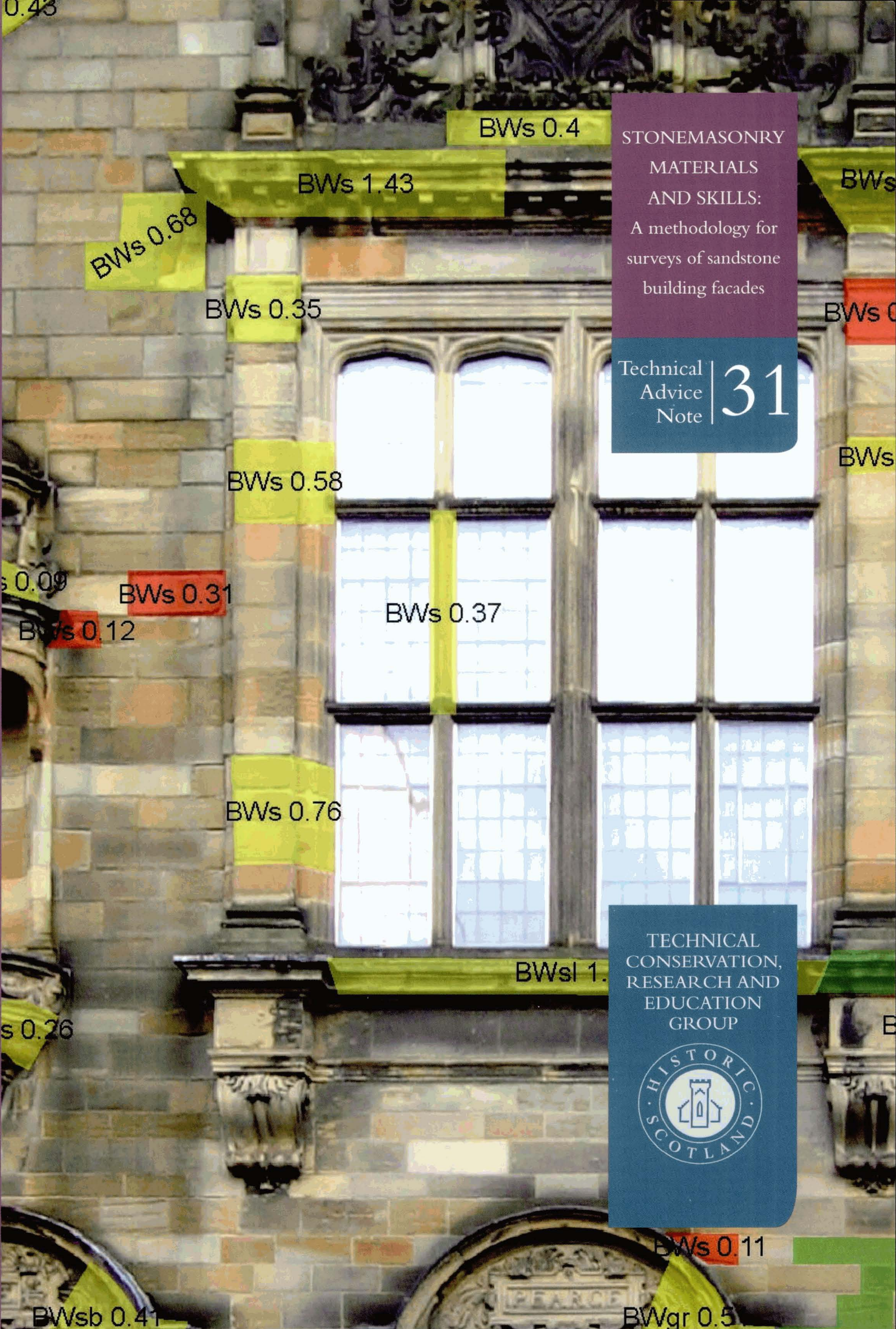
STONEMASONRY MATERIALS AND SKILLS:

A methodology for surveys of sandstone building facades

Technical Advice Note | 31



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STONEMASONRY SKILLS AND MATERIALS: A methodology to survey sandstone building facades

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FOREWORD

Sandstone is the predominant indigenous material utilised in the construction of traditional masonry buildings throughout much of Scotland. Moulded, carved and worked to create remarkable results, this embellished material can be found adorning the front of many important historic buildings. Despite its undoubted importance, in recent years there has been a growing awareness that the stones' unique character, and architectural quality, is increasingly being put at risk through natural and man-induced erosion.

The methodology outlined in this Technical Advice Note (TAN) is based upon the work carried out by the Scottish Stone Liaison Group (SSLG) in undertaking the "Glasgow Project" during 2005-06. Here, the Group carried out a pilot survey to assess the repair needs of stonework in the city. From the subsequent analysis of 230 building facades, it quantified the range and type of sandstone required to effect future repairs, and projected the extent of masonry craft skills needed to execute the work. A robust approach was devised to ensure that the complexities of the issues involved were fully addressed.

Looking across the face of the country, and recognising that similar issues to those found in Glasgow exist elsewhere, there is a need for similar surveys to be carried to gain a more comprehensive view of the overall scale of the problems. This is considered appropriate in order to obtain a fuller understanding of the challenges through building up a national picture of what is required. If this approach is to be successful, it could be argued that there is a need to adopt a standardised approach and methodology for carrying out the survey and analytical work. It is the aim of this TAN to promote an effective, tried and tested methodical approach to help achieve that consensus.

Stone can deteriorate for a number of reasons, and the proposed methodology gives those carrying out survey work on sandstone buildings relevant guidance on the range of decay mechanisms that are likely to be found. Whilst decay occurs naturally as part of a buildings' interaction with the environment, it can also be induced by factors such as poor maintenance, stone cleaning and inappropriate repair techniques. How to identify and interpret both natural and induced decay mechanisms is incorporated in the methodology.

The key part of this publication is the section that describes the approach and method to be followed when conducting surveys. Considerations, such as offering step by step guidance for field survey work, and a colour coding system for marking up façade images, are included. Thought is also given to what is an appropriate method for obtaining stone samples from a building in a way that minimises further damage.

There is much to commend in promoting and following the SSLG's pioneering approach. It is hoped that this publication will provide others with a clear, accessible and pragmatic method of surveying, analysing and identifying the repair needs of our stone built heritage. By suggesting a wider uptake of the methodology, it is anticipated that this TAN will be of value to building owners, funders, the construction industry, professionals, and education and training providers alike in planning for future needs.

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Director
Technical Conservation, Research and Education
Historic Scotland
December 2007

Figure 1. Typical examples of stone facades in Scotland's towns and cities (Photos: D Urquhart)

SUMMARY

The built heritage of Scotland is essentially a stone-built heritage but there is concern that this heritage is at increasing risk from a range of factors that are degrading its unique character. This concern was recognised by the Scottish Stone Liaison Group (SSLG) who, with the support of a range of organisations, conducted a survey of Glasgow's stone-built heritage to determine the repair needs of the stonework, the quantity and type of stone required and the skills that will be necessary to carry out the repairs. The resulting report in 2006 reinforces the need to expand the work to assess the wider Scottish situation. However, this technical advice note recognises that there must be a co-ordinated approach to this work. To this end, it is recommended that the work follows a methodology that is both rigorous and repeatable so that there is comparability between the results from different studies to permit the results to be drawn together with confidence. The purpose of this advice note is therefore to set down an appropriate methodology that can be used by the survey teams involved.

There are essentially two main parts to the guidance. The first part, Chapter 2, provides information on the mechanisms of decay of building stones and describes the forms of natural and induced decay that are most likely to be encountered on sandstone during the survey work. It is now well recognised that stone decay on building facades has been significantly increased by poorly executed stone cleaning. In addition, the use of hard cement mortar, and other mortar compositions, for the repair of decayed surfaces and as replacement pointing has further contributed to the decay of stone.

The second key section, Chapter 3, is a detailed description of the approaches to be adopted when undertaking the survey and in the analysis and recording of the results. Emphasis is placed on the need to adopt a rigorous approach to selecting the facades to be included in the survey so that a statistically valid sample is obtained. Once the sample has been determined, step-by-step guidance on the field survey work is set out. Within this methodology the recommended techniques for recording stone decay, together with a colour coding system for marking-up the facade images, are explained.

