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Building Stone Assessment:

An assessment of Hazeldene sandstone as a substitute for Edinburgh's historically significant Craigleith sandstone.

Report Id: *GR_202080*
Site Address: Hazeldene Quarry, South Charlton, Northumberland.
Sample Numbers: MC5705, MC5706, MC5707, S13724, MC8764, ED10822
Date of Report: 16/02/2011

1. Introduction

Hazeldene Quarry, South Charlton, Northumberland, has recently been acquired by the Hutton Stone Company Limited. The company plans to re-open the quarry and extract fresh reserves for dimension stone.

To the unaided eye, the sandstone from Hazeldene Quarry is closely similar to that from the historically important, and long-closed, Craigleith Quarry, which supplied stone for many of Edinburgh's historic buildings and tenements. BGS was asked by Marcus Paine, of Hutton Stone, to undertake a petrographic comparison of stone samples from Hazeldene Quarry and Craigleith Quarry, and to assess if the Hazeldene stone would be a good substitute for Craigleith stone in repairs to buildings constructed using Craigleith sandstone.

Samples of Hazeldene sandstone and Craigleith sandstone from the BGS Building Stones Collection have been examined (Table 1). One sample from Hazeldene Quarry and one from Craigleith Quarry were selected for full petrographic analysis. The analysed samples are assumed to be broadly representative of the stone from each quarry. However, the stone from these quarries, being a natural material, will inevitably display a wider range of colour and texture variations than is described here.

Sample Number	Source	General Appearance	Size	Sample Media	Analysis carried out
MC5705	Craigleith Quarry	Light greyish white, uniform sandstone. Weathered surfaces are brown in colour.	100 x 80 x 60 mm	Hand specimen, thin section	Full petrographic assessment
MC5706	Craigleith Quarry	Light greyish white, uniform sandstone with small black pieces of carbonaceous matter. Weathered surfaces have a brownish colour.	80 x 70 x 60 mm	Hand specimen, thin section	Visual inspection of hand specimen
MC5707	Craigleith Quarry	Light greyish white, uniform sandstone. Weathered surfaces have a brownish colour.	200 x 120 x 60 mm	Hand specimen	Visual inspection of hand specimen
S13724	Craigleith Quarry	Light greyish white, uniform sandstone with a small proportion of scattered, small black grains. Weathered surface is altered to grey and brown colours.	60 x 50 x 40 mm	Hand specimen	Visual inspection of hand specimen
MC8764	Hazeldene Quarry	Light greyish white, uniform sandstone. Sample is entirely fresh stone (no weathered surfaces).	2 sawn blocks each 150 x 150 x 30 mm	Hand specimen, thin section	Full petrographic assessment
ED10822	Hazeldene Quarry	Light greyish white, uniform sandstone with with a small proportion of scattered, small black grains. Sample is entirely fresh stone (no weathered surfaces).	2 sawn blocks each 80 x 80 x 20 mm	Hand specimen	Visual inspection of hand specimen

Table 1. List of samples that were compared for the purposes of this report. The analysis in Section 3 describes the thin sections of samples MC8764 (Hazeldene Quarry) and MC5705 (Craigleith Quarry) and also takes into account variations in the hand specimen appearance which the other samples show.

2. Methodology

Petrographic description

For each sample, a macroscopic examination is performed with the unaided eye and using a binocular microscope. A microscopic examination is performed on a thin section (a slice of the stone sample cut thin enough to be transparent), using a polarizing microscope. Before preparing the thin section, the stone is impregnated with blue resin to highlight pore spaces. The thin section is cut perpendicular to the bedding fabric of the stone (where this is visible), and is positioned to be as representative as possible of the sample. The thin section is typically cut to include the weathered external surface where this forms part of the supplied stone sample.

Observations from these examinations are recorded on a petrographic description form designed for building stones, to ensure the approach is systematic and consistent with the procedures set out in British Standard BS EN 12407:2000 (*Natural stone test methods – Petrographic examination*). The completed petrographic description forms are included in this report, with a set of accompanying notes providing basic information for most of the recorded properties.

