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STONECLEANING OF GRANITE BUILDINGS

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TECHNICAL ADVICE NOTE

STONECLEANING OF GRANITE BUILDINGS

TECHNICAL CONSERVATION, RESEARCH AND EDUCATION DIVISION

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Stonecleaning of Granite Buildings

Advice on the soiling, decay and cleaning of granite buildings and related testing, specification and execution of the work

by
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HISTORIC SCOTLAND

PREFACE

Over the last decade there has been an increasing concern by many throughout Scotland that the physical effects of stonecleaning were having a potentially damaging consequence on both the fabric and the aesthetics of stone buildings. As a result, a 2-stage research programme was devised. Initially, the programme investigated the effects of stonecleaning sandstone structures; sandstone being the predominant building stone used in Scotland. This led to the production of 6 different publications on the topic, and the hosting of an International Conference in Edinburgh during April 1992.

To assist those actively involved in writing specifications in this difficult area a subsequent publication entitled "Stonecleaning: A Guide for Practitioners", was published by Historic Scotland in April 1994. Although this volume considered such topics as the soiling of building facades, aesthetics, physical and chemical cleaning methods, testing methodology, health and safety, and planning issues, it largely only addressed the sandstone issue. Whilst a number of contemporary publications have also been released, the associated problems of cleaning granite had not been dealt with in any degree of detail so far, and this has had to be considered separately.

Granite is generally perceived as being a very durable stone, and less prone to the decay processes more usually associated with sedimentary rocks. To the lay, and to many professionals, it appeared that it might be cleaned using comparatively straightforward techniques, and that the stone would be left undamaged by these processes. To the more initiated, it was realised that there was no detailed research evidence to support this belief.

In recognising that it was unlikely that similar problems would occur to those investigated regarding the cleaning of sandstone, it was thought necessary by Historic Scotland that there was a need to provide more relevant information for practitioners upon which informed decisions to clean, or not to clean, could be made.

In order to obtain this understanding some basic historic data was required. In addition, the physical characteristics of the various granites needed to be identified, together with an awareness of the nature of previous interventions, earlier cleaning works and associated repairs. Against that background, a detailed research project into the cleaning of granite was projected and the brief for a multidisciplinary scientific and technical commission prepared. This brief qualified the intention that the research work should pay particular attention to the techniques currently being used by industry.

To fully realise the project's objectives, work was required to put the Scottish problem into a wider context. This called for a literature review which required an investigation of available sources of national and international information relevant to the cleaning of igneous stone.

The study required an assessment of current and proposed cleaning methods, techniques and materials, and a detailed analysis of the chemicals liable to be used.

The research project was jointly funded by Historic Scotland, Scottish Enterprise and Grampian Enterprise Limited, and commissioned from The Robert Gordon University, Aberdeen in January 1993. The final report was presented, with the Literature Review, to the commissioning clients in December 1995.

The outcome of that study has since been translated into this Technical Advice Note. Building upon the exemplary work already undertaken by The Robert Gordon University into the cleaning of sandstone, this new work on granite will greatly assist with the provision of further advice and guidance to practitioners and others operating in the field. However, it should be borne in mind that stonecleaning of listed buildings and buildings within Conservation Areas is not "permitted development" under the terms of the Town and Country Planning (General Permitted Development) (Scotland) Order 1992. Listed Building Consent or planning permission is required.This advice note, therefore, is also intended to be read in conjunction with Historic Scotland's Memorandum of Guidance on Listed Buildings and Conservation Areas (1993), to be revised 1997, where that need arises.

INGVAL MAXWELL
Director, TCRE
March 1997

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1. Introduction

The cleaning of stone facades to buildings has been the subject of much debate in recent years, and was strengthened by the awareness that the stone cleaning being carried out on the sandstone buildings of Scotland was, in many instances, resulting in irreversible damage to the stone. In the case of granite buildings there is a general perception by both the general public and practitioners that granite is such a hard and durable material that the problems apparent in cleaning sandstone have little relevance to granite, and that any cleaning technique that removes soiling at minimum cost can be employed, without damage to the stone. It is the case that most granites are hard and generally durable, but it is not the case that granite is immune to the processes of decay through natural weathering or through the effects of environmental pollution. Many historic buildings constructed from granite are subject to significant decay such as scaling, flaking or granular disintegration. Pollutants in the form of soluble salts (mainly gypsum) are present on many granite facades. These salts have been linked to decay of granite. Stonecleaning by physical or chemical processes can reduce the level of salts present at the surface of the granite. This is likely to have the effect \of reducing the rate of decay of the granite.