In addition to visual surveys, the need to obtain stone samples for stone matching is emphasised and a possible protocol for obtaining the samples is promoted, including obtaining listed building consent when appropriate. Proper and consistent interpretation of the evidence is essential and guidance is offered on how to categorise stone decay and a timescale for its replacement. A range of illustrations for both ashlar and rubble walls is provided to help with identification of decay types and their classification.

Because of the importance in obtaining data that is consistent and comparable, an example of a stone facade survey record pro forma is included. For ease of use this has been designed essentially on a tick-box format, which also allows the data to be readily incorporated into a statistical software package for subsequent analysis.

Figure 2. Examples of the results of facade surveys with stone decay identified by a colour coding system (Photos: BGS©NERC)

1. INTRODUCTION

1.1 Background

The built heritage of Scotland is essentially a stone heritage; it is the variety and range of its stone buildings and other structures that define its unique quality. However, over the past few years there has been an awareness that this heritage is at increasing risk and that, unless informed action is taken, much that is of significance could be lost to future generations. Also, the negative impact of this loss on the quality of the built environment of our towns and cities could be substantial; which, in turn, will affect their attractiveness to business, tourists and the population at large, possibly leading to long term environmental degradation. A further important consideration is that by properly maintaining the building stock the need for replacement by new build is reduced. Thus the retention of the existing stock takes advantage of the energy embodied within the fabric, and eliminates energy use and related carbon emissions associated with totally new construction.

It is this perception of risk that has led to the recognition of a need to establish definitive data relating to the condition of the heritage. The acquisition of such information will thus provide a sound basis for the political and strategic decisions that will be required to ensure the proper care and maintenance of this valuable resource. To date, apart from a recent project in 2006 in Glasgow (outlined below) and the Scottish Small Towns Report by Scottish Borders Council (2007), no research-based information is available on which a future Scottish strategy can be based. The purpose of this Technical Advice Note (TAN) is therefore to define a process by which such information can be collected and assessed in a rigorous and controlled manner, which can then be added to the data obtained by the 'Glasgow' project to provide a national picture of needs.

There is no information available on the total number of stone buildings in Scotland. However, it is estimated that there are around 500,000 pre-1919 traditionally-built buildings, of which a significant majority will be stone built. There is thus an urgent need to provide some guidance on how a national survey might be undertaken to quantify the stone material and stonemasonry skill needs within the foreseeable future. It is interesting to note that the Scottish Small Towns Report found that 48% of properties required urgent repair and, in the case of individual elements showing high priority defects, 45.39% of those properties surveyed had defects classified as 'falling masonry'. In addition, the regular Scottish House Condition Survey (2002) reports that 81% of houses have some kind of disrepair.

Figure 3. Decayed cornice presenting a risk of falling masonry (Photo: Edinburgh City Council)

The time horizon within which predictions on future stone repair needs can reasonably be predicted is taken as twenty years. This period is recommended for a number of reasons:

a) The processes of stone decay are slow and, although some decay can become obvious in a much shorter period, twenty years is a realistic time period for the projection of the future decay of stone.

b) Twenty years is a 'manageable' period; if a longer time frame is adopted, owners of buildings are unlikely to take such a long term view, especially if short-term leases or full repairing and maintenance leases are in force.

c) It is a reasonable period within which both strategic planning and implementation of skills training and repairs can be realistically accommodated.

1.2 Summary of risks to Scotland's stone-built heritage

While Scotland contains many fine stone buildings that predate the early nineteenth century, it is the case that the majority of stone buildings, especially in towns and cities, were constructed in the mid-to-late C19. The risks to this heritage are derived from a number of sources and are summarised below:

a) *Age of the buildings.* Most of the stone buildings are around 100 to 160 years of age and the effects of time, climate and natural weathering have taken their toll.

b) *Pollution.* The polluted urban environment of cities and some towns, from the coal fires and heavy industry of the late C19 and early C20 to the vehicle emissions of the present day, has promoted stone decay.

c) *Poor maintenance.* Inadequate maintenance of buildings over the years encourages increased moisture penetration of the stone, particularly from defective gutters and downpipes and from defective mortar joints. The action of moisture in stone is the primary 'engine' of decay.

d) *Lack of knowledge.* A lack of knowledge and understanding of natural stone by both building owners and some professionals and trades-people has permitted deteriorating stone conditions to continue, often resulting in accelerated decay.

e) *Inappropriate intervention.* Research commissioned by Historic Scotland (The Robert Gordon University 2003) has shown that the large-scale cleaning of stone facades in the 1980s, often poorly executed, has resulted in a deterioration of the condition of a significant number of stone facades. It is often the case that short-term cosmetic repairs to stone have been implemented, which were applied simply to cover up the decayed areas. Typically, coloured cement mortar (plastic repair) is used for this purpose and has a very short life before it too fails. Of more concern is the fact that this sort of intervention can increase the rate of decay of the stone to which it is applied and also to adjacent stones. The almost universal use of hard cement mortars for repointing has accelerated the decay process in many cases. In addition, research has also shown that the use of inappropriate sandstone for repairs can lead to accelerated decay of the remaining original masonry.

f) *Lack of funding.* It is the case that only the most important listed buildings are eligible for grant aid to carry out repairs. This means that many building owners will either not carry out stone repairs or will commission the cheapest and least satisfactory repair methods, such as plastic repair.

g) *Shortage of skills.* There is evidence that many repairs to stone, particularly on less significant buildings, are poorly executed. This may be due to shortage of skills, leading to the use of poorly trained workers.

h) *Shortage of stone materials.* The loss of practically all of the quarries from which the stone for Scotland's towns and cities was produced is likely to have a critical impact on the availability of appropriate stone to cater for any expansion of stone supply needs.

i) *Climate change.* The projected change to the climate of Scotland over the coming decades indicates that we can expect warmer but wetter winters, which will tend to keep stonework wetter for longer. This has the potential to increase the rate of decay of stone.

1.3 The Glasgow Project

The aim of this project (SSLG Report 2006) was to investigate the condition of Glasgow's stone-built heritage to enable an accurate prediction to be made of the craft skills and materials that will be required to ensure the future viability of this heritage. The project was initiated by the Scottish Stone Liaison Group (SSLG) and supported by Scottish Enterprise Glasgow, Glasgow City Council, National Heritage Training Group and CITB-ConstructionSkills. The building facade survey work was carried out by the British Geological Survey (BGS).

The findings of the project give cause for concern for the future of Glasgow's stone-built heritage. It was found that 97% of all of the stone facades will require some form of repair intervention within the next twenty years. If these results are extrapolated to cover all of the sandstone buildings of Scotland, even allowing for the possibility that Glasgow stonework is likely to be among the most problematic, it is likely to place a very great strain on the resources of the country to provide the necessary skills and the appropriate stone materials with which to effect even the minimum of repairs to preserve the heritage.

The experience of the Glasgow Project and the methodologies adopted provide a valuable template for the approach and methods that are promoted within this

TAN. However, refinements have been made to take account of the wider and more variable application of the methodology to a Scotland-wide situation.

1.4 Need for proper maintenance, repair and stone matching

The findings of the Glasgow Project clearly reinforced the fact that proper and timely maintenance of stone facades is essential if the processes of decay of the stone are to be minimised. The key to decay mitigation is the need to prevent as far as possible the long-term saturation of the stone from poorly maintained rain-water gutters and downpipes, and loss of water shedding and protective elements such as cornices, string courses and copestones. Sandstone, in particular, is a porous material and is therefore vulnerable to water retention within the pores. Even with projected milder winters, stone will still be subject to freeze-thaw cycles, which can result in increased stresses within the pores of sandstone, and other porous stones, resulting in breakdown of the stone surface. The introduction by water of soluble salts from a number of sources into the pore structure of sandstone is a significant cause of stone decay.

Over the past fifty years, for most building facades that are not protected by legislation – such as listed building consent, planning and building control – the use of inappropriate repair materials and methods are commonplace. Repairs, often commissioned on the basis of the cheapest estimate, have been based upon the use of coloured cement mortar (plastic repair) applied over the decayed surfaces of stone - occasionally to the extent that an entire facade has been plastered over, with false 'joints' in an attempt to replicate the stonework below (refer to Section 2.3 for further information).

