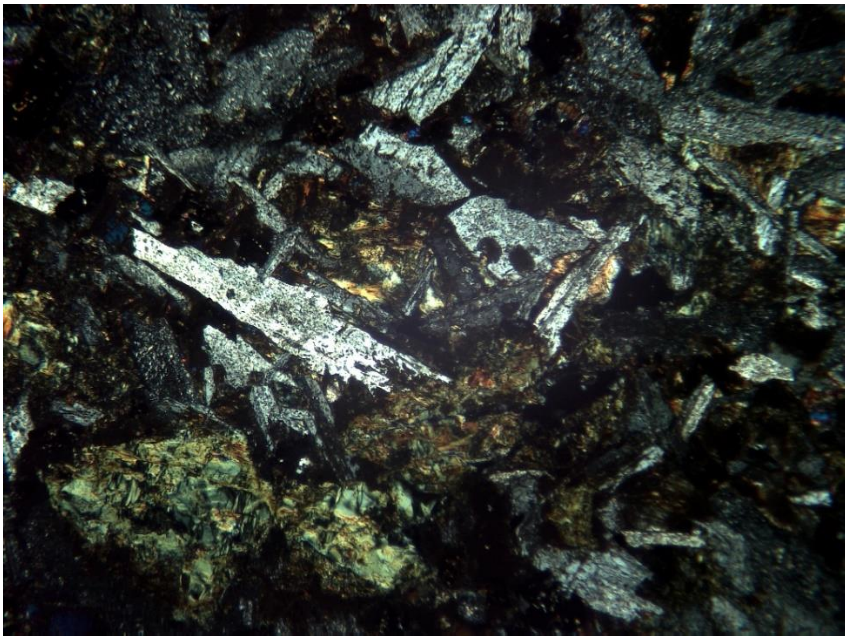
Mineralogy:

The stone contains a high proportion of medium to large euhedral lath shaped, elongate plagioclase crystals within a groundmass of clinopyroxene and olivine crystals. The groundmass consists of tightly interlocking, equigranular to anhedral crystals of clinopyroxene (in the form of augite) and a small proportion of sub-spherical to sub-angular, smaller sized olivine crystals that show high birefringence and high relief in thin section. Augite crystals show a poikilitic texture, whereby small crystals of plagioclase are found crystallised within its crystal structure. Plagioclase feldspar crystals show distinctive polysynthetic, multiple twinning and Carlsbad twinning throughout, with both types occasionally present in the same crystal. Both olivine and pyroxene show alteration throughout, forming a small proportion of chlorite within the rock, providing the stone with its green hue in thin section. Opaque iron minerals are also found as minor mineral constituents within the rock.

Porosity:

The sample contains a very low visual porosity and extremely low permeability, estimated to be < 3%. However, crystalline impervious rocks such as dolerite can become porous if large fractures are created within the stone from construction work/quarry extraction.

Photomicrographs:

	**Plate 2. Thin section of the sample under plane polarised light. Pore spaces are highlighted in darker blue, while areas of light blue indicate pore filling clays that have absorbed some of the blue dye. Image in plane polarised light showing the ophitic crystalline texture Chlorite (an alteration mineral) provides the thin section with its distinctive green hue.** **Field of view: 3mm.**
	**Plate 3. Thin section of the sample under cross polarised light. The stone is dominated by a high proportion of plagioclase feldspar laths that show Carlsbad and multiple twinning.** **Field of view: 3mm.**

COMMENT

Sample AP3480 S7 (type W1) from Hill Street Boundary Wall is a dolerite (also known as whinstone, diabase or microgabbro); it is a medium-sometimes fine crystalline basic intrusive igneous rock that is silica poor and is composed of a groundmass comprising a high proportion of lath shaped plagioclase feldspar and clinopyroxene, Olivine and augite have occasionally altered into chlorite, providing the thin section with is distinct green hue. This rock is likely from a quarry which worked an outcrop of the Midland Valley Sill Complex. In geology, a sill is an igneous intrusion, where molten lava gets pushed between pre-existing layers of rock. This major intrusion outcrops locally to Inverkeithing and is estimated to underlie an area of 1900 square kilometres around the inner Firth of Forth, and reaches a thickness of over 200m at some points. Details on historic quarries will be provided separately.

Tradstocks currently supplies dimensional ‘whinstone’, which might provide a suitable stone match. This stone is described as grey/dark grey to black and coarse to medium crystalline Gabbro/Dolerite. This stone might match petrographically with the dolerite whinstone from Inverkeithing, as it does provide hard, dark crystalline rock that shares similar porosity and permeability characteristics as well as colour and texture.

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.

A common suggestion when recommending suitable matching stone for crystalline rock (igneous/metamorphic) is to approach aggregate quarries that work similar hard rock. We do not recommend this approach on the basis of the unsuitable extraction process (blasting) at these quarries for dimensional stone. By blasting the stone for aggregate, this can produce both macro (large) and micro (small) fractures within the rock that can have detrimental future consequences for both the stone and the building it is used in. By creating fractures (even in low porosity and impervious rock), the water absorption rate of the rock can significantly increase, introducing moisture into the building that cannot be easily remediated, leading, in some cases, to severe future problems. It is with this in mind, that no matching stone quarries are listed, as there are none within the UK that currently produce matching dimensional stone. In the first instance, obtaining local reclaimed stone from a demolition contractor, or from local outcrops, would be recommended.

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

STONE ANALYSIS

& MATCHING REPORT

AP 3480
Bank Street Salon,
Inverkeithing Stone and Slate
Audit

Sample 10 - Type SS1

Masonry

SITE	Bank Street Salon, Inverkeithing Stone and Slate Audit
CLIENT	Fife Historic Buildings Trust
DATE SAMPLE RECEIVED	18/12/19
ANALYSIS/EXAMINATION DATES	18/12/19 – 28/02/20
ANALYSIS, INTERPRETATION & REPORT BY	Dr Katie Strang and Roz Artis
CLIENT REQUIREMENTS	Petrographic Examination for Stone Source Matching
STRUCTURE DATE	Mid 19th century
STRUCTURE TYPE	Hair salon
STONE TYPE	Sandstone
LOCATION/ FUNCTION IN STRUCTURE	Stone from side elevation
CONDITION OF SAMPLE RECEIVED	The sample received consisted of a fresh core of sandstone Total mass of sample received = 258.14 grams

DETERMINATION OF STONE CHARACTERISTICS

Method of Examination & Test

A sample comprising of one core of sandstone, taken from the side elevation of Bank Street Salon, by Stacey Rowntree and Dr Katie Strang, with the sample submitted for examination to assist in identifying a suitable source of replacement stone for use in remedial works.