Thin section photographs

The descriptions are accompanied by one or more photographs illustrating the typical character of each stone as it appears in thin section. All the thin section photographs in this report were taken in plane-polarized light. Pore spaces appear blue. The field of view in all images is the same (c.3.3 mm across), so the characteristics of stone from different sources can be compared directly.

3. Petrographic description:

3.1. Sample MC8764 (Hazeldene sandstone)

Hand specimen observations

Stone type [1] (general classification): sandstone

Stone colour [2] **–** fresh stone: light greyish white (visual) 2.5 Y 8/1 (Munsell)

Stone colour [2] **–** weathered stone: not available

Stone colour [2] **–** exterior surface: not available

Stone cohesion [3] – fresh stone: strongly cohesive

Stone cohesion [3] – weathered stone: not available

Stone fabric [4]: uniform

Distinctive features: none

Thin section observations

Stone constituents [5]:

Granular (detrital) constituents		Intergranular constituents	
Quartz	67%	Silica (overgrowth)	3%
Feldspar	4%	Feldspar (overgrowth)	0%
Rock fragments	2%	Carbonate	0%
Muscovite mica	<1%	Iron oxide	0%
Opaque material	<1%	Clay	5%
Other	<1%	Hydrocarbon	0%
Intragranular pores	4%	Intergranular pores	14%

Stone type [1] (detailed classification): subfeldspathic-arenite

Grain-size [6]: medium-sand-grade

Grain sorting [7]: well sorted

Grain roundness [8]: sub-angular to rounded

Stone permeability [9]: moderate

Cement distribution [10]: silica cement continuous

Supergene changes [11]: weak dissolution of feldspar

Comments:

- A second sample from Hazeldene Quarry (ED10822) appears to be closely similar to MC8764 in terms of colour and textural appearance in hand specimen, however it features a small proportion of scattered, small black grains (~0.3mm size and 10 – 20 mm spacing) distributed uniformly throughout the stone.
- Stone constituents: muscovite mica and zircon are present as accessory minerals.
- Weathering of feldspar grains has created intragranular pore spaces and clay particles. Grains representing each stage of this process are observed.
- Other stone constituents: kaolinite (a clay mineral that forms from the dissolution of feldspars) has grown in places between grains.
- Rock fragments: these consist of very-fine grained igneous and metamorphic types.

3.2. Sample MC5705 (Craigleith sandstone)

Hand specimen observations

Stone type [1] (general classification):	sandstone	
Stone colour [2] **–** fresh stone:	light greyish white (visual)	2.5 Y 7/2 (Munsell)
Stone colour [2] **–** weathered stone:	not applicable	
Stone colour [2] **–** exterior surface:	brown	
Stone cohesion [3] – fresh stone:	strongly cohesive	
Stone cohesion [3] – weathered stone:	not applicable	
Stone fabric [4]:	uniform	
Distinctive features:	none	

Thin section observations

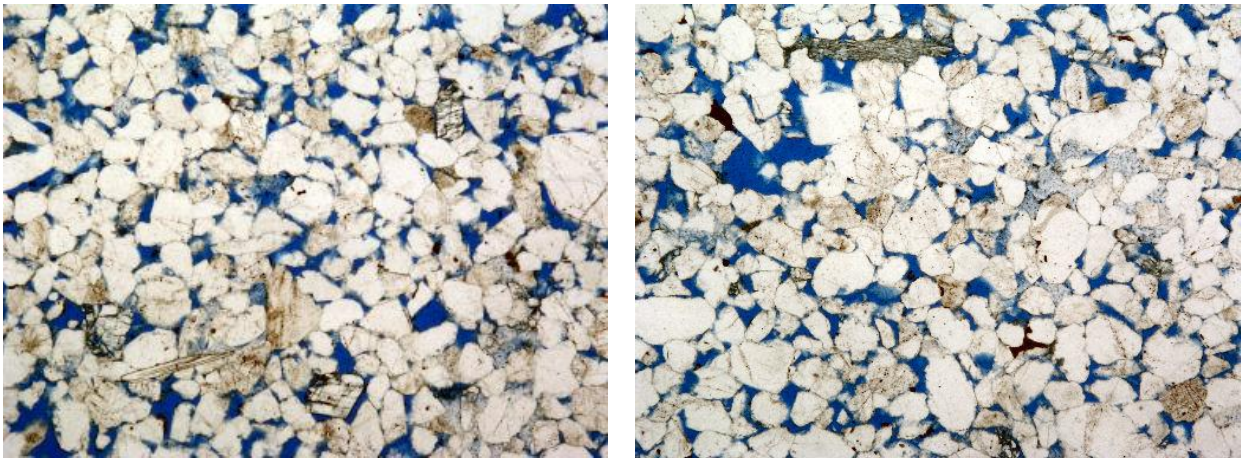
Stone constituents [5]:

Granular (detrital) constituents		Intergranular constituents	
Quartz	72%	Silica (overgrowth)	7%
Feldspar	3%	Feldspar (overgrowth)	0%
Rock fragments	<1%	Carbonate	0%
Muscovite mica	<1%	Iron oxide	0%
Opaque material	<1%	Clay	3%
Other	<1%	Hydrocarbon	0%
Intragranular pores	3%	Intergranular pores	12%

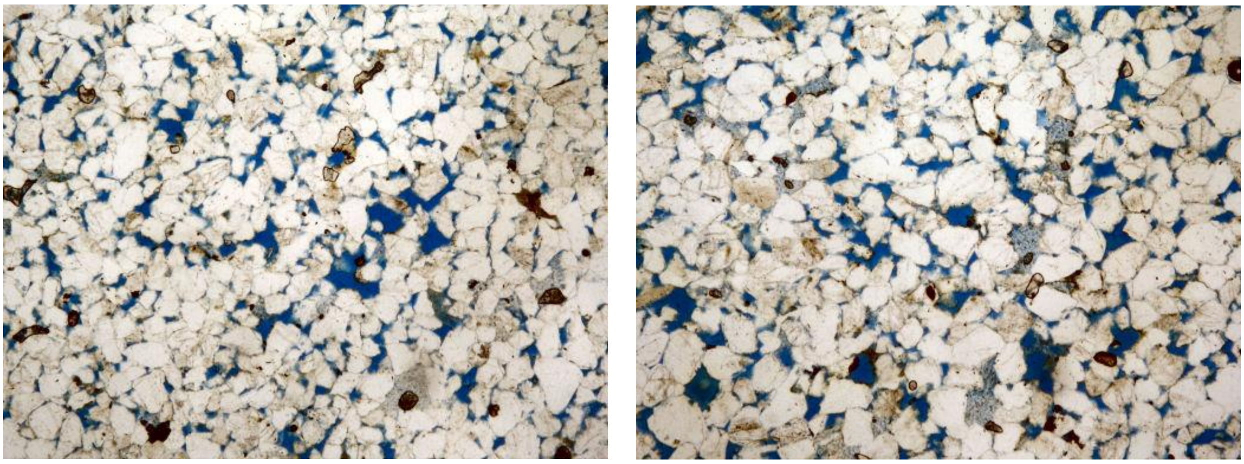
Stone type [1] (detailed classification):	quartz-arenite
Grain-size [6]:	fine-sand-grade to medium-sand-grade
Grain sorting [7]:	well sorted
Grain roundness [8]:	sub-angular
Stone permeability [9]:	moderate
Cement distribution [10]:	silica cement continuous
Supergene changes [11]:	weak dissolution of feldspar

Comments:

- Stone colour – exterior surface; the exterior surface of the sample is covered in a patina of brown soiling
- Three other hand samples of Craigleith sandstone from the BGS collection (listed in Table 1) are broadly similar to sample MC5705 in terms of colour, fabric and texture. However, MC5707 and S13724 are slightly finer grained, MC5706 contains pieces of black carbonaceous matter, and S13724 contains a small proportion of small black grains.
- Tourmaline is present as an accessory mineral.
- Weathering of feldspar grains has created intragranular pore spaces and clay particles. Grains representing each stage of this process are observed.