There is evidence that the interface between the mortar joint and the granite block may be a potential source of stone decay. The effect of chemical cleaning materials absorbed and retained in the mortar joints may be a factor contributing to the decay of the mortar and the stone. It is in this context that the cleaning of granite must be viewed.

Stonecleaning is one of the most visually dramatic changes to which buildings can be subjected. It is a process which changes not only the fundamental appearance of buildings but also the architectural and environmental context in which those buildings exist. The colour of stonework and the architectural detailing often become

Plate 1 Patchwork effect of partial cleaning of a terrace (King Street, Aberdeen). Note the incomplete removal of soiling below the gutter. The dark patch to the right-hand side of the cleaned foreground building is a result of moisture being retained at decayed stone surfaces. The decay is not attributed to the wet abrasive (slurry) cleaning system which was used.

more apparent following cleaning and there may be an important psychological effect on the way in which properties are perceived in urban areas. The significant difference between a typically soiled granite and a cleaned granite is the sparkle produced by the exposed mica grains once the soiling has been removed.

Different cleaning methods can produce variations in colour. If, for example, various properties in a terrace are cleaned at different times or by different methods, this can lead to noticeable colour variations along the terrace (Plate 1). Stonecleaning may also reveal staining beneath the soiling layer which may not have been visible beforehand. Staining may arise from weathering of the granite or from metal fixtures. It is dangerous to attempt the removal of such stains as excessive cleaning can cause damage to the stone.

Although stonecleaning may result in what is considered by some to be a visual improvement, cleaning carried out by unskilled personnel or by the use of inappropriate techniques can lead to permanent damage to buildings. It is therefore important that the potential risks associated with stonecleaning methods are fully understood by the building owner, the architect or agent, the contractor, and the grant awarding body.

This Note is concerned with the cleaning of granite buildings and monuments and will provide guidance on a range of relevant issues. Despite the widely-held perception that granite is virtually indestructible when used as a building stone, it is now clear that granite can be vulnerable to the processes of decay, particularly in polluted urban environments and with certain types of granite. In order to avoid damage it is necessary to ensure that information is available relating to the type and condition of the granite and the nature of the soiling (before cleaning is carried out) as this may influence the selection of a cleaning system.

Consideration should be given to the situation in which stonecleaning is to be carried out. Where the property to be cleaned forms part of a larger block, such as a terrace, cleaning will inevitably produce a patchwork effect, disrupting the architectural integrity of the larger unit. Subsequent cleaning of adjacent properties will generally not restore the uniform appearance of such a facade since the use of different cleaning methods at different times will produce variations in the colour of the stonework.

Despite detailed research and much improved knowledge of the effects of stonecleaning methods, there are still many risks associated with stonecleaning. Proposals to stoneclean, if they are acceptable in principle and accord with stated policy, must therefore be carefully considered. Stonecleaning should be approached on a damage limitation basis; if doubts persist, the option not to clean should be adopted.

Figure 1. Map of Granite areas in Scotland

2. GRANITE AS A BUILDING STONE

2.1 Formation of granite

Granite is an igneous rock produced by the crystallisation of magma beneath the Earth's crust. In building terms, many rock types may be referred to as 'granites' which are not true granites according to geological definitions. The term 'black granite', for instance, is often used for a rock type that geologists would call gabbro.

2.2 Composition of granite

Most granitic rocks are light coloured, medium to coarse-grained and composed of at least 20% quartz along with various proportions of other minerals including feldspars and micas (Plate 2). Some granitic rocks are porphyritic, that is, they contain larger crystals of particular minerals (e.g. feldspar). Although granites do not have bedding planes such as are encountered in sandstones, some granites may have a slight layering (foliation), often seen as an alignment of platy or elongate minerals. This foliation does not form a plane of weakness as it does in sandstones, so it is not possible to 'face-bed' granites.