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, one dimensioned sub-sample was prepared and submitted to a range of physical tests to determine the properties of the stone. In addition, a slice was cut through the remaining sample 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. Thin section preparation was undertaken by Mr Mike Hall of the Department of Geosciences at The University of Edinburgh.

The thin section was submitted to a microscopic examination, which was undertaken with the aid of a 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.

This report presents observations from the microscopic examination.

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 in the image. This area of masonry was representative of SS1 type sandstone and the core was taken from a unit which will need replaced. Note the distinct black crust apparent on some masonry units.

MACROSCOPIC EXAMINATION

Plate 2. Core sample post thin section preparation. Note the variability of the orange staining throughout the core. Scale is in mm.

Plate 3. Fresh end of the core (furthest away from environmental exposure) still showing significantly friability. Scale is in mm.

Plate 4. Fresh face of core. Note the slightly speckled appearance. Scale is in mm.

The fresh, unweathered dry stone had a distinct orange/brown/blonde colour and was found to be 10YR 8/2 – 6/4 ‘very pale brown’ to ‘light yellowish brown’ when assessed against the Munsell Soil Colour Charts. Both the fresh face and weathered end of the core displayed a buff coloured, orange-mottled appearance found to be 10YR 8/3 – 8/4 ‘very pale brown’ to 10YR 8/6 – 7/6 ‘yellow’, with the speckled areas appearing 10YR 6/6 ‘brownish yellow’. The stone is generally fine to medium grained, and is a relatively heterogeneous sandstone that is variable across each different masonry unit within the building. There is evidence of a wide range of sedimentary structures such as cross bedding, ripple laminations (generally characterised by fine laminations with higher concentrations of Fe-oxides and carbonaceous matter), and massive bedded units throughout the stone used in the building. The fresh, unweathered sandstone is relatively well-compacted, hard, cohesive and is comprised of mainly sub-rounded to rounded and occasional angular quartz grains, 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 silca cement, along with lower proportions of calcite cement (as indicated by a weak reaction with 10% HCl acid). The main matrix of the stone is characterised by a blonde, to orange/brown, mottled appearance, which is imparted on the stone by Fe-rich clay inclusions and Fe-nodules. The abundance of these Fe inclusions is variably throughout the stones thickness, occasionally concentrated within bedding planes, which vary in their thickness and contain a greater proportion of these minerals. The stone appears to be of poor building stone quality, owing to the inherent fabric/texture of the stone.

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 (although this can be seen in hand specimen). The stone is predominantly fine to medium grained, moderately well sorted sandstone. The stone is relatively texturally sub-mature to mature, with most grains ranging in shape from angular to well-rounded and elongate to spherical, (but also some sub-angular to sub-rounded and rounded, and sub-spherical to spherical). Grains are primarily bound by silica 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.

Mineralogy: The stone contains a detrital framework mineralogy comprised predominantly of quartz grains, which are found as mainly monocrystalline, unstrained varieties (most 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. Silica, 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, however it is not completely homogenous.

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

Porosity: The stone contains a moderate visual porosity and moderate permeability (which may be reduced over areas which exhibit higher proportions/concentrations 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 14.93% - 19.68% respectively.

Photomicrographs:

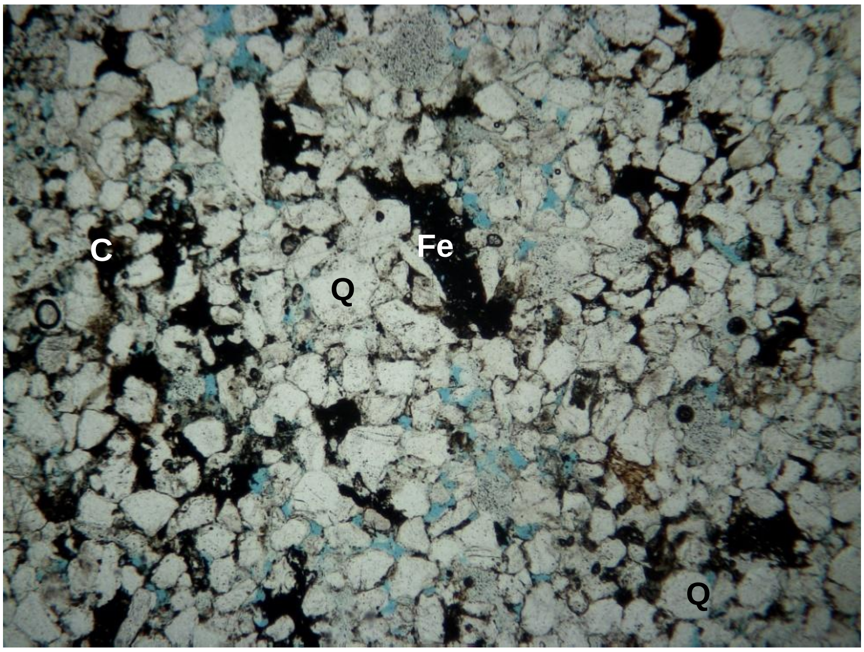


Plate 5. Thin section of the sample under plane polarised light. Pore spaces are highlighted in darker blue, while areas of light blue indicate pore filling clays that have absorbed some of the blue dye. The stone contains a high proportion of authigenic minerals, which in some areas may act to fill in and block pores spaces in varying regions throughout the stone. This is what imparts the speckled/mottled appearance to the stone in hand specimen. Q: quartz, Fe: Fe-oxide, C: carbonaceous matter.

Field of view: 3mm.