Research published by Historic Scotland (Hyslop 2004) draws attention to the need to ensure that, when new stone is used to replace decayed stone, careful analysis is carried out to ensure that the new stone has a similar match in terms of petrographic characteristics to the surrounding stone. Stone with different characteristics is likely to have different moisture evaporation rates, which may result in accelerated decay of the existing stone.

1.5 Stonemasonry skills

There is clear evidence that, to cope with even the current demand for stone repair, the existing stonemasonry skills, including lime working, are in extremely short supply. This was confirmed by the findings of the Glasgow Project in a survey carried out as part of the project by CITB-ConstructionSkills. The survey estimated that in 2006 the total workforce for the whole of Scotland (stoneworkers and apprentices) is 449. The term stoneworker includes stonemasons' labourers, stone sawyers and managers, which reduces the actual number of available skilled stonemasons. However, this excludes the number of stoneworkers directly employed by Historic Scotland and who, therefore, are only available for work on properties in its care. This number can be put into perspective when set against the number of stonemasons who will be needed to carry out all the repairs identified by the Glasgow Project. It was estimated that a total of around 300 stonemasons will be required to be employed each year for twenty years to complete all the identified repairs.

A key element in the survey of Scotland's stone repair requirements will be the collection of data that will inform the strategic and financial decision making processes relating to the expansion of training for stoneworkers. The currently available training facilities, and the output of trained stonemasons, are barely adequate to cope with current demands and will have to be expanded significantly if we are to meet the anticipated increase in stone heritage repairs over the next twenty years.

Figure 4. Stone mason apprentice in training (Photo: Historic Scotland)

1.6 Stone availability

As identified in Section 1.2, and given the need for a significant increase in the availability of stone to carry out repairs over the next twenty years, it is possible that existing sources of supply will be severely stretched. Also, given that for repair purposes it is important to match the characteristics of the replacement stone with the original, we are currently faced with the problem of finding suitable matching stone. The time and resources required to find such matching stone should not be underestimated. If, as is likely, it is necessary to reopen former stone quarries (or even to open completely new sources) obtaining the necessary consents and financial investment will be time consuming. The need to identify the repair needs of the stone heritage, as promoted by this methodology, is therefore a vital component within both political and strategic planning at national (Scottish) and local levels.

The British Geological Survey has records of many thousands of former stone quarries that served the local needs. However, there are less than ten significant currently operating building stone quarries in Scotland producing building stone, as opposed to many more quarries producing crushed aggregate. Many of the former quarries have been lost forever, but a significant number remain which, may still have the potential to be used for either small-scale stone extraction ('snatch' quarrying) or longer-term supply of stone for repair purposes: a few have indeed been utilised for this purpose to provide matching stone for use in Edinburgh. Since 2000, two historic sandstone quarries in the south of Scotland have reopened providing stone for repairs and local needs, including new-build, both containing sufficient resources for several decades of production.

An excellent guide to stone in Scotland has been published by the British Geological Survey (BGS) (Hyslop et al 2006).

Figure 5. This disused sandstone quarry in Fife, which supplied stone for construction in Edinburgh and the local area prior to closing in 1914 (Photo: E Hyslop, BGS©NERC)

2. OVERVIEW OF STONE DECAY MECHANISMS

2.1 Decay of building stones

This chapter is designed to provide a very brief introduction to the forms of decay that are most likely to be encountered during the survey of building facades. It will provide some guidance on how to identify the decay forms so that the pro forma used in the survey process (see Section 3) can be completed with reasonable confidence. However, the limitations of the information should be recognised and much fuller descriptions of the appearance and processes can be found in the Historic Scotland, Technical Advice Note (TAN) 25 (Young et al 2003). A detailed system for stone decay classification is given by Fitzner and Heinrichs (2002). Another useful reference is BS EN 12670:2002, which gives advice on the terminology used in describing natural stone.

There are many forms of weathering and decay of building stone. All stone will decay to some extent due to the natural effects of weathering, and different stone types will deteriorate to different extents. Sandstones in particular can be very variable in durability, especially on older buildings. In addition, the rate of decay can be influenced by anthropogenic interventions, which can cause further damage by inappropriate treatments, such as excessively aggressive stone cleaning or poorly executed repairs, particularly cement mortar patching or pointing. Young et al advise that *'there is no fundamental difference between natural and induced forms of decay, the distinction lies in the rapidity and in the relative intensity of types of decay'*.

In assessing a facade and the condition of individual stones, it is important to understand that the presence of decay is common and that localised decay may be minor and insignificant in terms of the long-term durability of the stone. It is the predicted rate of decay that is important; in some cases the rate can be almost imperceptible, often less than 1 mm per century (Young et al). In other cases where the stone is particularly vulnerable, the rate of decay can be very rapid, especially when it is increased by interventions such as inappropriate stone cleaning and repair. For some sandstone types Young et al predict rates of surface area decay of up to 17% per decade.

2.2 Identifying decay forms

Of the stone types found in our towns and cities sandstone is by far the dominant stone and is also one that is particularly vulnerable to decay processes. The other important stone type found in Scotland is granite, especially in the north-east and south-west of the country. The decay of granite has not been included here. While granite is subject to weathering and decay, the nature of granite is such that the effects of decay are unlikely to pose a serious risk to the facade and thus the need for stone replacement.

Table 1 is an extract from TAN 25 that identifies seventeen different decay forms encountered on sandstone. Surveyors carrying out facade surveys are advised to refer to this table during the survey process to ensure, as far as possible, that a correct identification has been made. While the table is useful in identifying decay forms, the surveyor is required to make a judgement on the rate of decay and whether replacement will be necessary. The most common forms of decay on sandstone identified by Young et al are granular disintegration, contour scaling and multiple scaling.

Decay form	Description	Natural or induced
Honeycombing	Deep or cavernous pitting in a honeycomb pattern. More common in coastal locations.	Natural
Case hardening (crust)	Hardened crust on top of soft, friable interior. Caused by mineral dissolution, with deposition and hardening near surface.	Natural
Multiple scaling	Detachment of multiple planer elements parallel to a stone surface, unrelated to underlying texture in the stone.	Natural
Crumbling	Loss of surface through detachment of clusters or clumps of grains.	Mostly natural
Pitting	Small, irregularly distributed pits on a stone surface. In sandstone, often caused by variations in type or degree of cementation.	Mostly natural
Differential decay	Differential weathering of individual stone components due to naturally occurring differences in their vulnerability to decay.	Mostly natural
Decay of components	Zones of decay due to loss of clearly bounded elements or inclusions, eg clay nodules or pebbles.	Mostly natural
Granulation (granular disintegration)	Loss of surface through detachment of individual grains. May be associated with salt efflorescence.	Natural and induced
Flaking	Detachment of small, thin, planar elements parallel to a stone surface.	Natural and induced
Blistering	Localised blistering of a stone surface.	Natural and induced
Contour scaling	Detachment of large, planar elements parallel to a stone surface, unrelated to underlying texture of a stone.	Natural and induced
Dissolution	Soluble minerals, especially carbonates, dissolved by rainwater and/or stone cleaning fluids.	Natural and induced
Back weathering	Extreme decay, when a single block has weathered back to a significantly greater degree than a surrounding stone.	Natural and induced
Delamination	Detachment of a single or multiple planar elements parallel to foliation or bedding plane. Often exacerbated by edge bedding.	Natural and induced
Abrasion from cleaning	General loss of surface or sharpness of detail as a result of aggressive stone cleaning.	Induced
Mechanical damage	Loss of compact stone fragments by fracturing due to impact or other stresses acting on the stone.	Induced
Fissures or cracks	Lines of fracture or open cracks wholly or substantially crossing a stone block. Often caused by settlement or impact damage.	Induced

Table 1. Forms of natural and induced (man-made) decay on stone building facades (from TAN 25, Young et al 2003)

2.3 Stone cleaning and plastic repair

From Table 1, where decay forms are identified as being induced, those so identified, apart from mechanical damage and fissures, can be promoted by stone cleaning and plastic repair. It is now clear that poorly executed stone cleaning has left a legacy of decay, especially on some blonde sandstone types. The effects of abrasive cleaning systems became obvious soon after treatment. Loss of surface and sharpness of detail lead in turn to increasing surface erosion over time. Chemical cleaning too has contributed to the decay process by dissolution of sandstone cements, leading to various forms of surface deterioration. In addition, the retention of salts below the surface of the stone (cryptoflourescence) creates pressure within the pores leading to further surface loss. Stone adjacent to roads and footpaths is particularly vulnerable to damage from de-icing salts.

