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# St. John the Baptist church
# GRIMSTON
## Leicestershire

Plate 1: General view of the church from the north.

# Report on the stonework
## November 2017

**Skillington Workshop Limited**
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## 1 Introduction

1.1 This report has been commissioned by the architect Peter Rogan, of Peter Rogan Associates Ltd of Nottingham, on behalf of the Parochial Church Council (PCC) of St. John the Baptist church, Church Lane, Grimston, Leicestershire LE14 3BZ. The survey was carried out by Dr David Carrington ACR of Skillington Workshop Ltd (SWL) on 13 September 2017. The report has been written by and the mortar analysis carried out by Dr Carrington, with a sample of stone sent to Dr David Jefferson of Jefferson Consulting Ltd for geological identification and for recommendations for potential replacement material. That report is included here as Appendix A, the mortar analysis report as Appendix B.

1.2 St. John the Baptist church is in the Diocese of Leicester.

1.3 The initial brief from Peter Rogan, dated 28 March, was as follows:

> Report required on general ironstone walling to the Tower, Nave, Transept and Chancel. The ironstone walling is very heavily weathered - the assessment should include exploration of voids and drilling of joints to establish the original and remaining thickness of walling stones, and checks as to the condition of the wall core and extent of voids within stonework. Damp is also penetrating the tower walls and leaving internal staining and an assessment of the mechanism of moisture penetration and what remedial measures, if any, could be tried.

SWL's fee proposal, dated 6 April 2017, added the caveats that (a) The findings and recommendations would be fairly generalised rather than given on a stone-by-stone basis, and allowance was made for surveying from ground level or short ladder access only, (b) Allowance is made for a dispersed and surface water survey as well as a comparison of internal and external ground levels to help understand those aspects of moisture content; and finally (c) Allowance is not made for extensive moisture analysis of core samples. This may be a way forward to help understand moisture profiles, but I think is best considered in a carefully targeted way once the present survey is carried out.

## 2 Grimston and St. John the Baptist church

### 2.1 Grimston

Grimston is a small village in a civic parish of the same name (which also includes the nearby village of Saxelbye), in the Melton District of Leicestershire. In the 2011 census the population of the parish was recorded as 294.[1]

It is situated some 4 miles to the north-west of Melton Mowbray, just to the south of Six Hills Lane and three miles to the east of the Fosse Way. These are both Roman roads, the Fosse Way being a major arterial route running from Exeter to Lincoln, the Saltway being a lesser route running roughly east west from Ermine Street to the Fosse Way. I am, however, aware of no direct evidence of there being a Roman Settlement here.

There was certainly a settlement here by 1162 when the church is listed as a possession of Launde Priory[2]. In the 13th century ownership of the church (and manor?) passed to the Knights Templars at Rothley (to the north of Leicester) - where they had become firmly established in 1231 when they were granted the manor by Henry II[3]. However the Templars were suppressed in 1312 by Edward II, and ownership of Grimston passed to the Hospitallers. From the Reformation the Soke of Rothley passed to the Babington family, who were lords of the manor of Grimston and Wartnaby until 1865[4].

### 2.2 St. John the Baptist church

The church is listed grade II* (reference NGR: SK6855121893), the listing being as follows:

Church. C13 and C15. Restored by R W Johnson 1866. Coursed, squared ironstone, slate roofs. Chancel, nave, S transept, S porch and W tower. 2-bay chancel has 3-light E window with Perpendicular tracery with hood mould and label stops, lancet window to N, 2-light windows to S with straight heads, cued ogee-arched heads to lights and hood mould with label stops. Nave has blocked arch to forum (*sic*) N transept, blocked N door with chamfer and hood mould, and 3 2-light windows at clerestory level with Perpendicular tracery, 4-centred heads and hood moulds. 4 similar

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[1] Wikipedia.org/wiki/grimston,_leicestershire, accessed 26/11/17.

[2] I am relying here on a guide booklet in the church, not dated, but compiled by Mrs Alison Blythe.

[3] Pevsner, N. (1984) *The buildings of England: Leicestershire and Rutland* (2nd edition revised by E. Williamson), London: Penguin. Pages 364.5.

[4] Again, my source here is the church guide booklet.

clerestorey windows to S. S transept has small lancet window to E and 3-light window to S with Perpendicular tracery, both with hood moulds. Renewed S door with shafts, many-moulded head and, hood mould in C19 porch with shafted doorway and hood mould. 2-stage tower has 3-light W window with Perpendicular tracery and 2-light bell-chamber openings with Perpendicular tracery, all with hood moulds. Cusped lozenge frieze to base of battlemented parapet; gargoyles and crocketed pinnacles to angles. Interior: Double piscina in transept with pointed trefoiled arches. Nave has Perpendicular roof with arch-braced ties on carved head corbels, 1 tier of moulded purlins, moulded ridge and bosses. Clock of c.1600, a very early provincial example of an anchor escapement. Stain-glass SE chancel window, early C20 by Baguley, Newcastle.