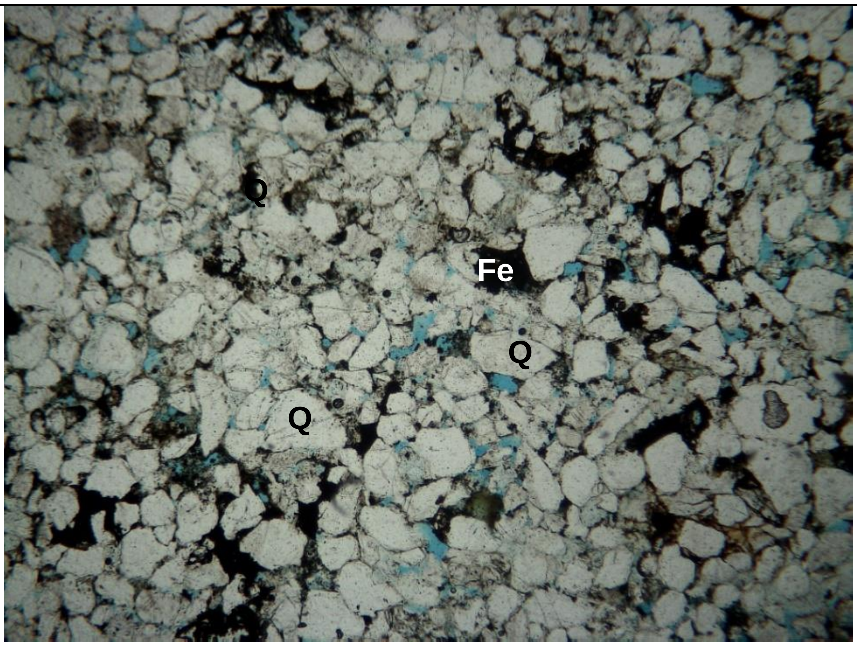


Plate 6. Thin section of the sample under plane polarised light. The stone contains a moderate open porosity throughout most of the stone, comprised of similarly sized intergranular pores. Q: quartz, Fe: Fe-oxide.

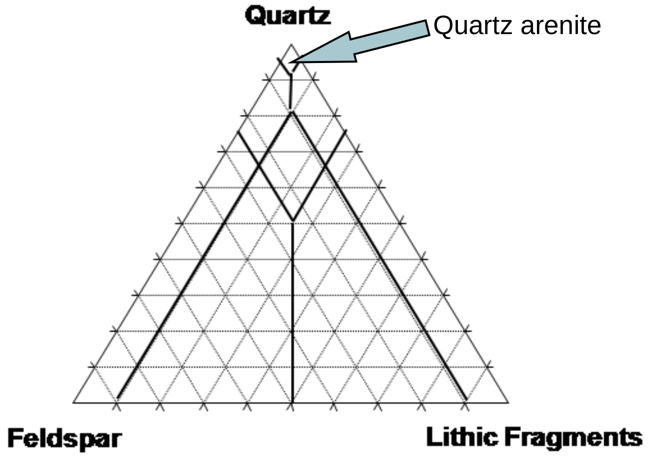
Field of view: 3mm.

Point Count Data:

Components	Total (%)	Q/F/L (quartz/feldspar/lithic % proportion)
Detrital Components		
Quartz	84.5	97.1
Feldspar	1	1.2
Lithic fragments	1.5	1.7
Detrital Clay	2	
Muscovite Mica	1	
Authigenic Minerals		
Quartz Overgrowths	0.5	
Indeterminate Clay	1.5	
Calcite	2	
Opaque Minerals	6	
Total	100	100
Porosity	14.93% - 19.68%	

Table 1: 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 and smaller proportions of feldspar grains and lithic fragments.



Classification of sandstone after McBride (1963)[1]

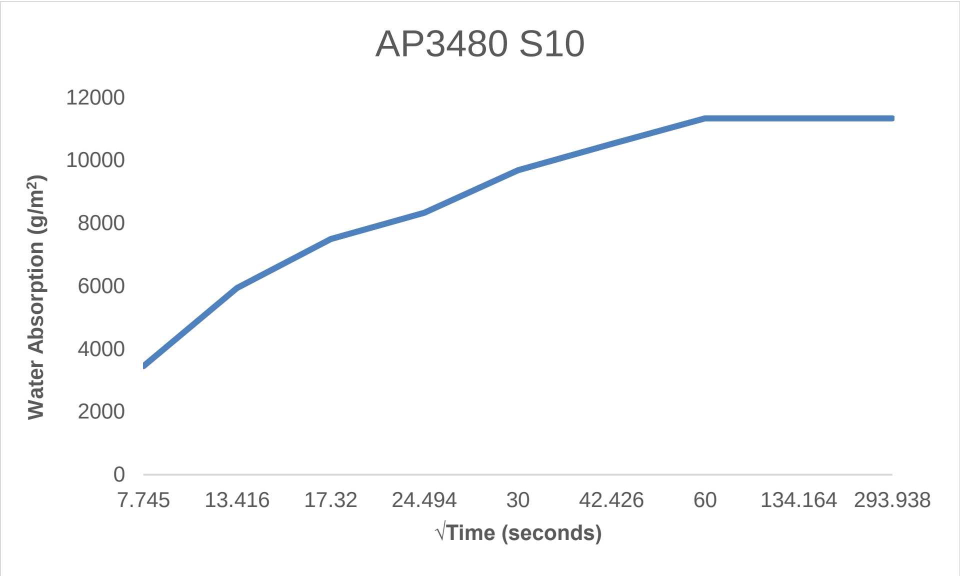
[1] McBride, E. F. (1963), A classification of common sandstones. Journal of Sedimentary Petrology 33, 664-669