Equally damaging to sandstone is the use of hard cement mortar, and other hard mortar compositions, for the repair of decayed surfaces (plastic repair) and as pointing. Such mortars when used for plastic repair purposes have a relatively short life, often failure occurs within five years and have a maximum life of around twenty years. These mortars, frequently coloured to 'match' the stone, have quite different characteristics to sandstone: they transpire moisture at a different rate and tend to trap moisture within the stone behind, resulting in a further breakdown of the stone. Often, the first indication of this is the presence of fine cracks on the surface of the plastic repair.

In addition to the damage to the stone behind the repair, the effect of a reduction in moisture evaporation through the repair results in increased transpiration from adjoining stones (especially the stones above), which, in turn, causes loss of surface from these stones. A similar effect is observed when hard mortar pointing has been used. Unfortunately, the use of such repairs is ubiquitous and is now a major cause of accelerated decay of sandstone in Scotland (and elsewhere).

When faced with a decision on the expected life of a plastic repair the surveyor should assume that there is decayed stone behind the repair, even when the mortar appears sound, and the stone should be noted for replacement.

Figure 6. An extreme example of sandstone decay promoted by chemical stone cleaning. Falling masonry is now a risk on this building (Photo: D Urquhart)

Figure 7. Typical example of plastic repair causing damage to the underlying sandstone (Photo: D Urquhart)

3. METHODOLOGY: THE KEY STEPS

3.1 Desk study

3.1.1 Define boundaries

Within the town or city the geographical limits or boundaries of the study area must be defined. This is an important feature of the study as it will be used to identify the total number of buildings within the area, from which the number of stone facades that potentially may require repair over the next twenty years can be quantified. It is recommended that the geographical boundaries enclose, not just conservation areas for example, but also include stone buildings that may be not listed or which lie outwith conservation areas. Such buildings nevertheless contribute to the overall character of the stone heritage.

The geographical area may therefore include:

- all of the area that contains traditional stone buildings with exposed stone facades,
- a town centre,
- a town centre and adjoining streets with stone facades,
- conservation area/s,
- conservation area/s including adjoining streets with stone-built properties.

3.1.2 Determine the total number of facades (the population)

The following sources and issues should be considered:

a) Given that all decayed stonework within the area is unlikely to be replaced within the time scale, it is necessary, before determining the total population of stone facades within the study area, to decide the nature of the facades that will be included. For example, is the study to be confined to ashlar and exposed rubble masonry types? Such information is important because scaling up of the data to the total population will be required on completion of the survey work.

b) Seek the collaboration of the local planning or conservation officers and/or local heritage trusts. It is likely that these people and organisations will have an intimate knowledge of the study area and will be in a position to identify stone facades on suitably-scaled plans.

c) From appropriate scale O.S. maps (min. 1:1250 scale) determine the number of stone facades within the area (ie the population). Historic maps of Scottish towns and cities, may sometimes be available and can be a valuable reference source. It is recommended that the following approach to the facade count is adopted:

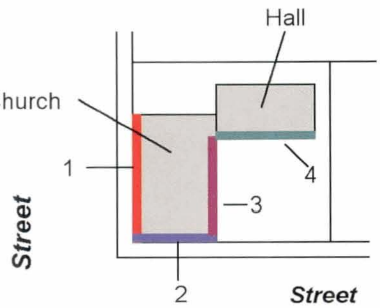
i) Large detached buildings (such as churches and schools etc.) are identified and a decision made on the number of stone facades to be included. It is suggested that only those that front onto a street are used in the count (see Fig. 5).

ii) Tenements, including tenements with shops at ground level. Each facade that fronts on to a street counts as one – a corner block with facades on two streets (ie a corner) counts as two facades. In most cases a tenement facade will occupy the width of frontage where apartments are accessed from either side of a common stair (see Fig.5).

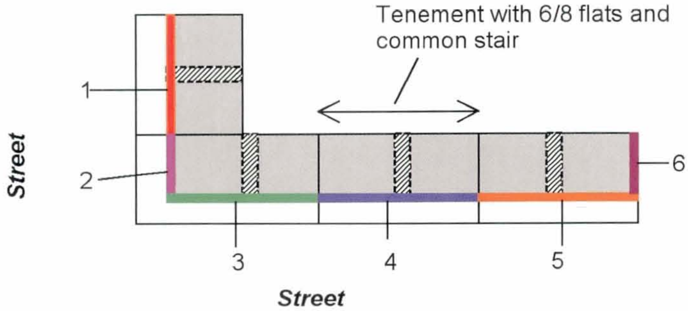
iii) Terraces and semi-detached buildings. Each main facade to a street that is contained within the property boundary lines on the OS 1:1250 master map plan counts as one. Typically this covers two properties.

iv) Detached houses or mansions. Only the main facade is counted – count as one.

The counting system described above is likely to underestimate the actual number of facades for many buildings. For example, a mid-terrace or tenement block is likely to have two stone facades (front and rear), and detached buildings will have more. However, in many cases the rear and side elevations of stone buildings were constructed from different (perhaps lower quality) stone, or brick in some cases.



Example 1. Detached church and hall complex. Numbered facades are the main stone facades



Example 2. Tenement block – only main facades to streets are counted

Figure 8. Identification of facades for counting

d) Identify the number of listed buildings (for use in the survey pro-forma data sheet – see Appendix A)

3.1.3 Stratified samples

a) From the total population of facades identify variables and extract data for preparation of stratified samples. Group the stone buildings into the various stratifications. Typical strata are noted below, although not all may be required for any one situation.

i) Building type

Residential

Tenement/mixed residential commercial, Terraced, Semi-detached/detached.

Ecclesiastical

Public

Commercial

Industrial

Monument

ii) Age (pre 1800, 1800–1850, 1850–1919, post 1919)

iii) Stone type eg red or blonde sandstone.

b) Determine population of each group (stratum).

c) Determine the total sample size and choice of sample size for each stratum and calculate the percentage in each group. Percentages of each stratum should be the same as within the total population.

Assume minimum sample sizes as indicated in Table 2:

Total Population of Facades	Sample size	% of Total population
<100	20	20%
100 – 499	30	30% to 6%
500 – 999	50	10% to 5%
1,000 – 1,499	60	6% to 4%
>1,500	70	reducing from 5%

Table 2. Suggested sample sizes

Example: Conservation area, mainly residential (all sandstone – no record of sandstone type) contains:

Tenement/commercial facades 25
(Age: 1850 – 1919)

Ecclesiastical (facades) 6
(Ages: 2 No 1800-1850 and 4 No 1850-1919)

Terraces (facades) 215
(Ages: 170 No 1850-1900 and 45 No post 1919)

Total number of facades 246

Stratified samples required for a population of 246 = 30 total (12.2%), the sample size within each stratum is shown in Table 3.

Stratum 1: Building Type	Stratum 2: Date	% of Total Population	Sample size
Tenements etc	1850 - 1900	10.42	3
Ecclesiastical	1800 - 1850	0.8	1
	1850 - 1919	1.63	2
Terraces	1850 - 1919	71	21
	>1919	19	6

Table 3. Determination of sample sizes in the example

Total number in sample = 33 (sample size 13.4%)

3.1.4 Selection of facades to form the sample

Because the purpose of the research is to determine the repair needs of the total population of stone facades within the area it is important to avoid bias in the selection, which could occur if the selection is made during an on-site inspection. There may be a tendency to focus on the stonework in poorest condition. A possible approach to reduce bias is to allocate a code number (on a plan) to each facade within a stratum and to hold a draw (or use random number generation) to select the facades to be surveyed. Note: some changes may be necessary when the facades are viewed on site; for example, to better reflect the balance between blonde and red sandstone or between sandstone and other stone types.

While the example above appears to give a precise number, it is important not to have a fixation on this; there is a degree of flexibility in selection to accommodate potential anomalies. For example, the above stratum for ecclesiastical buildings, identified in Table 3, numbers only six facades (three churches). To avoid the possibility of introducing error into a small sample by eliminating key data, it is sensible in such cases to survey a larger proportion (or even all buildings within the stratum) to increase the sample of the stratum and, in this case, include all six facades in the sample.