Figures 1 & 2: Photomicrographs of Hazeldene sandstone, as it appears in thin section. The images were taken in plane-polarised light, and the field of view is c. 3.3 mm. Pore space appears blue.



Figures 3 & 4: Photomicrographs of Craigleith sandstone, as it appears in thin section. The images were taken in plane-polarised light, and the field of view is c. 3.3 mm. Pore space appears blue.

Supporting notes for the petrographic description

Each numbered note below relates to a superscript number in the preceding petrographic description forms.

1 The determination of stone type follows the classification and nomenclature of the BGS Rock Classification Scheme.

2 The 'visual' determination is a simple, visual assessment of the stone colour in natural light. The 'Munsell' determination is a quantitative determination obtained by matching the stone surface to the appropriate coloured patch in a Munsell Rock Colour Chart; each patch has a unique code (the 'Munsell code'), which incorporates values for hue and chroma. In stones displaying variable colour, both the 'visual' and 'Munsell code' determinations record the colour deemed by the geologist to be most representative. The determination of stone colour is made on a broken (not sawn), dry surface.

3 A simple, non-quantitative assessment of the degree to which the stone is cohesive. This property is recorded in terms of four conditions, each representing one segment of a continuum: *strongly cohesive*, *moderately cohesive*, *moderately friable*, and *very friable*. The grains in a *strongly cohesive* stone cannot be disaggregated by hand, whereas the grains in a *very friable* stone can be readily disaggregated by hand.

4 A record of whether the distribution of detrital constituents in the sample is essentially isotropic (uniform) or anisotropic (non-uniform). The type of anisotropic fabric is recorded.

5 A record of the identity and relative proportions of all granular (detrital) and intergranular (authigenic materials and pore space) constituents currently in the stone. The proportions are estimates, expressed in %, which are based on a visual assessment of the whole thin section area.

6 The terms are those used for grain size divisions in the BGS Rock Classification Scheme.

7 A simple, non-quantitative assessment of the degree to which detrital constituents display similarity in terms of physical characteristics (in particular the size and shape of grains).

8 A simple, non-quantitative assessment of the degree to which detrital constituents are abraded.

9 A simple, non-quantitative assessment of stone permeability, presented as one of five terms (*very low*, *low*, *moderate*, *high*, *very high*) expressed relative to a nominal 'average' permeability in building stone sandstones. The assessment is based on: (i) a water bead test; (ii) the proportion of pore space in the stone; (iii) a visual assessment of the degree to which pore spaces appear connected in the thin section.

10 A record of the type and extent of authigenic minerals that act to bind detrital grains, as observed in thin section. *Isolated* means the cement occurs in discrete locations (e.g. as overgrowths on individual detrital grains) that are typically not connected in the plane of the thin section. *Discontinuous* means the cement is formed in patches, each of which typically encloses several to many detrital grains. *Continuous* means the cement is more-or-less connected across the thin section.

11 A record of the evidence observed in thin section for mineral alteration that occurs in the stone when it is near the ground surface. Such alteration processes typically begin before stone is quarried, but some may continue, or be initiated, after stone is extracted from the ground.

4. Comparison of Hazeldene and Craigleith stone

The analysed samples of Craigleith sandstone and Hazeldene sandstone are closely similar in nearly all of the recorded attributes. The fresh stone is essentially the same colour (light greyish white), and both contain similar ranges and proportions of constituent minerals. The Hazeldene sandstone contains a slightly larger proportion of feldspar; the difference is small but it is enough to mean the two classify as different types of sandstone: the Craigleith sandstone is quartz-arenite whereas the Hazeldene stone is subfeldspathic-arenite. Both are texturally uniform stones, lacking clearly defined bedding or any other fabric. The Hazeldene sandstone is slightly, but distinctly, coarser-grained than the Craigleith stone. The intragranular components of both stones are characterised by silica overgrowths, with no carbonate minerals and no iron oxide.