PHYSICAL PROPERTIES

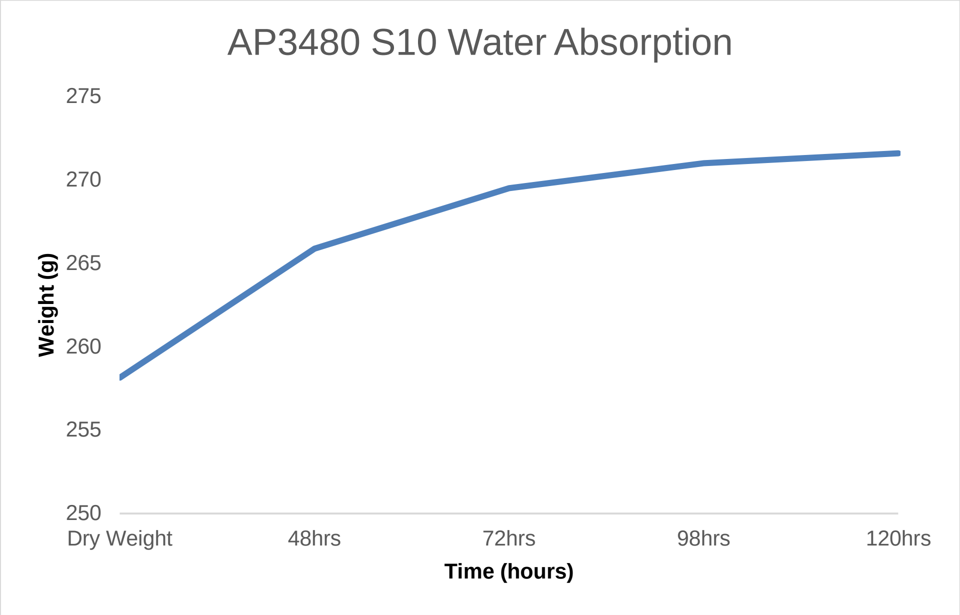
The results obtained from the physical tests are reproduced below, along with the data from stone that may be considered as potential replacements. The data reported for the potential sources was obtained from that held in the laboratory along with that reported in the current edition of the Natural Stone Directory, No. 20, 2016 – 2017, and data obtained from a range of stone suppliers.

Total (%)	Analysed Sample	Blaxter sandstone	High Nick sandstone	Swinton Sandstone	Scotch Buff sandstone
Water Absorption %	5.21	6.14	6.00	6.4	5.70
Apparent Density (Kg/m^{-3})	2717	2110	2140	2130	2130
Total Porosity %	14.93 (effective) – 19.68 (open)	13 (effective) – 18.63 (open)	14.7 (effective) – 20.5 (open)	19.0 (open)	14 (effective) – 19.8 (open)
Saturation Coefficient	0.99	0.63	-	0.65	0.77
Capillary Coefficient (g/m^2/s)	185.15	52	72	-	134
Compressive Strength (MPa)	-	38 - 55	44	57	75
Acid Reaction	No reaction	Pass	Pass	Pass	Pass

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



Capillary coefficient graph for AP3480 S10



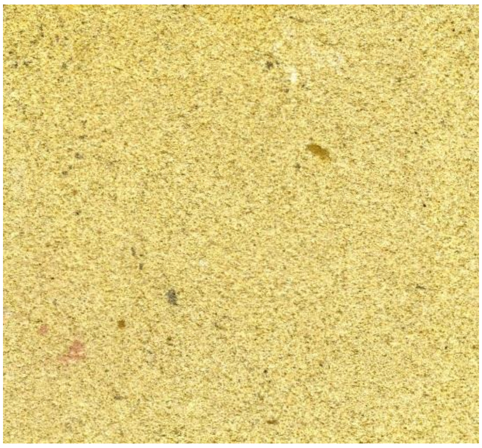
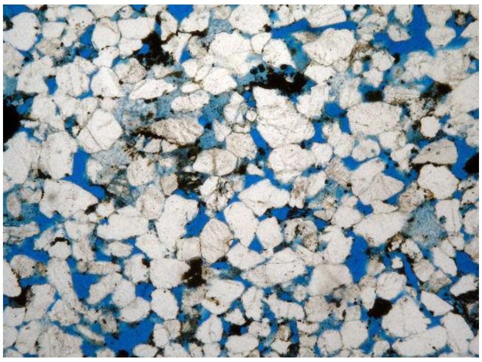
Water absorption graph for AP3480 S10

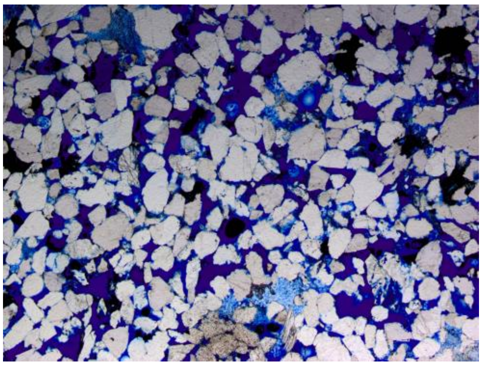
COMMENT

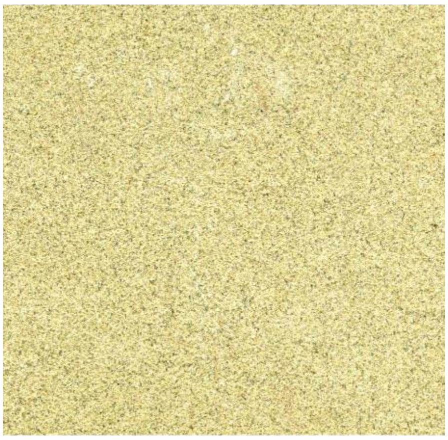
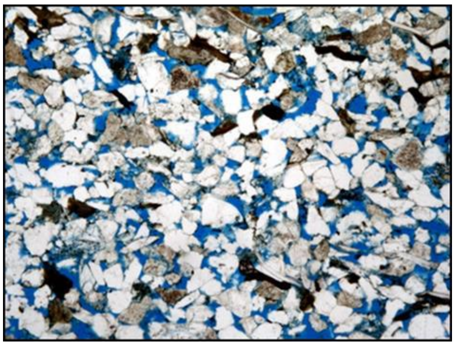
Sample AP3480 S10 (type SS1) from the side elevation of Bank Street Salon is a heterogeneous quartz arenite sandstone, which exhibits varying degrees of Fe-oxide remobilisation within the stone. The stone has experienced considerable supergene changes and undergone significant weathering and alteration, particularly towards the exposed surface, through the precipitation and remobilisation of Fe-oxide within carbonaceous laminations in the stone. Grains are commonly bound by thin silica lenses and some authigenic pore filling clays. This accounts for the variations in the colour of the type SS1 stones; mainly due to the quantity of remobilised Fe-oxides (which could be a result of longer/exposure. This stone resembles common carboniferous stone used throughout the central belt and details of historic quarries will be provided separately. The below contains information on currently available matching sandstones.