A little more can be added to this. The north transept apparently collapsed in 1740, not to be rebuilt[5]. The medieval nave roof beams survive, although the chancel roof structure is clearly of the 19th century restoration. It is also somewhat of an over-simplification simply to say that the building is of ironstone. This is by far the predominant material but a grey-cream coloured limestone has also been used for much of the dressed stone and the tower parapet – see plate 1 and Appendix A.

The listed building description describes the roofs as slated but in fact this is only the chancel and south porch; the nave and transept (and presumably the tower) have leaded roofs.

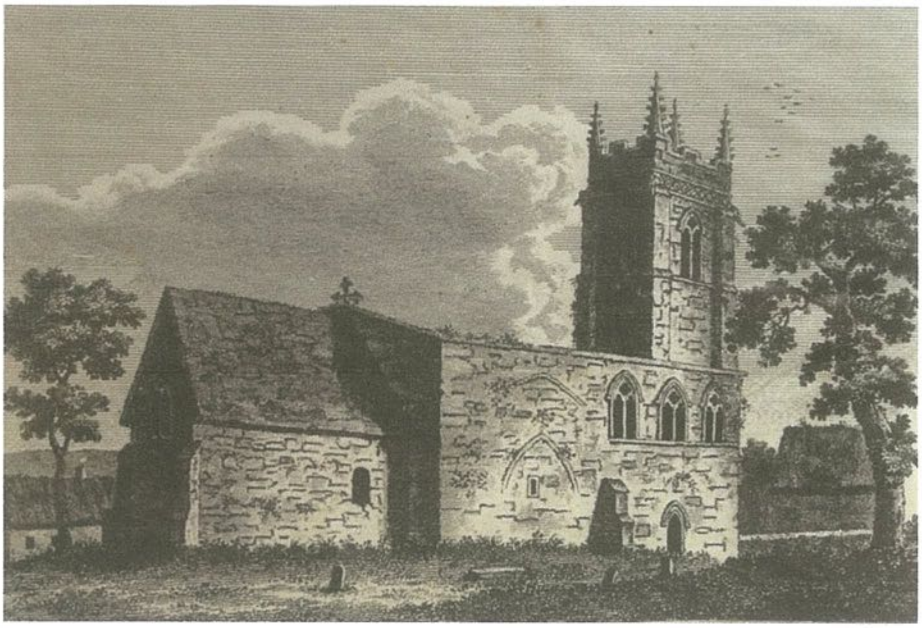

Plate 2: The church from the north in a drawing of 1794, on display in the church[6].

[5] From the church guide leaflet.
[6] Presumably from John Nichols's *History and antiquities of the County of Leicester* of 1775-1811, although I haven't verified this.