Craigleith sandstone has a larger proportion of silica overgrowth, and has more contacts between grains, due to a tighter, denser packing, and may therefore prove to be stronger (e.g. if subjected to a Compressive Strength test). However, both are strongly cohesive stones. Given their similar petrographical characteristics (particularly the extent of cementation between the sand grains) it is expected that both stones will broadly be in the same range of compressive strength. Both stones have similar proportions of pore space and moderate permeability, although the permeability of Hazeldene is very slightly higher.

Some hand samples of Hazeldene and Craigleith stones show varying proportions of small black grains, and there are fragments of carbonaceous matter in some Craigleith samples. It should be noted that the stone from either quarry may display these and other variations in colour and texture.

The degree to which a replacement stone is a good ‘match’ (or substitute) for an original stone can be judged in terms of several factors. These include:

1) *Appearance* (colour and texture) – i.e. how similar do they look? A replacement stone can be selected to match the fresh part, the weathered part, or the external surface of an original stone, each of which can look very different.
2) *Weathering performance* – are they likely to respond in similar ways to the physical and chemical changes associated with weathering?
3) *Permeability* – if the permeability of the replacement stone is significantly lower than in the original stone, it could inhibit the migration of fluid (air and water) between stone blocks, which could lead to accelerated decay in stone adjacent to the replacement stone.
4) *Strength* – this will be important if the original stone performed a load-bearing role.
5) *Ease of shaping and tooling* – this will be important if the stone to be replaced was carved or shaped in a particular way.

The degree to which Hazeldene sandstone might be expected to be suitable for repairs to Craigleith stone is assessed briefly below in terms of each of these factors.

Appearance
The analysed samples of Hazeldene and Craigleith stone are light greyish white sandstones

with closely similar textural characteristics. Hazeldene stone should therefore provide a very good appearance match for Craigleith sandstone.

Weathering performance
The main factors which can influence weathering performance are: stone cohesion; the presence of minerals that are susceptible to alteration; porosity and permeability characteristics. Both stones are essentially similar in all of these respects and there is therefore no reason to expect their weathering performance would be significantly dissimilar.

Hazeldene has a slightly larger proportion of feldspar, which may make it more susceptible to weathering in certain environments than Craigleith sandstone. However, the difference is slight and not likely to be an important factor in most situations.

Permeability
Both stones have moderate permeability.

Strength
Both stones are strongly cohesive. However, Compressive Strength test data for both stones should be compared to determine the degree to which Hazeldene stone is a good match for Craigleith stone in terms of strength.

Ease of tooling and shaping
The range of petrological characteristics affecting this property (which includes various textural features and stone cohesion) are essentially similar for both Craigleith and Hazeldene sandstones. Both stones are therefore likely to be similarly suited to tooling and shaping as they are both texturally uniform (freestones).

5. Conclusions

On the basis of this comparison of selected stone samples from Hazeldene and Craigleith quarries, Hazeldene sandstone is likely to be a good match for Craigleith sandstone in terms of most of the main stone matching criteria.

Analysis by: _________________ **Paul Everett**

Checked by: _________________ **Dr Martin Gillespie**

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6. Information and Limitations of this report

This report provides a petrographic examination of a sample or samples of building stone. It is designed for use by professionals involved in building repair and/or conservation but it might also be useful for private individuals to help them judge whether or not further professional advice should be sought. We recommend that members of the public consult a qualified professional about the results in this report before making any major decisions based on it.

This report is based on analysis of the sample or samples provided and cannot be assumed to be representative of all materials in a building or structure unless an on-site assessment has been carried out by a qualified professional.

Please note that a recommendation of a replacement stone does not constitute a repair specification. All aspects of the building (location, detailing, other materials) must be considered in competent repair work.

The report provides a petrographic examination of stone type. This does not guarantee that a replacement stone is suitable for a particular purpose (e.g. carved detail), nor does it guarantee specific properties of a stone such as strength. Aspects such as bed height, block size etc. will have to be discussed with the supplier.

Recommendations for replacement stone are based on and limited to an interpretation of the records in the possession of The British Geological Survey (BGS) at the time the examination is carried out.

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