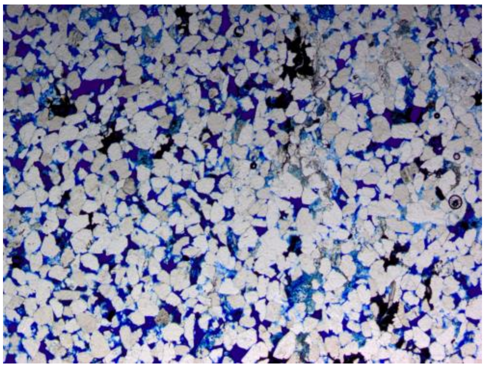
In regards to choosing a suitable matching stone, it must be remembered that because stone is a natural material, it can vary in colour and appearance both over time and spatially within a quarry. It is therefore important to check the colour and appearance/obtain representative samples of the stone 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:

<table>
<tr>
<td>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.</td>
<td>Dunhouse Natural Stone
Dunhouse Quarry Ltd,
Darlington,
County Durham,
DL2 3QU
Tel: 01833 660 208

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

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.	**Border Stone Quarries,** **Kirkholmedale** **Lanty's Lonnen** **Haltwhistle** **Northumberland** **NE49 0HQ** **Tel: 01434 322140**  

Swinton Sandstone **Colour:** Buff to grey to green **Fabric:** Mainly uniform **Grain size:** Medium grained. **Permeability:** Moderate to high. **Distinctive features:** Swinton sandstone can commonly show tonal colour variation caused by Fe-oxide remobilisation. **Comments:** The more buff coloured variety should be sought.	**Swinton Quarry** **Hutton Stone Co Ltd.** **Masons & Stone Merchants,** **West Fishwick,** **Berwick Upon Tweed,** **TD15 1XQ**  

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.	**Blockstone Ltd,** **Gatherly Moor (Scotch Buff Quarry),** **Gilling West,** **Nr Richmond** **DL10 5LL,** **Tel: 01246 927100 (sales)**  

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.

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.

SCOTTISH LIME CENTRE TRUST

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

STONE ANALYSIS

& MATCHING REPORT

AP 3480
Thistle Locks,
Inverkeithing Stone and Slate
Audit

Sample 13 - Type SS4

Masonry

SITE	Thistle Locks, Inverkeithing Stone and Slate Audit
CLIENT	Fife Historic Buildings Trust
DATE SAMPLE RECEIVED	18/12/19
ANALYSIS/EXAMINATION DATES	18/12/19 – 28/02/20
ANALYSIS, INTERPRETATION & REPORT BY	Dr Katie Strang and Roz Artis
CLIENT REQUIREMENTS	Petrographic Examination for Stone Source Matching
STRUCTURE DATE	Mid-19th century
STRUCTURE TYPE	Retail
STONE TYPE	Sandstone
LOCATION/ FUNCTION IN STRUCTURE	Stone from side elevation.
CONDITION OF SAMPLE RECEIVED	The sample received consisted of a fresh core of sandstone Total mass of sample received = 294.86 grams

DETERMINATION OF STONE CHARACTERISTICS

Method of Examination & Test

A sample comprising of one core of sandstone, taken from the side elevation of Thistle Locks (side facing High Street), by Stacey Rowntree and Dr Katie Strang, with the sample submitted for examination to assist in identifying a suitable source of replacement stone for use in remedial works.

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, one dimensioned sub-sample was prepared and submitted to a range of physical tests to determine the properties of the stone. In addition, a slice was cut through the remaining sample 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. Thin section preparation was undertaken by Mr Mike Hall of the Department of Geosciences at The University of Edinburgh.

The thin section was submitted to a microscopic examination, which was undertaken with the aid of a 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.

This report presents observations from the microscopic examination.

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 in the image. This area of masonry was representative of SS4-type sandstone and the core was taken from a unit that will need replaced. Note the distinct black crust apparent on some masonry units.

MACROSCOPIC EXAMINATION

Plate 2. Core sample post thin section preparation. Not the laminations throughout the core. Scale is in mm.

Plate 3. Fresh end of the core showing accumulation of Fe oxides and carbonaceous matter. Scale is in mm.

Plate 4. Fresh face of core. Scale is in mm.

In hand specimen the fresh, unweathered sample was found to be 10YR 8/1 ‘white’ to 8/2 ‘light brown’ and 10YR 7/2 ‘light grey’ when assessed against the Munsell Soil Colour Charts. The sandstone is predominantly fine grained with occasional medium grains throughout; it preferential weathers along the weaker laminations, which are characteristic of this rock. It contains a discolouration on the bottom surface resulting from the staining of mobilised Fe from inherent layers in the stone, while granular and scaling decay are also evident, although to a lower extent, and from alignment of mica and carbonaceous material. The stone is characterised by distinct narrow and generally discontinuous ‘wispy’ laminations that are present throughout the thickness of the sample; ranging in thickness from ~0.5mm to a maximum of 1.2mm. The stone appears to be semi-texturally immature, mineralogically mature in the most, with moderately sorted grains; with two main grain size classes visually identified under binocular microscope. The stone is composed of sub-angular to sub-rounded, sub-spherical, grey coloured quartz grains, with a relatively low proportion of Fe-oxides, clay inclusions, muscovite mica and lithic fragments within the main matrix mineralogy. Fe-oxides, carbonaceous matter, clays and mica are accumulated in high concentrations within the distinct laminations in the stone. The layers appear to vary in thickness throughout the depth of the sample and show a generally ‘wispy’ texture. Small fractures are also present throughout the thickness of the core and tend to follow inherent weaknesses within the laminations of the stone. Grains are bound by ‘frosted’ textured cement (likely silica) throughout the sample that tightly binds regions of grains together, with evidence of point and line contacts, especially between the smallest grains, while the larger, rounded and more spherical grains are generally less well compacted, showing a uniform compaction, with a majority of point contacts and high open porosity. The stone experienced a moderate to relatively slow water absorption rate when subjected to the water droplet test. This slow water absorption rate indicates a moderately to poorly interconnected or tortuous internal pore structure.