## 3 Observations

### 3.1 Dispersed water survey

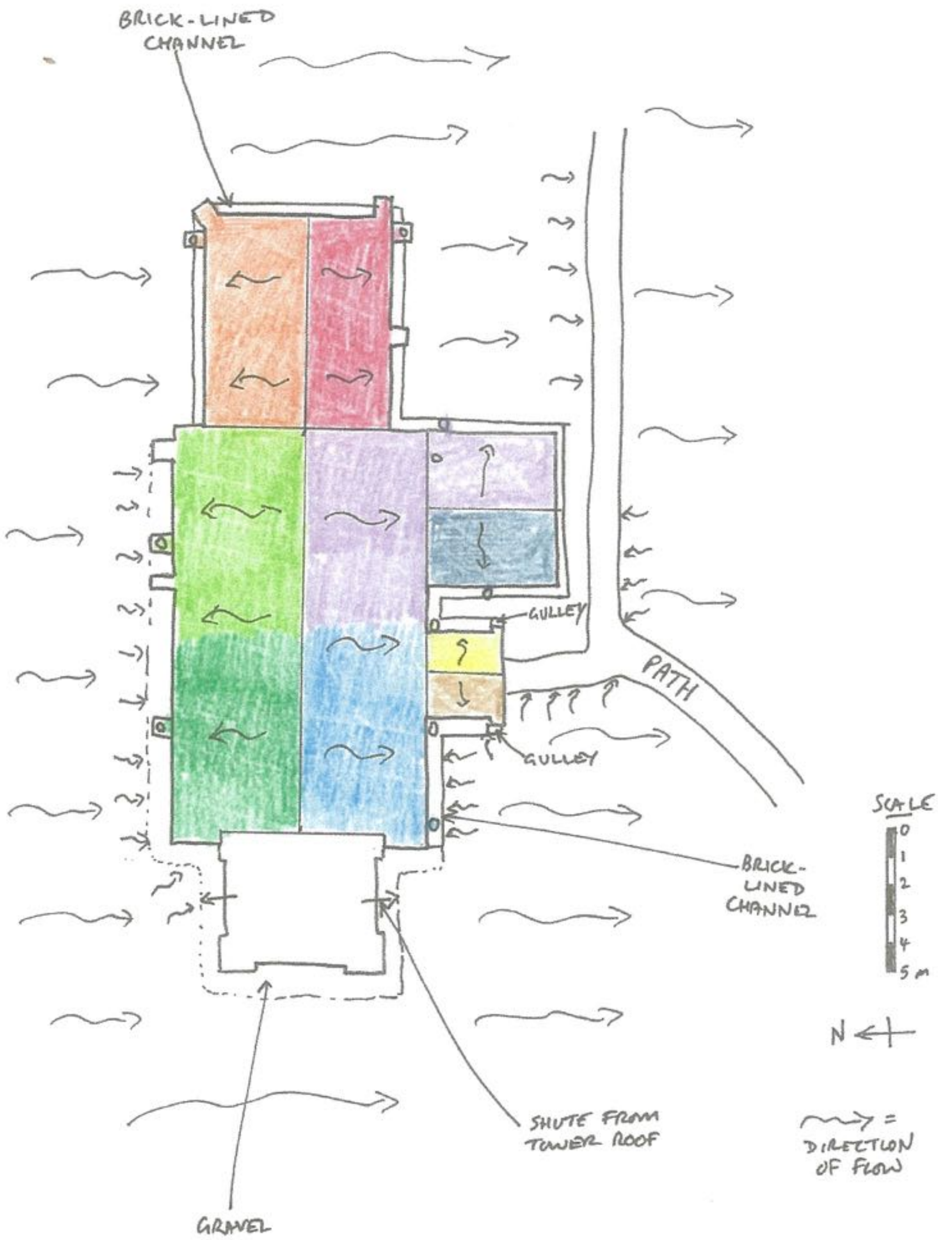


Plate 3: Dispersed water survey – see text below for explanation.

The scale plan above (plate 3) shows how rain and surface water moves and is disposed of. The roofs are divided into zones of different colours showing how much water is directed into the various downpipes. The one which might be flagged up as taking an exceptional amount of water is the 'lilac zone' served by a downpipe on the east side of the south transept.

Plate 4: View of the east wall of the south transept, looking along the south wall of the chancel.

This downpipe can be seen in plate 4, above. Here also can be seen the brick-lined channel running around the chancel and the south transept. See also plate 5, below. The channel is in poor condition, with no obvious outlet (it may be hidden by detritus), with many open joints in the masonry and much debris in the bottom. Although well-intentioned it now might even be serving more during periods of heavy rainfall as a moat than a drain.

Plate 5: Detail of the channel at the north-east corner of the chancel.

The gravel at the base of the walls to the north side of the nave and the tower may be part of a French drain arrangement, with a buried perforated pipe taking water away, in theory at least. However it is very silted up and must now be serving much the same function as if it were just earth. Rainwater in this area though is disposed of via gulleys to drains and, presumably, a remote soakaway. Underground drains were not inspected as part of the survey. However neither of the downpipes and gulleys on the north side of the nave were functioning when I carried out the survey. The 'dark green' downpipe was clogged, and the light green gulley blocked. Meanwhile the tower water shuts are simply throwing water onto the ground at the base of the tower.

As can be seen from the survey drawing, and also well illustrated in plate 4, the general fall of the ground is fairly steeply from north to south. This presents plenty of opportunities for surface water pooling, which may be obvious if the ground is inspected after prolonged rainfall, and makes it all the more important that the drainage arrangements along the base of north walls in particular are functioning well - which they clearly aren't at present.

### 3.2 The church interior

Internally the walls are 'scraped' of any early plaster and have been re-pointed with cement ribbon pointing. The chancel and south transept walls are however plastered, but this looks like modern plaster, probably gypsum-based.

The floors are largely of Victorian tiles - hard and impervious - and ledger slabs. The tower floor has limestone flagstones. Timber pew decks in the nave look to be quite recent; in the chancel 19th century.