Care should be exercised on whether or not to include nationally important historic buildings within the survey. Buildings that are in the care of Historic Scotland should be excluded because they could be considered not to be part of the total population. Such buildings have a carefully controlled repair and maintenance regime, usually with a programme of stone replacement, carried out by a dedicated workforce. The inclusion of buildings of this type into the sample will tend to skew the results, especially within a small total population.

3.1.5 Stone sampling protocol

It is important to check the status of the building at the outset and any agreements that may have to be obtained are resolved before starting work. Agree with the planning department a standard protocol for stone sampling from listed buildings and apply for listed building consent or, from Historic Scotland, for scheduled ancient monument consent where appropriate. However, as a general rule, scheduled ancient monuments should not be considered for coring. In some cases the planning department may agree to the standard protocol for coring being applied to all identified buildings without the need for individual applications. In other cases consent may have to be applied for separately for each building. A typical protocol is provided in Appendix B and is based upon the protocol approved by Historic Scotland and Glasgow City Council for the Glasgow project.

Typically, sampling will take the form of a small diameter (35 mm) core, 150 mm in length, extracted from an inconspicuous area of the facade that is representative of the stone type for that facade. In some cases, it may be possible to gain access to core from the inside face of the stone, for example a building which is currently being redeveloped or repaired. Where possible a core can be taken from a similar stone in a less visible part of the building, or from damaged or decayed stone that will be replaced (particularly when buildings are undergoing or about to undergo repairs).

Where necessary, core bore holes will be plugged by using part of the core and sealing the joints with lime mortar. Care must be taken to minimise the visual impact of the coring. If a mixture of sandstone types is present in a facade, and the facade is actually undergoing repair, it would be normal practice to take core samples from the different stone types. However, for the purposes of this exercise, such an approach would add considerably to the cost and time taken. It is therefore suggested that, to reduce the number of cores, only the dominant stone type, or the stone type with the greatest propensity to decay, is selected for coring. Where it is considered that this advice would result in an important stone type within the study area not being available for petrographic analysis, additional cores should be taken.

3.2 Field survey: Stage 1

The following equipment will be required to carry out this phase of the field survey:

- *A good quality digital camera, 10.0-megapixel imaging sensor is recommended, along with wide-angle lens for facade images and zoom lens for photographing high-level details (Note: the images may be rectified using either a rectifying lens or by computer).*
- *Tripod for the camera.*
- *Measuring tape/rod or electronic measuring device to measure suitable features for scale purposes.*
- *Maps of the area to be surveyed with the sample buildings identified (minimum scale of 1:1250 is recommended).*
- *Coloured pens for marking up the maps.*

A summary of the main elements and tasks within this part of the field survey are given below:

i) Carry out a preliminary inspection of selected facades to confirm their suitability.

ii) Identify buildings from which stone samples are required (ie small diameter cores). An initial visual identification should be made to classify the main sandstone types (or other stone types) within the survey area and to then determine the minimum number of stone samples (normally cores) required to enable categorisation.

iii) Obtain agreements from the building owners to allow access for sampling. Note: this can be time-consuming and may require alternative facades to be sampled when permission is not obtained.

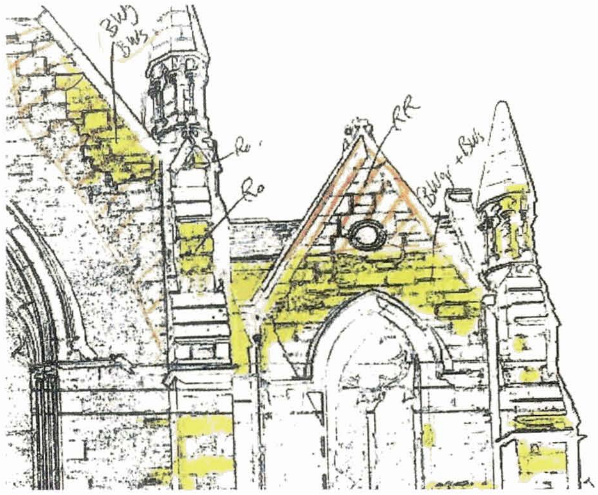
iv) Once owner agreements have been obtained, apply for listed building or scheduled monument consent where appropriate.

v) Undertake rectified digital photography, with the inclusion of a measured scale, of the selected facades. In many situations, due to a restricted distance from which to encompass the full width or height within a single frame, it will be necessary to build up a composite facade image by merging a number of separate photographs. It is advisable to take a range of images of a facade, with some at an oblique angle, so that the best image can be selected and to ensure that all the stone elements can be properly identified and delineated.

vi) From the rectified photographs and using rectification software in association with a CAD program, Adobe PhotoShop or other suitable software, obtain a measured line diagram showing individual stones, for use with the detailed survey in Stage 2. Figure 6 is an example of the marked-up diagrams.

vii) Conduct a trial survey to test out your approach and systems.

a) Outline image produced from rectified photograph



b) Outline image marked up with site notes

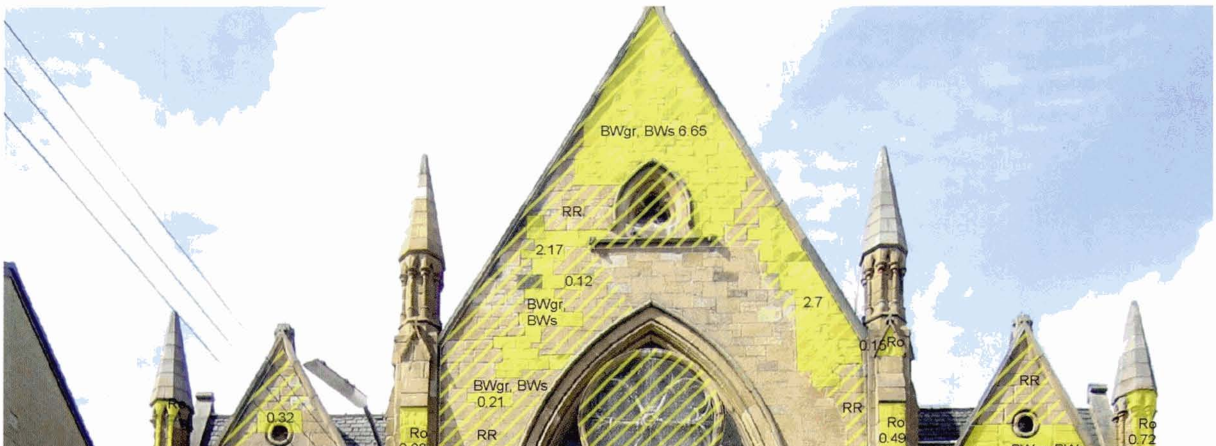


Figure 9. Outline of a part of the image marked up with site notes (Images: British Geological Survey, BGS©NERC, from SSLG Glasgow Report)

3.3 Field survey: Stage 2

The following items and equipment are likely to be required for the visual survey:

- *A pro forma survey sheet for each facade, or a hand-held digital tablet or computer on which the data can be recorded (see Appendix A).*
- *A measured line diagram for each facade – preferably contained within clear film for marking up with waterproof pens.*
- *Permanent coloured marker pens.*
- *A check list of stone decay types with identification codes.*
- *Good quality digital camera with zoom lens – wide angle and macro lens are also advisable to record images previously omitted in Stage 1.*
- *Binoculars or tripod-mounted telescope.*
- *Measuring tape or electronic/laser measuring instrument.*
- *Sample bags for collection of pieces of detached stone.*
- *Large umbrella.*
- *A standard letter explaining the purpose of the project for issue to building owners who may require reassurance.*

For small-diameter core sampling, unless the survey team has the relevant training and experience, it is recommended that a specialist contractor is employed for this work – including plugging the hole with a piece of the extracted core.

The steps within Stage 2 of the survey are identified below:

1. Using the measured diagrams, conduct a detailed survey of each facade in the sample. The following details should be recorded:

i) Each stone block where decay is present, including any plastic repair.

ii) The area of decay.

iii) The type of decay using the standard decay identification codes.

iv) Photographs for the preparation of close-up images of decayed areas for further assessment.

v) An assessment of the anticipated life of each decayed stone on a five-point scale:

immediate replacement,

replacement within twenty years,

replacement within twenty years unless immediate maintenance is carried out,

some decay but will last for more than twenty years,

replacement in future unless maintenance is carried out.

vi) Areas of saturated stone resulting from poor maintenance.

vii) Select key dimensions on the facade, for example the height and width of a door or window opening and the average stone-block dimensions, and record accurately the sizes (for applying a scale to the marked-up decay diagrams), as shown on Figure 8.

viii) Completion of the survey pro forma for each facade.