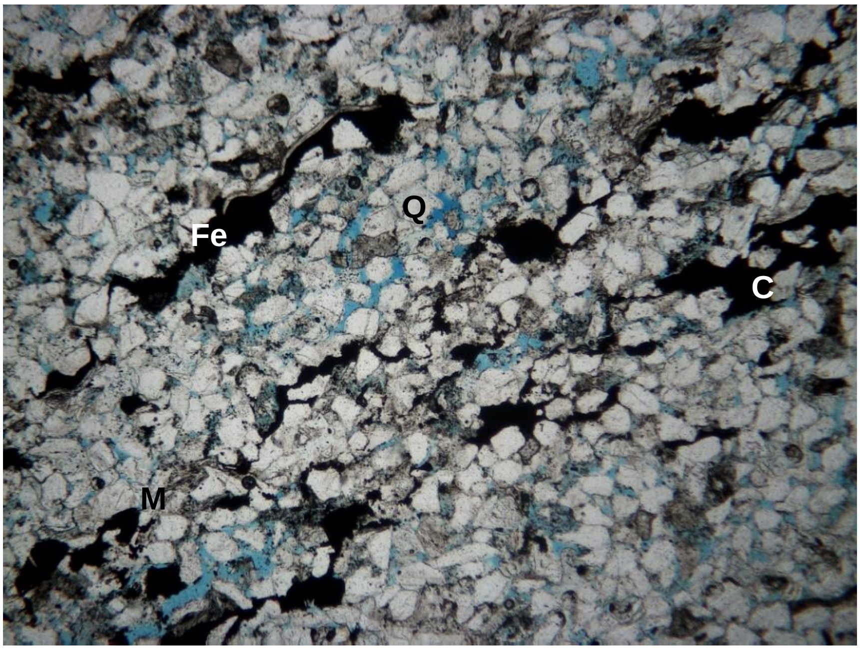
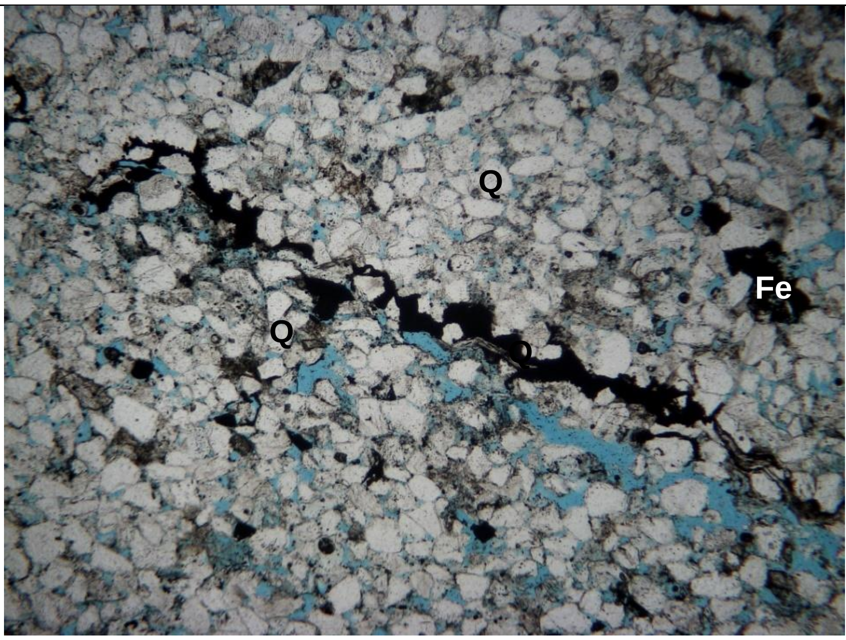
MICROSCOPIC THIN SECTION EXAMINATION

Texture: The stone contains a microscopic laminated texture that is prevalent throughout the thickness of the sample. Most layers comprise accumulated Fe-oxides, clays, muscovite, biotite and carbonaceous matter and are regularly very narrow, while other considerably thicker layers are evident in hand specimen. These laminations are very common on the microscopic scale, infilling pore spaces and as narrow veins that infill pore throats. Fe-oxides are authigenic minerals; those that formed after the rock had formed (been lithified), and have precipitated on layers rich in carbonaceous plant matter within the stone. The remaining stone is relatively uniform, with muscovite grains providing a weak lineation between the carbonaceous laminations. The stone is medium to fine grained, with several fine-grained and coarser grained regions and layers evident between laminations throughout the stone. Some of these fine-grained layers appear to show graded bedding, whereby a grain-size gradient exists between the normal stone matrix, diminishing in size towards the fine-grained beds. The sample is relatively texturally immature and moderately to poorly sorted, containing a range of sub-angular to sub-rounded and sub-elongate to sub-spherical grains throughout. Most grains are fine to medium-grained and sub-angular to sub-rounded and sub-spherical in shape and are well compacted and cemented. Grains show a range of grain contact types and are bound by silica cement along grain point contacts (as quartz overgrowths). There is a majority of line and point contacts evident, with occasional concave-convex contacts also present.

Mineralogy: The main framework mineralogy is composed of a majority of fine to medium grained, sub-rounded, sub-spherical quartz grains, found as both mono-crystalline and to a significantly lower proportion poly-crystalline varieties and as unstrained and strained grains that show an undulose texture. The sandstone is relatively mineralogically mature, containing a low relative proportion of mainly similar sized and shaped (in relation to quartz) feldspar grains, found as both microcline (orthoclase) and plagioclase feldspar, dolomite cement, authigenic and detrital clays, a range of different sized muscovite and biotite mica grains, Fe-oxides and carbonaceous matter; the latter three of which are found concentrated within narrow laminations in the stone. Feldspar and muscovite grains show a relatively low degree of decomposition and alteration into kaolinite and chlorite clays, respectively, within the main stone matrix and therefore generally have a negligible influence on the pore network properties. Muscovite grains show a similar orientation to the Fe-rich laminations and generally poorly distributed throughout the stone.

Porosity: The stone contains a low to moderate open and total porosity (for sandstone; measured as 12.91% - 13.14%), that is moderately to poorly connected, providing the stone with a medium to low permeability parallel to laminations that is spatially variable throughout the thickness of the stone. Pores are evident as medium sized open pores and as narrow pore throats, while the permeability is severely reduced through Fe-rich laminations in the stone, shown to completely block pores in these regions and provide a barrier to flow. Authigenic minerals can severely lower the open porosity within the stone by partially and fully in-filling pores throughout.