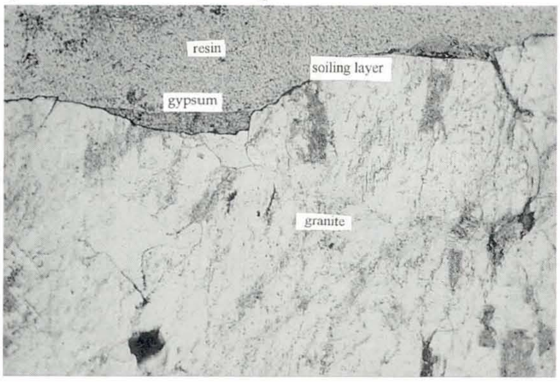

Plate 2 Microscopic thin section of soiled granite approx 15 magnification. Note thin soiling layer at outer edge of the sample and the gypsum deposit on the surface.

2.3 Porosity and permeability

Porosity is a measure of the amount of empty space within a rock and is measured as a percentage. Permeability is a measure of how easily fluids can move through a rock. Granites normally have low porosities, generally less than 1.5%, and almost all of this pore space is caused by chemical or physical processes including the weathering of minerals or fracturing of the stone. By contrast, sandstones often have porosities of 15-25%. In more porous rocks, the pore space allows circulation of fluids within stone. Movement of fluids through a stone is important with respect to decay and is very important when considering how the stone will respond to cleaning, especially chemical cleaning. It is the low porosity and permeability of granites which slows their rate of decay relative to other rock types such as sandstone. The low porosity of granites also reduces their ability to absorb and retain applied cleaning chemicals.

2.4 Sources of Scottish granite

Over the last three centuries there have been in excess of 100 granite quarries operating in the area around Aberdeen at various times. The stone produced came from a relatively small number of granite masses of variable composition. Many of the quarries were small, local quarries and only a handful produced building stone for use outside their immediate area. The principal quarries of the Aberdeen area included Clinterty, Corrennie, Craigenlow, Dancing Cairns, Dyce, Gask, Kemnay, Lower Persley, Rubislaw, Sclattie, Tom's Forest and Tyrebagger. Today most of these quarries are closed and only Corrennie, Kemnay and Tom's Forest quarries remain operational. Tom's Forest quarry produces only crushed granite.

One of the earliest quarries in Aberdeen was the quarry at Loanhead, opened in 1730. This quarry produced granite for many of the older properties in Aberdeen. This granite is of poor quality and frequently has a weathered, crumbling surface which is likely to be severely affected by stonecleaning.

In south-west Scotland there are four main granite masses of variable size. These are the Criffell-Dalbeattie, Loch Doon, Cairnsmore of Fleet and Cairnsmore of Carsphairn masses. The largest of these is the Criffell-Dalbeattie intrusion. This granite is quarried at Dalbeattie on Craignair Hill and has been used extensively for building purposes both locally and further afield. The quarry is still open and produces granite for roadstone. Other quarries on this mass include Cowpart, Oldham (or Old Land), Steadstone, Barnbarroch (or Gallowleck), Kipp and Fairgirth. Granite is also quarried south of Creetown from a small granite mass and has been used in the past for building stone.

The Ross of Mull granite is pale to deep red in colour and coarse-grained. The stone has been widely used for building and polished stone and is still worked at the present time.

Plate 3 The ornate facade of the Esslemont & Macintosh Building, Aberdeen The granite is Kemnay. Cleaning history is not known.

2.5 Use of granite in buildings and structures

In Scotland, the use of granite as the main material for wall construction is generally confined to Aberdeen City, areas of Aberdeenshire, Strathspey and parts of south-west Scotland (e.g. Dalbeattie and Creetown) (Plates 3 and 4). Granite was widely exported to other parts of the country for use in special structures such as bridges and harbour works as well as forming features in buildings constructed from other types of stone. More recent use of granite has been in the main as a facing material to provide a decorative finish, often with a polished surface. Most of the granite used in buildings in recent years has been imported from a variety of sources.

2.6 Mortar joints and pointing

The characteristics of mortars and joints can affect the decay of granite, but relatively little research has been done on the effects of mortar on granite decay. Soiling of granites may, in some cases, be associated with run-off from pointing mortars. Pointing which projects from the surface of the facade may accelerate granite decay by reducing the rate of water run-off over the facade, thus increasing the period of dampness. Projecting pointing can also channel water into joints.