2. In addition, for a facade where a core (or other sample) is taken, ensure that the location of the core is recorded and that each sample is properly identified with a core number and facade identification code. For petrographic analysis it is best to use a piece of fresh stone from the middle of the core: the external end of the core should therefore be marked on the core sample.

3.4 Follow-up work

i) The survey record diagrams are transferred to a composite digital rectified image of each facade, ideally on colour print-outs at A3 size. Each image will contain the following information:

- An appropriate colour code for each decayed stone and areas where maintenance is required.
- Decay codes for affected stones.
- Areas(m^2) of stones requiring replacement, obtained from the digital facade images or by direct measurement.
- The scaled key dimensions eg door or window opening.

An example of a composite rectified image with decay overlays is shown in Figure 7. It is recommended that the same colour codes used in Figure 7 is adopted throughout. The recommended colour codes, based on a traffic lights system, are:

- Red: immediate replacement.
- Yellow: replacement within twenty years.
- Yellow hatched: replacement within twenty years unless immediate maintenance carried out.
- Green: some decay but will last for more than twenty years.
- Green: hatched replacement in future unless maintenance is carried out.

Key to colour coding on marked-up images

- Stone requiring immediate replacement
- Stone requiring replacement within 20 years
- Stone requiring replacement within 20 years unless urgent maintenance is carried out
- Stone showing some deterioration, but will last more than 20 years
- Stone requiring future replacement (>20yrs) unless maintenance carried out

Figure 10. Rectified image of facade with overlays showing stone decay codes and repair needs. Note: the hatched doorway area was measured on site for image scaling as was the average block dimensions. (Image: British Geological Survey BGS©NERC from SSLG Glasgow Report)

ii) Data from each survey pro forma is entered into a computer data base. The survey pro forma has been designed to be compatible with SPSS to allow easy extrapolation, cross tabulation and analysis of data. It is intended that all such information will be transferred to a central data base covering the whole of Scotland. However, the initial analysis may be carried out using an Excel spreadsheet, which can then be directly transferred into SPSS.

iii) Microscopic thin sections are prepared from each stone sample to undergo petrographic analysis using the procedure given by BS EN 12407:2000 for stone characterisation. The sections should be recorded at the same scale for ease of comparison. The data from the slides are then recorded in the data base.

Figure 11. Example of a thin section image of sandstone showing a uniform texture of quartz grains. Scale width represented by the slide is 3 mm. The porosity of the stone is indicated by the blue resin. (Image: British Geological Survey, BGS©NERC, from the Glasgow Report)

iv) The data from the survey record diagrams are transferred to a standard form for each facade to allow quantification by an experienced stonemasonry estimator of volume of replacement stone, banker mason and site mason times and carver time when necessary.

v) Rescale and extrapolate the data (materials and skills needs) to cover the whole population using the appropriate percentages for each stratum.

vi) Analyse the data and prepare a report on findings and conclusions.

vii) Enter the relevant data into a data base for transfer to the national data base (see Section 3.6).

3.5 Factors influencing the decision on projected life of a stone

During the process of a facade survey in Stage 2 it is necessary to make a decision on the expected life of the stonework (Section 3.3, 1(iv) above). The decision may, however, be modified upon detailed examination of the photographic evidence and on the analysis of the stone petrographic characteristics. The assessment of the expected life of a stone requires expert analysis by a person experienced in the examination of both stone masonry and building facades. The decision on the expected life of a stone should give consideration to the factors noted below. ***It is important, however, to recognise that the purpose of the survey is not to carry out a full structural survey of the facade – the purpose is to gain only sufficient information to allow general predictions to be made of the total stone repair needs of an area.***

When making a decision on the projected life of a stone it is important to understand that there is a need to distinguish between ashlar and rubble stonework. In the case of ashlar, particularly where a number of stones are affected, even a small depth of surface decay can be visually obtrusive. This can adversely affect the appearance of the facade and may have a financial and commercial impact that could lead to the building becoming economically less valuable, which, in turn, may result in further deterioration through lack of maintenance. In the case of a rubble facade, the surface appearance of an individual stone is generally not nearly so critical and a considerable loss of surface could be tolerated before replacement is considered necessary. Figure 10 at the end of this section provides a selection of typical decay forms and their classification in accordance with the descriptions in Table 4.

When assessing a stone it is necessary to assess its condition against three main criteria, namely structural, functional and aesthetic. The structural criterion is the ability of the stone to provide structural support to the surrounding masonry and other elements. The functional criterion is the ability of the stone to perform its designed task, such as acting as a drip mould to shed water from underlying stonework. The aesthetic criterion is the ability of the stone to maintain its value within the overall aesthetic character of the facade; where loss of surface tooling, for example, may result in a degradation of character.

The guidance below is not intended to be definitive and each case must be assessed on the evidence available.

a) Does the stone perform an essential structural function? For example, decay present in a stone mullion that is supporting several storeys of bay windows above is a critical element where loss of cross sectional area will present a significant risk to the structure. It is important to understand that stone patched up with plastic repair will not have the same structural capabilities as a complete stone. Generally, *if structural stability is compromised, the stone should be replaced immediately*.

b) Cracks and fissures may or may not be critical to structural stability, but expert interpretation is necessary. In some cases *the stone may be left in place and will last for more than twenty years*. In other cases the stone may be able to be repaired using resin grout and non-ferrous pins or dowels, without the need for replacement. However, for the purposes of this exercise, unless any crack or fissure is obviously superficial and confined to the surface *it is* *best to assume that the stone will be replaced immediately where there is a structural risk.*

c) When dealing with buildings and monuments of traditional construction, works of repair should be kept to the minimum required to stabilise and conserve the structure to ensure its long-term survival. This guidance could allow stone to suffer a considerable loss of surface before replacement with new stone is carried out. However, in the case of the stone heritage of towns and cities, it may be necessary to carry out intervention at an earlier stage in the decay process to preserve the economic viability of the building and will, as a result, influence the decision on when repair (if any) is required.

d) Where decay is present to the extent that a stone feature, such as a drip moulding, has lost its function in shedding water from the surface – *then it should be considered for immediate replacement.* When decay is present but the stone is still performing its function *consider for replacement within twenty years.*

e) Decay of ashlar stone. (Note: rubble stonework is normally able to tolerate a greater degree of surface loss and each case must be assessed individually).

- *Superficial surface loss,* where the surface features are still distinguishable *classify as having some decay but will last for more than twenty years,*
- *Some loss of surface* extending to several millimetres into the stone, eg as a result of large-scale scaling *classify as replacement within twenty years.*
- *Extensive loss of surface* extending to more than 20 mm into the stone depth *classify as immediate replacement.*

f) Carved features are an important element on stone buildings; frequently they are of sculpture quality and, unfortunately, many have been lost. The preservation of those that remain is thus of the highest priority. This calls for a decision to be made on whether the carving needs to be replaced in its entirety or whether it can be repaired. It is suggested that where there is only a *minor loss of sharpness in the detail that no replacement is required.* The other extreme is *where all or most of the feature is eroded to the extent that the detail is not discernable; in this case it is suggested that replacement within twenty years is the best option.* For other situations, *repair by indenting* new stone, appropriately carved, may be the best option *the area of indented replacement stone needed should be recorded for replacement within twenty years.* Carved masonry was often formed from softer stone that is more susceptible to decay. As a result, many such features become insecure and present a risk of injury by falling masonry.

g) Generally, wherever lack of maintenance poses a potential risk to stonework, *immediate maintenance* should be recorded.