The floor level, measured from the blocked former north transept arch in the north side of the nave, is about 400mm lower internally than at the bottom of the brick-lined channel outside. By contrast, at the south window of the south aisle the ground outside is some 200mm lower than the floor inside.

## 3.3 An observation on the tower construction

The tower, visible in plate 1, is strengthened at each corner by square buttresses, although they are not buttresses in the more usual sense. Looking at the plan of the church in plate 3 it can be deduced that these may well extend inside and they can indeed be seen on the east face, which is part of the west wall of the nave. See plate 6 below. What is interesting here is that there is a clear break in construction between it and the nave west wall suggesting to me that it was built first and the nave added later (perhaps very soon afterwards). Also note the well preserved faces of the ironstone at higher level – this gives a glimpse of what the outside must have originally looked like (if the pointing is ignored!). Finally, the impact of high liquid moisture levels and damage caused by soluble salts crystalising at evaporation zones can be seen to the lower level stonework.

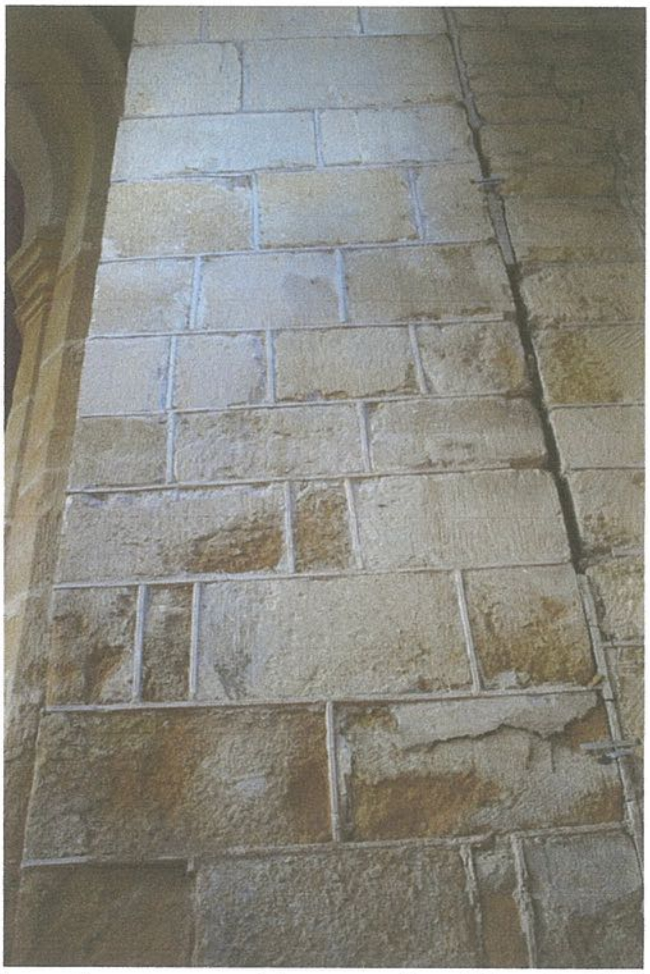

Plate 6: The north-east corner of the tower viewed from inside the church.

## 3.4 Observations relating to the external masonry

One of the specific questions forming the brief to this report was to report on the thickness of the ironstone masonry units. The walls, of course, are typical medieval construction with inner and outer faces of dressed stone with a mortar and rubble fill. Earth mortars were used extensively in the medieval construction. The inner and outer skins are generally bonded into the corework by having irregular backs to the stones, with the occasional tying between skins with masonry units (windows and other openings serving this function as well).

I measured the wall thickness overall to be 0.73m in the south transept and 1.80m in the tower (at a height of just over 1m above floor level, measured as a section through the tower arch). The wall thickness at the chancel arch is 0.63m, at the south transept arch 1.00m.

We can get as good an idea of the thickness of masonry units by looking at quoins as by drilling into random stones. We can conclude in this way that the thickness in general wall construction blocks is 150-200mm, but with thicker stones in the tower, typically 200-300mm thick. Note that perp joints in particular are likely to be tapered. I was able to substantiate this for the general walling masonry by measuring thickness back to a projected full face level and looking into holes in the pointing to where the back of stones could be detected.

We are therefore looking at typically wall thicknesses (away from the tower) of say 650-1000mm; with inner and outer skins of ironstone at circa 150-200mm thick, and a mortar and rubble core of between 250 and say 600mm thick in the centre.