Since granites generally have low porosities and permeabilities, mortar joints can act both as reservoirs for water and as the main route for transport and evaporation of moisture. Mortars vary widely in their composition, but are generally composed of sand as an aggregate with a binder of lime and/or cement. The more sand-rich the mortar, the more penetrable it is by water and by chemicals. Water is involved in most decay processes and any factor which increases duration of wetness can increase the decay rate of a stone. Sand-rich mortar which is more porous than the granite may act as a reservoir for water and pollutants. However, harder, less porous mortars are usually considered to be more damaging since they increase moisture retention by reducing the rate of evaporation of moisture through the joint.

2.6.1 Lime mortars

Lime mortars are higher in soluble calcium than cement mortars. They can be a source of calcium salts in the same way as limestones and other calcareous stones, and may cause similar decay problems to those encountered in limestone-

Plate 4 Cleaned granite in Dalbeattie. Buildings cleaned circa 1970.

granite contact zones. Calcium derived from the mortar may cause gypsum (calcium sulphate) to form by reaction with oxides of sulphur which are components of air pollution and acid rain. Gypsum, a soluble salt, is implicated in the decay of granite. Thicker soiling deposits, including crusts composed mainly of gypsum, are often found in association with joints, although it is unclear whether any of the calcium in these crusts is derived from the joint.

Regarding chemical cleaning, the role of lime in mortar may be that of a neutralising agent for acid-based chemicals. However, in weathered mortar there may be less lime present to neutralise the applied acid, which would allow greater penetration of the chemical into the body of the mortar. The effect of alkali cleaning agents on mortar has not been investigated, but there is a risk of salt formation.

2.6.2 Cement mortars

Hard cement mortars, although less porous than lime mortars and sand-rich mortars, can encourage moisture retention as they tend to crack and become detached from the stone in the joint, allowing penetration of moisture. Decay of granite associated with hard, impermeable cement mortars has been observed around Aberdeen and other areas. In modern times, hard mortars using Portland cement tend to be the most widely used as they are stronger and less permeable, easy to use and widely available. A Portland cement mortar will not encourage the formation of damaging gypsum salts to the same degree as a lime mortar.

With respect to reaction between mortar and surrounding stone, pointing mortars are of more concern than bedding mortars since the pointing mortars are in immediate contact with the surface environment and have most interaction with moisture and pollutants. The pointing mortar should therefore be more permeable than the surrounding masonry to allow water evaporation through the joint rather than through the stone. There is an unfortunate tendency to repoint the stone using very hard, cement-rich mortars which thus reduce evaporation rates.

Many modern proprietary mortars attempt to imitate the characteristics of the stone in their chemical, physical and mechanical properties in order to decrease the possibility of stone decay.

2.6.3 Pointing and re-pointing

In the Aberdeen area, methods of re-pointing have undergone a radical change in recent years. Flush pointing (smearing) mortar on stone is the traditional method of pointing in Aberdeen, particularly on buildings composed of rubble and coarse ashlar. The new methods of 'tuck' pointing with hard cement on ashlar faces creates a substrate for the growth and spread of algae which may be aesthetically displeasing. Projecting, or 'ribbon' pointing can accelerate granite decay by trapping water running over the facade, increasing the time of wetness of the stone above the joint and creating a sheltered area beneath where pollutants may accumulate. Vertical projecting pointing may also channel water into joints where jointing material has been lost or has cracked. Since most decay processes require the presence of moisture, any lengthening of the saturation period of the granite may increase decay rates (Plates 5 and 6).

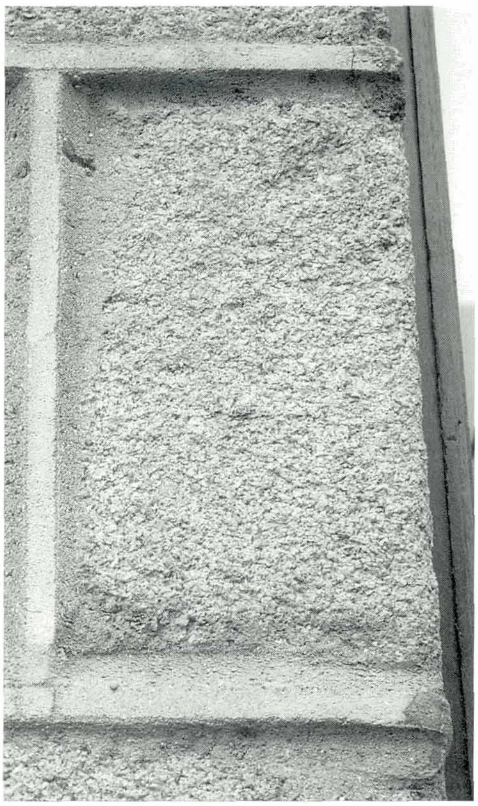

Plate 5 An example of repointing which has destroyed the visual impact of the granite. The granite is of the Loanhead type with a weathered and friable surface. The hard dense pointing will tend to increase the rate of decay of this granite.