Photomicrographs:

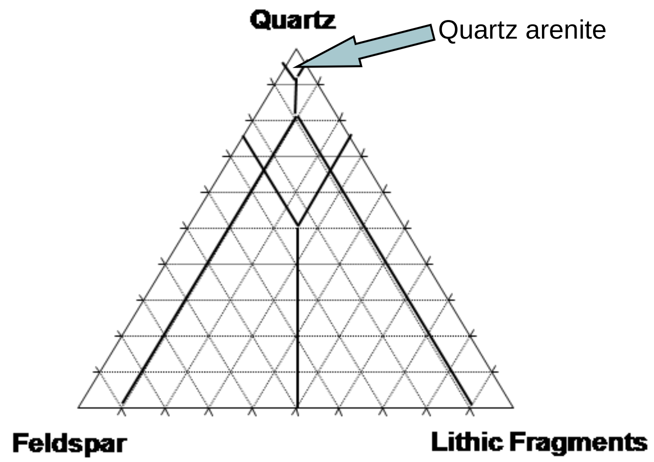
	**Plate 5. Thin section of the sample under plane polarised light. Pore spaces are highlighted in darker blue, while areas of light blue indicate pore filling clays that have absorbed some of the blue dye. Narrow carbonaceous and mica-rich laminations are evident throughout the sample, completely blocking pores and creating barriers to flow in these regions. The majority of the matrix grains are generally fine to medium grained (grains above dark lamination in the image), creating a moderate permeability and visual porosity. Q: quartz, Fe: Fe-oxide, C: carbonaceous matter.** **Field of view: 3mm.**
	**Plate 6. Thin section of the sample under plane polarised light. This image shows an area which has undergone depletion/dissolution of minerals alongside one of the wispy laminations – these areas will be weaker and the rock is more likely to fracture along these planes Q: quartz, Fe: Fe-oxide.** **Field of view: 3mm.**

Point Count Data:

Components	Total (%)	Q/F/L (quartz/feldspar/lithic % proportion)
Detrital Components		
Quartz	82	97.0
Feldspar	1	1.2
Lithic fragments	1.5	1.8
Detrital Clay	2	
Muscovite Mica	2	
Authigenic Minerals		
Quartz Overgrowths	0.5	
Indeterminate Clay	2	
Calcite	1	
Opaque Minerals	8	
Total	100	100
Porosity	12.91% - 13.14%	

Table 1: 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 and smaller proportions of feldspar grains and lithic fragments.



Classification of sandstone after McBride (1963)[1]

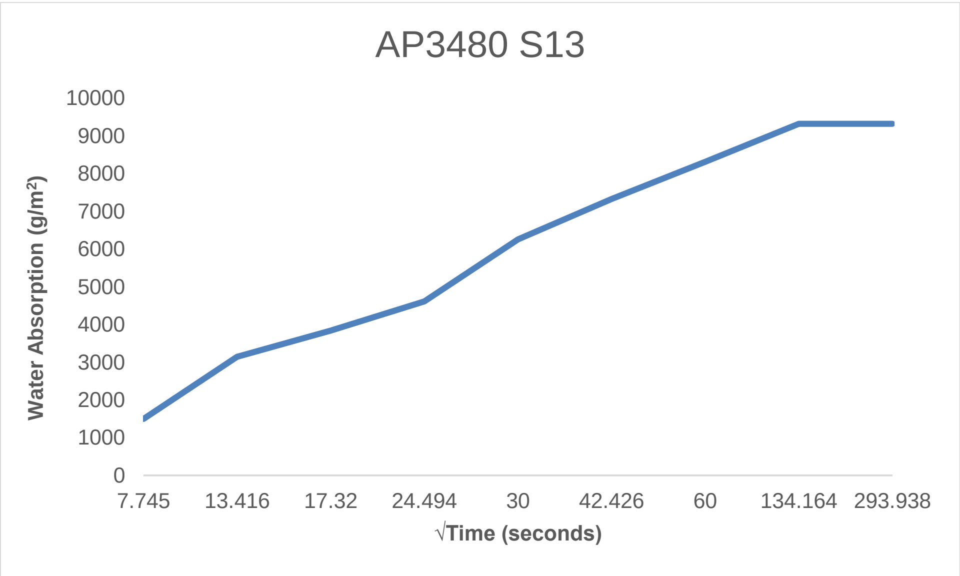
[1] McBride, E. F. (1963), A classification of common sandstones. Journal of Sedimentary Petrology 33, 664-669

PHYSICAL PROPERTIES

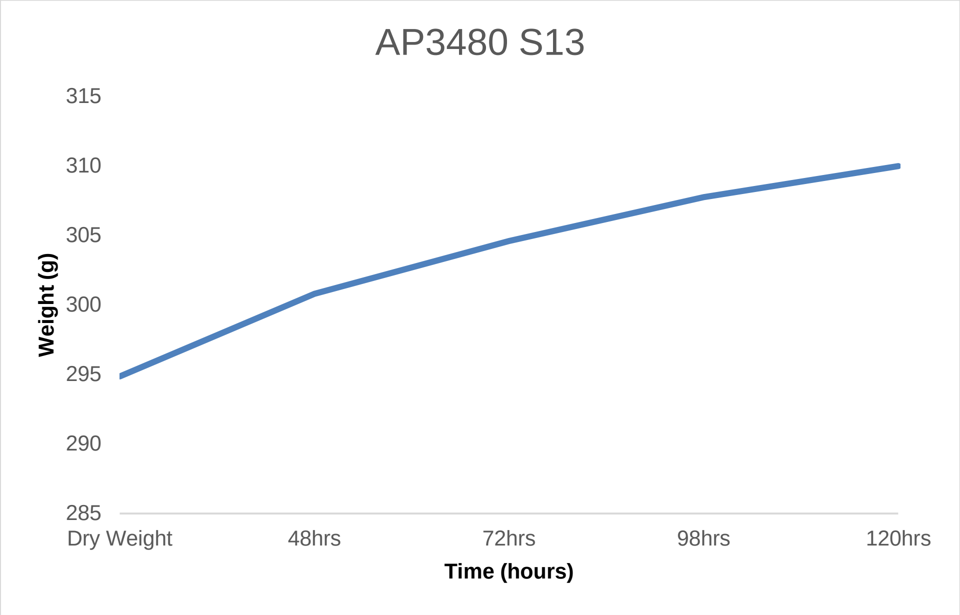
The results obtained from the physical tests are reproduced below, along with the data from stone that may be considered as potential replacements. The data reported for the potential sources was obtained from that held in the laboratory along with that reported in the current edition of the Natural Stone Directory, No. 20, 2016 – 2017, and data obtained from a range of stone suppliers.