## 4 Conclusions

1. From section 3.1 it is clear that the drainage around the base of the church walls clearly needs a major review, although the downpipes themselves are generally sound - subject to some unblocking on the north side of the nave. Although this might be expected to cause higher than usual liquid moisture levels to the building fabric at low level, and general dampness to floors internally, it is not realistically a major factor in the weathering of the ironstone walling generally. The impact of salts mobilised by liquid moisture which is present to a higher degree due to poor drainage is clear at low level internally, and may be reduced in the long-term by drainage improvements.
2. The church interior, discussed in section 3.2, does nothing to allay these concerns. There may be mileage in a phased programme of re-pointing internally in lime and of reviewing the use of impervious plasters to help improve the general 'health' of the building envelope, in conjunction with drainage improvements outside.
3. The general walling is of iron-rich beds of the Marlstone rock formation obtained relatively locally. This is quite a poor quality stone (hence why stone was imported from further afield for dressings and weatherings) and is well known for weathering back significantly from the original surface. Weathering is, frankly, inevitable and all we can do externally is to avoid factors that might exacerbate it further. If replacements are required there are potential sources of suitable stone from quarries at Wroxton and Harlestone (both Northamptonshire). See Appendix A.
4. Generally the stone, although weathered back externally from its original surface, is continuing to perform its intended structural function. A repair programme based on consolidation of what survives by packing out voids in the core, where found, with mortar and by re-pointing both externally and internally will help to preserve the structure for a reasonable period of time (say 25 to 50 years) before further works are required. Stone replacement should be kept to a minimum. The difficulty with replacing isolated stones is that the conventional approach of replacing to the original surface level can create a visually unsatisfactory surface with ledges that can form water traps. A more satisfactory solution of isolated stones weathered beyond their reasonable limit (say leaving less than 75-100mm of thickness of stone) might be to restore such areas to the surface level of adjacent stones using replacement stone slips say 40mm thick on bed, set in mortar.
5. Mortars for conservation works are discussed in Appendix B as well as alluded to in Appendix A. The recommendation is for site trials based on a

'hot lime' mix of 1 part quicklime to 3 parts (for example) Baston plastering sand, possibly with added trass.

Plate 7: The south-west corner of the nave where the brick drainage channel meets the gravel. The very poor condition of the channel is clear. The limestone weatherings are basically sound. The ironstone visible can be conserved by localised repair, re-pointing and consolidation with mortars as described.

Plate 8: An area of weathered ironstone. The heavily weathered quoin with stones above and below surviving to almost full face is a rare case for replacing a stone complete.

Plate 9: This area of stonework has not weathered heavily and can just be brushed down and re-pointed in lime mortar.

Plate 10: An area of stonework affected by masonry bees with quite deep and large pockets in the mortar, and lots of old patch repairs in cement. Although in principle it would be nice to be able to accept and accommodate the bees, here they are starting to cause structural problems. The voids here need grouting and filling, and the joints re-pointing in lime mortar. None of the stones visible in this photograph need replacing.

# Appendix A

# Jefferson Consulting Ltd geological report

# Jefferson Consulting Limited

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## St. John's Church
## Grimston
Leicestershire

Analysis of a sample of original stonework
in order to determine its provenance
and advise on suitable stone for repairs

## INTRODUCTION

Grimston church is Listed Grade II*, the listing text indicating that the church is built of coursed, squared ironstone with a slate roof. The earliest part of the church dates to the 13th century, coming under the Templers of Rothley in 1244. Some of the building is also attributed to the 15th century. As was relatively typical for this type of country church, there was a 19th century 'restoration' undertaken in 1866 by R. W. Johnson; this probably included building the porch. The roof collapsed in 1895 and was subsequently rebuilt. The top of the tower is castellated and is likely to be part of the 19th century restoration. This addition to the tower appears to be built of grey oöidal limestone, a material which has also been used for repairs to the quoins, string courses and windows. In other areas brick has been used for repairing the fabric, in particular the base of the tower and parts of the base of the east end.

Geological data indicates that the village and the church are built on the Charmouth mudstone, although the building stone is clearly from the iron-rich beds of the Marlstone Rock Formation, which outcrops about two kilometres to the east. The oöidal limestone may be from the Ancaster stone quarries on Wilsford Heath north of Grantham, or may be from similar Lincolnshire Limestone strata between Grantham and Melton Mowbray.

Much of the external fabric is in a poor condition, especially at higher levels where it has been repaired with limestone, and at lower levels where bricks have been used. In more recent 'repairs' rather crude pointing has been carried out with cement-based mortar. A traditional ditch remains round part of the church, although on the north side this is absent with the result that the base of the wall is wet. Inside the church some extremely detrimental ribbon pointing using a hard, probably Portland cement-based, mortar has been used on the walls. However, the most significant problem within the church is the high level of moisture in the base of the walls, especially at the east end and on the north side of the west end. At this latter location the stonework at the base of the tower is saturated and the moisture is rising up the tower. It is essential that the source of this moisture is investigated, the iron-rich building stone being extremely sensitive to moisture.