Replacement Category	**Typical examples of decay forms in *ashlar* masonry**	**Typical examples of decay forms in *rubble* masonry**
Immediate	• Extensive surface loss to depth of >20mm • Severe granular disintegration – loss of cementing between grains to depth >20mm • Surface crust with extensive granular disintegration behind • Complete loss of functional performance e.g. drip moulds • Hard mortar pointing causing significant loss of stone • Plastic repair where detachment and/or cracking a of repair present • Plastic repair causing accelerated decay of underlying and/or adjoining stones	• Extensive surface loss to a depth where support for adjoining stonework and other elements is compromised • Complete loss of functional performance eg drip moulds
Within 20 years	• Some surface loss to depth of < 20mm, unstable surface and continuing to decay • Some original surface still attached but granular disintegration present below the surface • Surface crust with some granular disintegration behind • Surface loss due to salt action (cryptoflorescence) that is continuing. • Some loss of functional performance, with continuing decay • Hard mortar pointing causing some decay of stone • Plastic repair in apparently good condition • Facade completely covered with coloured cement mortar (with false joints to replicate stone). Sometimes painted • Complete loss of detail from carved features	• Some surface loss but stone is still performing structurally erosion is still continuing • Some loss of functional performance, with continuing decay • Complete loss of detail from carved features
Decay but will last for 20 years	• Above decay forms present but surface still inherently intact (Note: stones with plastic repairs will require replacement within at least 20 years)	• All of the above features present but surfaces still inherently intact
Future replacement (<20 years) unless urgent maintenance carried out	• Evidence of long-term leaks from gutters or downpipes with saturated stonework showing incipient stone decay • Pointing missing or in poor condition signs of stone erosion at joints	• Evidence of long-term leaks from gutters or downpipes with saturated stonework showing incipient stone decay • Pointing missing or in poor condition, signs of stone erosion at joints
Future replacement (>20 years) unless maintenance carried out	• Early evidence of poor maintenance eg plant growths in gutters, pointing missing from cope stones etc. resulting in some dampness in stone at critical points	• Early evidence of poor maintenance eg plant growths in gutters, pointing missing from cope stones etc. resulting in some dampness in stone at critical points

Table 4. Summary of the possible application of the various stone replacement categories on sandstone facades.

TYPICAL EXAMPLES OF STONE DECAY CLASSIFICATIONS

1. Ashlar walls

a) Surface crust formed (tooling on surface is still intact) but the loss of sandstone cement from the grains below the surface has led to granular disaggregation in the surface zone for more than 20 mm depth.
Classification: Immediate replacement

b) Crust plus granulation: Edge erosion: similar action to illustration a) and decay is accelerated by loss of pointing in both the drip moulding, and in the stonework generally, and/or use of hard mortar.
Classification: Immediate replacement

c) Loss of stone surface. Primary cause is difficult to determine but the facade has been cement plastered and painted resulting in entrapped moisture. Maintenance will be required on this facade to remove the cement plaster within the next twenty years.
Classification: Immediate replacement of decayed stone and maintenance of plastered areas within twenty years

d) Granulation: Serious loss of binding cement in the blonde sandstone. Possibly associated with salt action and hard pointing.
Classification: Immediate replacement

e) Flaking: Pre-existing decay accelerated by a covering of cement mortar plastic repair.
Classification: Immediate replacement

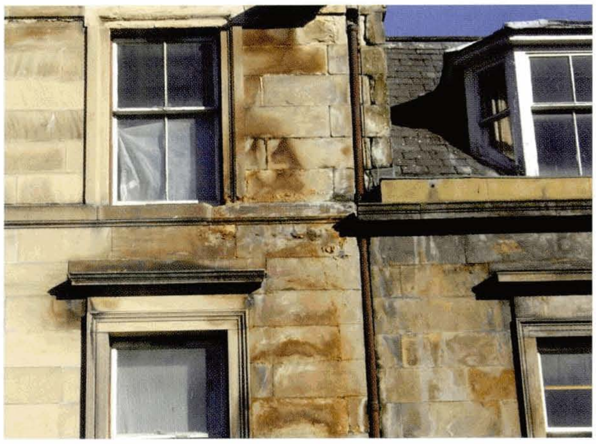
f) Partial loss of stone from drip moulding leading to surface runs of rainwater but some function still retained.
Classification: Replacement within twenty years

g) Contour scaling on ashlar – large sheets several millimetres in thickness.
Classification: Replacement within twenty years

h) Cement mortar patch; in this case the stone decay is minimal behind the patch.
Classification: Decay but will last for more than twenty years. Immediate maintenance (to remove the cement render).
(Photo: E Hyslop BGS©NERC)

i) Differential decay. Natural weathering of stone on 200 year old facade.
Classification: Will last for more than twenty years

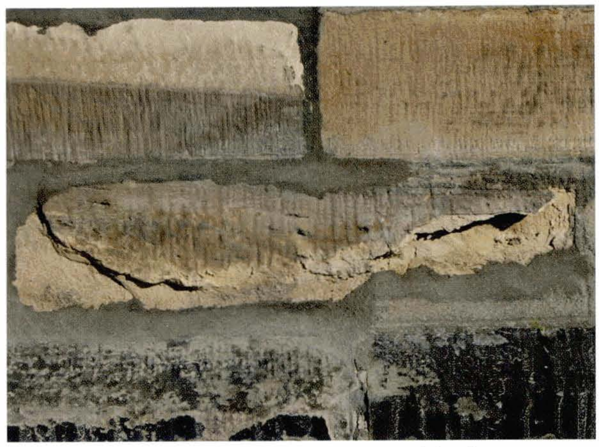
j) Multiple scaling: Surface scaling of lintel. No immediate structural problem.
Classification: Replacement within twenty years



k) Water leaking from parapet gutter has saturated stone causing iron staining.
Classification : Future replacement if no maintenance

2. Rubble walls

l) Squared rubble (clay-rich sandstone) has suffered long-term granulation, possibly aggravated by salt action due to coastal location. While a lot of surface has been lost the stone remains structurally sound.
Classification: Decay but will last for more than twenty years.



n) Squared rubble. Scaling due to association with hard mortar, allowing water penetration into the wall.
Classification: Replacement within twenty years

m) Back weathering: Rubble wall - stone erosion due to hard mortar pointing.
***Classification: Replacement within twenty years unless maintenance is carried out to replace hard mortar** (with appropriate lime mortar).*

Figure 12. Typical examples of stone decay classifications (Photos: D Urquhart unless otherwise noted).

3.6 Quantifying stone and skills

Within the methodology, in Section 3.3 (iv), the requirement to quantify the materials and skills required, for both individual properties and for the area as a whole, is identified. This is, of course, the primary objective of the exercise and needs to be given very careful consideration to ensure that all the data is determined in a manner that is comparable across the country.

When the survey work has been completed, and the colour-coded photographic images with the areas of decayed stones on the facades included (areas in m^2), the calculation of stone quantities and skills can proceed. This part of the work may progress in stages as the completed survey data becomes available. The services of an experienced stonemasonry estimator should be utilised because, during this process, decisions or assumptions will have to be made regarding the work required to produce and build in each stone identified for replacement. However, as the estimate of materials and skills is not required for a real-life repair project, a lesser degree of certainty and accuracy can be accepted than would be the case in a quotation for a client.

To ensure that the results are recorded in a form that can be used to build up the national picture of stone and skills requirements, it is recommended that the estimator completes a standard pro forma for each facade or property. The pro forma should be prepared and partially completed with facade details by the project team before passing to the estimator. The Record of Materials and Masonry Skills form should contain, at least, the following headings shown in Table 5.

Pro forma Heading	Completed by
1. Facade identification	Survey team
2. Property address	Survey Team
3. Listed building category • A = Cat A listed • B = Cat B listed • C = Cat C(s) listed • Con = Conservation area • N = Not listed or in conservation area	Survey team
4. Property type • R = Residential • E = Ecclesiastical • P = Public • C = Commercial • I = Industrial • M = Monument • O = Other	Survey team
5. Repair period • Immediate • Less than 20 years	Survey team
6. Finished masonry stone (cubic metres converted to tonnes) *Note: For stone as supplied by the quarry it is normal to allow for 50% loss of stone from the supplied quarry block in the production of the finished masonry element.*	Stone estimator
7. Random block (tonnes)	Stone estimator
8. Site mason time (days)	Stone estimator
9. Banker mason time (days)	Stone estimator
10. Stone carver (days) *Note: A carver employed for features that require the specialist services of stone carver/sculptor rather than a stone mason)*	Stone estimator

Table 5. Standard information to be recorded in the Record of Materials and Masonry Skills pro forma.

3.7 Central data base

While the data and its analysis are valuable for strategic decision making at a local level, these data are vitally important at a national level. Because stone resources, skilled stonemasons and stoneworkers, recruitment of trainees and provision of training facilities will require decisions to be made at national rather than local level, it is essential that all the key information is held within a national (Scottish) data base.