Total (%)	Analysed Sample	Blaxter sandstone	Bearl sandstone	High Nick sandstone	Scotch Buff sandstone
Water Absorption %	5.12	6.14	4.3	6.00	5.70
Apparent Density (Kg/m^{-3})	2564	2110	2216	2140	2130
Total Porosity %	12.91 (effective) – 13.14 (open)	13 (effective) – 18.63 (open)	- 14.3 (open)	14.7 (effective) – 20.5 (open)	14 (effective) – 19.8 (total)
Saturation Coefficient	0.89	0.73	0.64	-	0.60
Capillary Coefficient ($g/m^2/s$)	152.20	52	-	72	134
Compressive Strength (MPa)	-	38 - 55	30.47	44	75
Acid Reaction	No reaction	Pass	Pass	Pass	Pass

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



Capillary coefficient graph for AP3480 S13



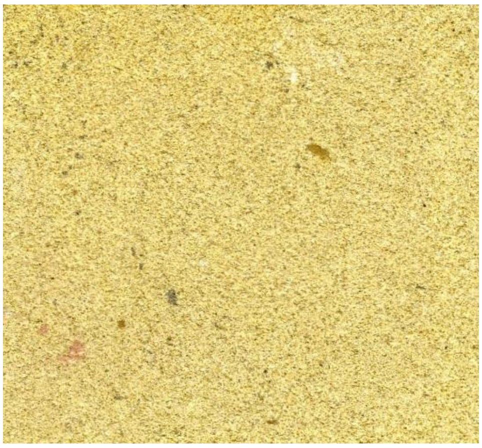
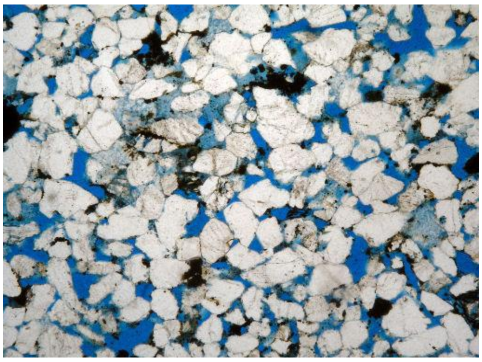
Water absorption graph for AP3480 S13

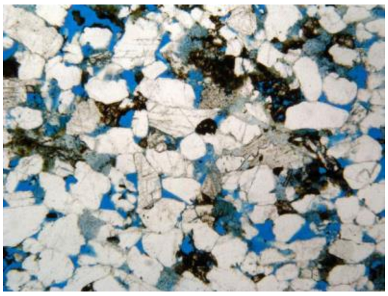
COMMENT

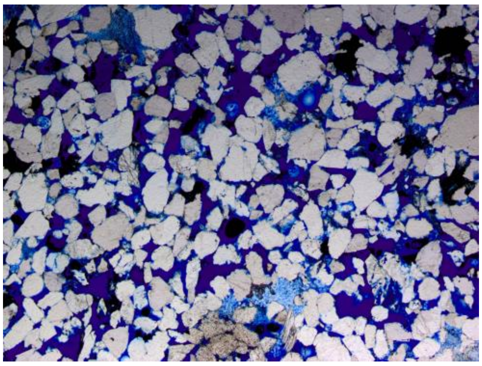
Sample AP3480 S13 (type SS4) from the side elevation of Thistle Locks is an irregularly laminated, quartz arenite sandstone that is relatively texturally immature and relatively mineralogically mature. The stone contains a majority of sub-angular to sub-rounded, sub-spherical, fine grained quartz, with high relative proportions of mica and low proportions of feldspar and lithic fragments. The stone has experienced considerable supergene changes and undergone significant weathering and alteration, through the precipitation and remobilisation of Fe-oxide within carbonaceous laminations in the stone. Grains are commonly bound by thin silica lenses and some authigenic pore filling clays. This stone resembles common carboniferous stone used throughout the central belt. For example, it is known that certain beds within the carboniferous Craigleith quarry contained ripple bedded sandstone (commonly referred to as “feak” rock) similar to, and this bedded Craigleith stone is seen in many buildings throughout Edinburgh (e.g. National Monument, Calton Hill). This Craigleith feak rock is recorded as having been used for rubble work, foundations, steps, plats and paving and is essentially indistinguishable from Hailes sandstone. It is therefore likely that that this material is from a similar deposit.

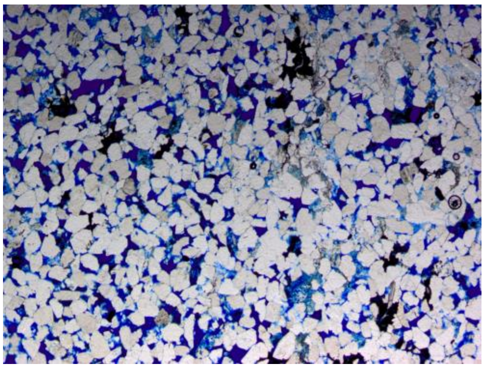
In regards to choosing a suitable matching stone, it must be remembered that because stone is a natural material, it can vary in colour and appearance both over time and spatially within a quarry. It is therefore important to check the colour and appearance/obtain representative samples of the stone 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:

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**  

Bearl Sandstone **Colour:** Buff to cream with visible bedding **Fabric:** Uniform (with visible bedding). **Grain size:** Medium to coarse grained. **Permeability:** Moderate. **Distinctive features:** Bearl sandstone exhibits distinct bedding and commonly shows distinct Fe-staining. **Comments:** The medium grained variety should be sought.	**Dunhouse Natural Stone** **Dunhouse Quarry Ltd,** **Darlington,** **County Durham,** **DL2 3QU** **Tel: 01833 660 208**  

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.	**Border Stone Quarries,** **Kirkholmedale** **Lanty's Lonnen** **Haltwhistle** **Northumberland** **NE49 0HQ** **Tel: 01434 322140**  

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.	**Blockstone Ltd,** **Gatherly Moor (Scotch Buff Quarry),** **Gilling West,** **Nr Richmond** **DL10 5LL,** **Tel: 01246 927100 (sales)**  

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.

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.