As a result of a number of possible factors, such as mechanical fracturing due to movement, possible incorrect orientation of the stone in the fabric, and moisture ingress into the fabric, repairs to the stonework are required. Unfortunately the local iron-rich building stone is now not commercially available. Where viable, for example when repairs to Belvoir Castle have been required, one of the old quarries can be temporarily re-opened. This is unlikely to be possible in the case of repairs to St. John's Church. It is therefore necessary to identify a commercial stone which is strictly compatible in terms of petrography, chemistry, physical properties and appearance, to the original material. A sample has therefore been petrographically analysed in order to confirm its provenance and identify such a source of replacement stone.

## THE SAMPLE

Figure 1. A sample of the stone from the church. The scale bar is 5 cm long.

The stone is a fine-grained material, moderate yellowish orange in colour, about 10YR 6.5/5 on the Munsell® colour scheme. It has a rough texture and contains some scattered fossil shell fragments. The stone is illustrated in Figure 1. In thin section, a photomicrograph of which is shown in Figure 2, the material is seen to be composed of a mass of angular to sub-angular fragments of quartz, typically 100 μm in diameter, together with more rounded calcitic fossil fragments from about 350 μm upwards in diameter. All the clasts are bound in a matrix consisting largely of limonite, that is cryptocrystalline goethite, an iron oxide hydroxide. Since the predominant constituents are quartz grains, the stone would be classified as a ferruginous sandstone.

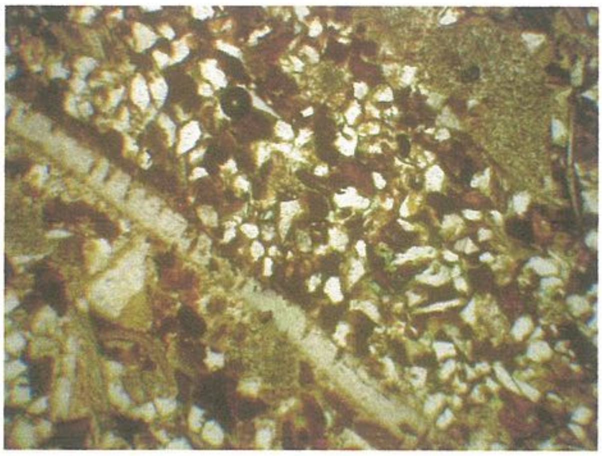

Figure 2. Photomicrograph of the stone from the church. Small clear quartz grains and larger, more mottled, shell fragments, are enclosed in reddish-brown limonite. Width of the photograph is 2.16 mm.

Commonly referred to as 'ironstones', very few are in fact true ironstones, a material which has sufficient iron content for it to be considered as a potential iron ore. Furthermore in the context of building stone the term encompasses true ironstone, ferruginous sandstone and ferruginous limestone, the only connecting factor being their rusty red to brown colour. When stone for repairs to historic 'ironstone' buildings is required, care must be taken to ensure that the mineral content of the new stone matches that of the original.

REPLACEMENT STONE

Although no ferruginous rocks are now worked in the Marlstone Rock Formation of the Jurassic Lias Group in Leicestershire, they are still extracted for building and aggregate purposes from the Jurassic Northampton Sand Formation of Northamptonshire and Oxfordshire. These vary from true ironstones to ferruginous sandstones, although the suppliers always appear to term them 'ferruginous limestone', possibly on the basis of their reaction to dilute acid due the broken calcite shell content. Of those currently available, that which is petrographically most similar to the stone in the church is the Northamptonshire stone from Harlestone quarry. A photomicrograph of this stone is shown in Figure 3. Although lacking in shell fragments, the stone is a ferruginous sandstone consisting of quartz grains in a ferruginous matrix, similar to that from the church. In hand sample the stone ranges from light brown, about 5YR 6/6 on the Munsell® colour scale, to moderate brown,