Unfortunately, at the time of writing, this national data base has still to be established. However, it is anticipated that the data base will be developed and held by the Scottish Stone Liaison Group (SSLG), who will be responsible for co-ordinating the local surveys and ensuring that data is held centrally. SSLG will ensure that the data base is accessible to legitimate users and that confidential information relating to individual buildings is not released into the public domain. The transfer of survey information into GIS will be part of the SSLG remit, in conjunction with the British Geological Survey who already hold much relevant data in an appropriate format.

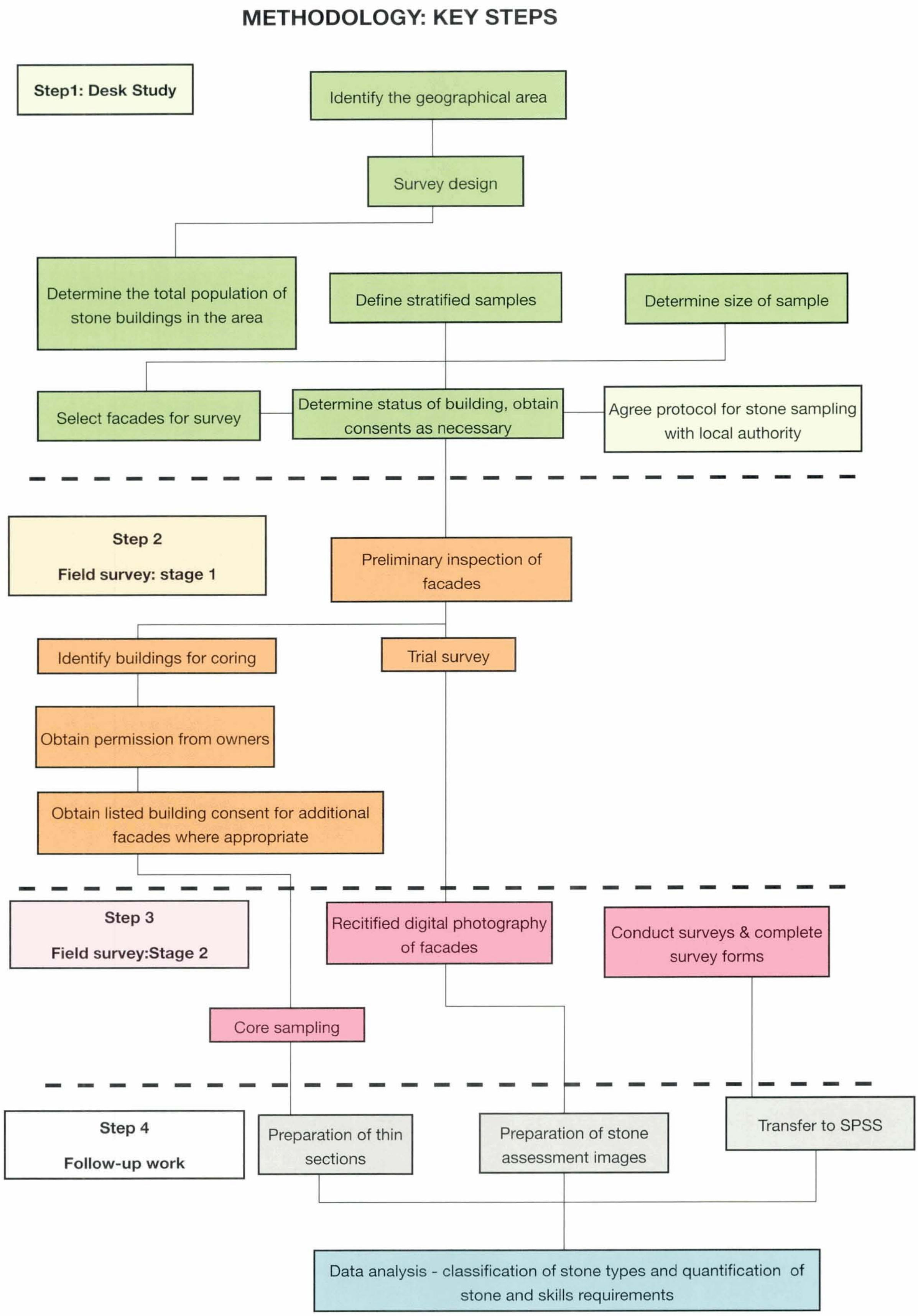


Figure 13. The key steps in the methodology

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APPENDIX A

EXAMPLE OF SURVEY PRO FORMA

Façade ID

STONE FACADE SURVEY RECORD

1. Address/Name

2. Building Category
Residential – *Tenement etc* ☐ / *Terraced/semi/detached* ☐ Ecclesiastical ☐ Public ☐ Commercial ☐ Industrial ☐ Monument ☐

3 Listed building Cat A ☐ Cat B ☐ Cat C(s) ☐ Unlisted ☐

4. Conservation area YES ☐ NO ☐ **5. Date** <1800 ☐ 1800-50 ☐ 1850-1919 ☐ >1919 ☐

6. Façade orientation N ☐ NE ☐ E ☐ SE ☐ S ☐ SW ☐ W ☐ NW ☐

7. Stone type/s Blonde sandstone ☐ Red sandstone ☐ Other stone ☐ (describe____________)

8. Stone description (grain size/texture/other)

9. Masonry type/s (tick all that apply)
Coursed ashlar ☐
Random ashlar ☐
Coursed rubble ☐
Squared rubble ☐
Random rubble ☐
Other ☐

10. Surface finish/es (Tick all that apply)
Polished ☐ Droved ☐ Tooled ☐ Stugged ☐
Picked ☐ Broached ☐ Rock faced ☐ Other ☐

11. Stonecleaned YES ☐ NO ☐
Abrasive ☐ *Chemical* ☐

12. Plastic repair YES ☐ NO ☐
Extensive ☐ *Some* ☐ *Very. Limited* ☐ *None* ☐

13.Overall assessment of stone decay Extensive ☐ Moderate ☐ Slight ☐ None ☐

14. Decay forms (tick all that apply)
Crusts ☐ Contour scaling ☐ Granular disintegration ☐ Face bedding detachment ☐
Back weathering ☐ Blistering ☐ Dissolution ☐ Fissures ☐ Hard pointing ☐
Salt induced ☐ Stonecleaning induced ☐ Plastic repair induced ☐ Other forms ☐

15. Sample YES ☐ NO ☐ If Yes: location____________________
Core ☐ *Other* ☐ *(describe____________)*

16. Maintenance required YES ☐ NO ☐
Describe problems

17. Additional notes

Surveyor__________________ Date of survey__________

APPENDIX B

EXAMPLE OF CORE EXTRACTION PROTOCOL

Core extraction Protocol

1. Cores will only be extracted from buildings where permission has been given.

2. Cores to be extracted from parts of buildings where there will be minimal visual and no structural disruption. No core will be taken where it would result in an unsightly appearance or cause disruption in any way. In some cases (eg buildings which are currently undergoing repair) it may be possible to get access to core from the inside face of the stone so that nothing is visible on the facade.

3. Where possible, cores can be taken from similar stone from another less visible part of the building, or from already damaged or decayed stone (in particular for buildings which are currently undergoing or about to undergo repairs).

4. Cores will be small diameter (normally using 35 mm or 45 mm drill bits) and less than 150 mm in length.

5. Coring will be carried out using an appropriate masonry drill, for example, a hand-held 110V diamond masonry drill operating from either mains supply or hand-held petrol generator.

6. As part of the project risk assessment, a health and safety procedure will be drawn up for the coring exercise. Site safety plans will be followed where relevant. Coring will only be carried out by approved persons who have been trained in use of the equipment. The coring will be supervised by a responsible person from the survey team.

7. Where necessary, cores will be plugged by using lime mortar and capping the hole using a part of the core. Care will be taken to minimise the visual effect of the coring.

8. Core samples will be labelled and, following analysis, registered in the archives of the British Geological Survey, where they will be available for consultation.

Fig 14 Diamond core drilling to extract small-diameter plug of stone from damaged masonry (Photo: BGS©NERC)

Fig 15 Detail of sandstone core showing decay in the outer few centimeters (Photo: BGS©NERC)