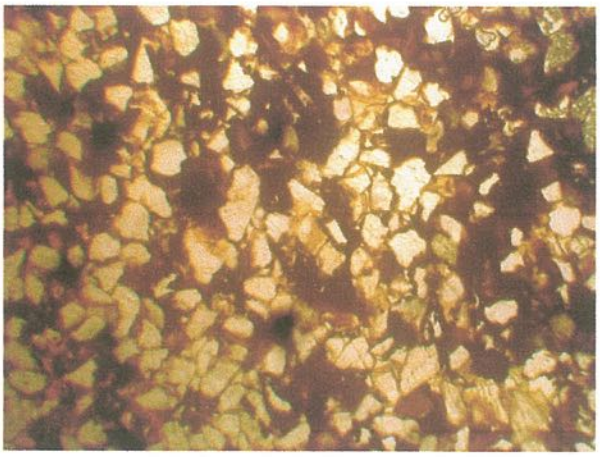

Figure 3. Photomicrograph of a sample of ferruginous sandstone from Harlestone quarry. The stone consists of quartz clasts bound with iron minerals such as limonite. Width of the field of view is 2.16 mm.

about 5YR 4/4 on the scale. Although darker than the sample provided, stones of a similar colour range do occur in the fabric of St. John's church. A lighter coloured stone, potentially closer in hue comes from Wroxton, also in Northamptonshire. However this material appears to have a somewhat lower silica content. Photographs of both these stones are shown in Figures 4 and 5 respectively. Although varying in silica, calcite and limonite content from the original stone, both would be petrographically and chemically compatible with it. Choice could therefore be made on the basis of the colour and texture of the current output from the quarries. Both stones are worked and supplied by Peter Bennie Limited, details at *www.peterbennie.co.uk.*

Figure 4. A sample of ferruginous sandstone from Harlestone quarry. Scale is 5 cm.

Figure 5. A sample of stone from Wroxton quarry. Scale is 5 cm.

NOTE ON MORTAR

Due to the permeable nature of the iron-rich stone used in the church, care should be taken in the composition of mortars used for repairs. Such materials may contain reactive minerals, such as phyllosilicates and cryptocrystalline silica, which can form secondary minerals such as soluble silicates when in the presence of alkaline solutions, such as those found in traditional lime mortars. Hot lime or pozzolanic lime, the preferred pozzolan being volcanic trass, should be considered in order to overcome this potential problem. Mortar based on NHL should not be used.

# Appendix B

# Mortar analysis report

# Report describing the results of the analysis of four mortar samples from St. John the Baptist's church, Grimston, Leicestershire

## Introduction

The analysis described in this report has been carried out as part of a wider programme of survey work being undertaken by Skillington Workshop Ltd at St. John the Baptist' church, Grimston.

The survey has been commissioned by Peter Rogan of Peter Rogan Associates Ltd, architect for the church, on behalf of the PCC.

The survey is being carried out by Dr David Carrington ACR of Skillington Workshop Ltd, who took the samples on 13 September 2017. All analysis and the preparation of this report (which forms a section of the broader survey report) has also been by Dr David Carrington.

The analysis aims to provide the following information:

1. Visual description of the samples.
2. Assessment to ratio of insoluble: soluble portions in hydrochloric acid.
3. Interpretation and inferences regarding binder: aggregate ratios.
4. Characterisation of the binder(s).
5. Characterisation of insoluble aggregate(s).
6. Indication of suitable plaster mix for repair work.

Note that there are limitations both to the relatively simple analysis carried out. As such it is strongly recommended that the results are taken as an indication towards site mortar mix trials rather than as a stand alone answer.

## Historic context

St. John the Baptist church dates mainly to the 13th and 14th centuries, undergoing a major restoration in 1866 by the architect R.W.Johnson (see main report for further details).

General description

Four samples were taken externally, as follows:

(1) Construction (core) mortar from the west wall of the south transept at a height of circa 1.5m above ground level. Visually it looks like lime mortar rather than earth mortar – indeed, there is no sign of pure earth mortar being used in the construction.
(2) What appears to be original bedding mortar to an ashlar pilaster at the north-west corner of the tower, at a height of circa 2.0m above ground level.
(3) A historic repair mortar used to make up an area of surface to the east wall of the south transept with bricks and tiles.
(4) Original bedding mortar from the west wall of the nave to the north of the tower, at a height of circa 2.0m above ground level.

The samples were inspected by naked eye and by microscope (x10 – x20) prior to crushing or dissolving in hydrochloric acid. The results of this visual examination are given in Table 1, below.

Table 1: Summary of visual and pre-dissolution assessment of sample.

| Sample ref. | Colour | Texture | Hardness | Context | Inclusions |
|---|---|---|---|---|---|
| G/060/ C (1) | Brown/ orange | Fine. | Fairly hard | Core mortar | Visible white and black, no more than 1mm in size. Sand grains visible under magnification. |
| G/060/ C (2) | Cream | Fine | Fairly hard | Bedding | Sand grains visible under magnification. |
| G/060/ C (3) | Cream | Medium | Hard | Later repair | White inclusions up to 2mm in size. Under magnification sand grains visible and plenty of what look like tiny air pockets. |
| G/060/ C (4) | Cream | Fine | Fairly soft | Bedding | Sand grains visible under magnification. |

The hardness in the above table is assessed by thumb pressure. A sample described as 'soft' will easily crumble under light pressure, one described as 'fairly soft' will start to crumble under moderate pressure, one which is 'fairly hard' only starts to crumble under great pressure and will not scratch easily, whereas 'hard' samples are all but impossible to crumble between thumb and forefinger.

Solubility in 1.18 Hydrochloric acid

For each sample a weighed amount of oven-dried mortar was dissolved in standard strength hydrochloric acid, observing the form of reaction. Once the reaction was complete in excess acid, the sample was washed in de-ionised water and oven dried. The weight of the remaining insoluble portion can then be compared to that of the soluble part to indicate the proportion (by mass) of calcareous matter to inert material. For the standard solubility test the aggregate was further analysed using a set of British Standard sieves. The results are given in Table 2, on page 3.

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Determination of percentage of sample which is soluble in hydrochloric acid | | | | |
| Sample including tray & label | 13.27g | 7.56g | 11.05g | 7.07g |
| Tray & label | 1.52g | 1.85g | 1.36g | 1.06g |
| Oven dry mass prior to dissolution (g) | 11.75g | 5.71g | 9.69g | 6.01g |
| Reaction with hydrochloric acid | Immediate & vigorous | Immediate & vigorous | Immediate & vigorous | Immediate & vigorous |
| Mass of oven-dry insoluble portion (g) | 6.64g (56%) | 2.36g (41%) | 4.85g (50%) | 2.34g (39%) |
| Portion of dry sample lost upon dissolution | 44% | 59% | 50% | 61% |
| Particle Size Distribution analysis of insoluble portion | | | | |
| Portion greater than 2.36mm in size (%) | 10% | 18% | 0 | 0 |
| Portion between 2.36 and 1.18mm (%) | 3% | 4% | 1% | 3% |
| 0.6-1.18mm (%) | 5% | 11% | 5% | 16% |
| 0.3-0.6mm (%) | 30% | 31% | 39% | 33% |
| 0.15-0.3mm (%) | 36% | 27% | 47% | 39% |
| 0.075-0.15mm (%) | 10% | 10% | 5% | 9% |
| Less than 0.075mm (%) | 4% | 3% | 1% | 2% |

Table 2: Results of dissolution in hydrochloric acid.

Visual assessment of insoluble portion

The insoluble portions are all very close in colour and texture as well as grading suggesting a common source - presumably a local sand quarry - used by medieval masons as well as - for sample 3 - post-medieval restoration masons. Interestingly the lack of fines distinguishes all samples from those that might contain clay-like earth.

Sample 2 is distinguished by having many large white inclusions. They look like unburnt lime, but if so should have dissolved in the acid.

The sand in each case has light brown grains predominating, sub-angular to sub-rounded in shape.

Interpretation

Firstly, looking at the hardness, appearance, and type of reaction we can surmise that the samples have non-hydraulic or feebly hydraulic lime as a binder. I am a little unsure of the nature of the larger white clasts remaining in sample 2 (could they suggest that there's a gypsum content? - unlikely but there are gypsum quarries in the region - further analysis would determine this), but it is certain that there's no Portland cement present. The ratio is high, about 1 part binder to 1 part insoluble aggregate by weight.

Photograph to show sample (1) as sampled next to the insoluble aggregate extracted from it.

As can be seen in the photograph above there are occasional larger sand particles in the insoluble aggregate, but generally it is not too far different from for example Baston quarry 'plastering sand'.

Conclusions

Despite being of different dates the four samples are all broadly similar. Looking primarily though at the original construction, it appears that a good 'like-for-like' mortar mix would be 1 part non-hydraulic lime to 1 part Baston plastering sand or similar, perhaps with some added pozzolan.

Modern thinking however suggests that a good mortar should comprise 1 part lime to 2.5 or 3 parts sand, but more recently work with 'hot limes', that is lime made by mixing the aggregate with burnt lime, can work with higher ratios of lime. A mix of 1 part quicklime to 2 parts sand, mixed whilst the lime is slaking in damp sand, would give a final mix of about 1:1. I would start on this basis, perhaps going to a 1 part quicklime to 3 parts sand mix ratio.

I would also trial the use of Trass as a pozzolannic additive, used at about 5% of the total mortar mix volume. This could be expensive though if large volumes of mortar are required.

There is no evidence for the use of earth mortars.

As previously noted, this must be taken as a guide to inform site trials when replicating historic plaster mixes, and not a specification in its own right.

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