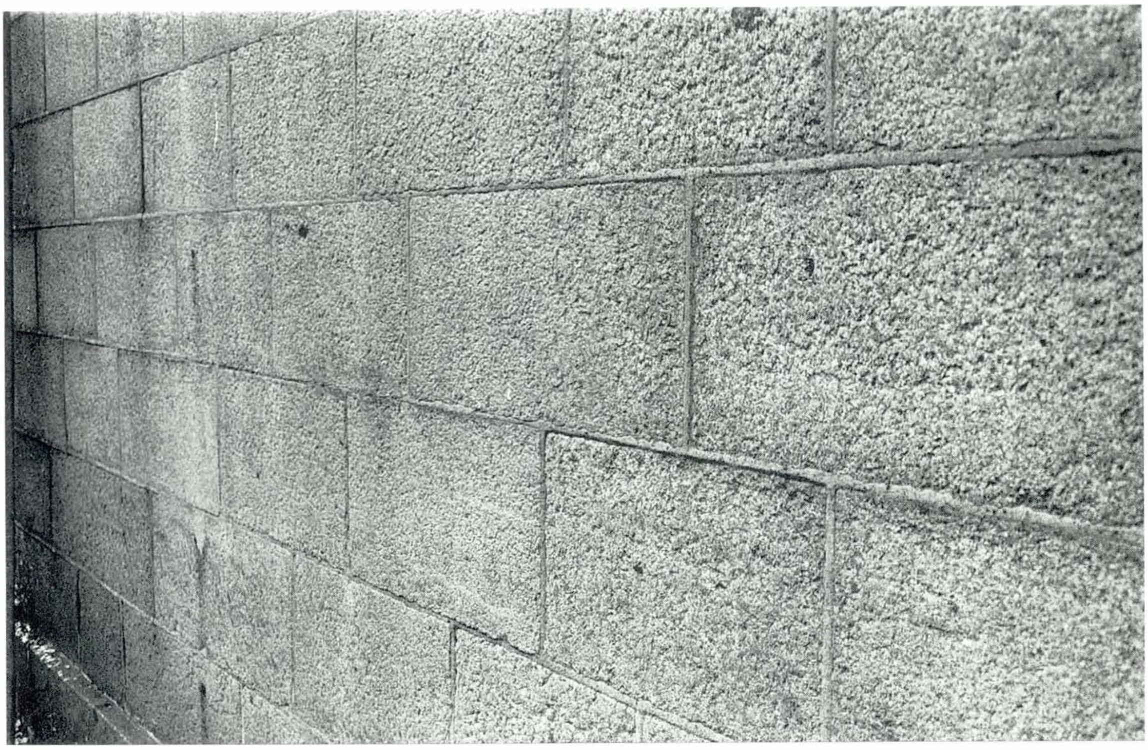

Plate 6 Traditional flush pointing of Rubislaw granite. This granite has not been cleaned.

2.7 Granite in combination with other stone types

It has been found that when granite is in contact with other building materials it may suffer more rapid or extensive decay than granite elsewhere on the facade. Problems arise most often where the granite underlies a more porous stone type and where the stone is calcareous (e.g. limestone). Granite decay under these circumstances has been attributed to the deposition and growth of gypsum (calcium sulphate) in the stone where calcium may be derived from limestone or mortar and sulphur from atmospheric pollutants.

Where granite on a facade is in contact with sandstone, and especially where sandstone overlies granite, there can be occasionally some decay of the sandstone close to the contact plane (Plate 7). This may be related to the physical or chemical properties of the sandstone and may also be exacerbated if salt residues from chemical cleaning remain in the stone. In a small scale study of decay associated with granite in contact with other building materials (mainly sandstone) conducted in Glasgow, Edinburgh and Aberdeen, it was found that of thirty-one facades examined, only seven showed any decay of sandstone at the sandstone-granite contact. There was no visible damage to the granite in the contact zone. Sandstone decay took the form of blistering, spalling, granulation or flaking of the sandstone adjacent to the granite over a distance of several centimetres.

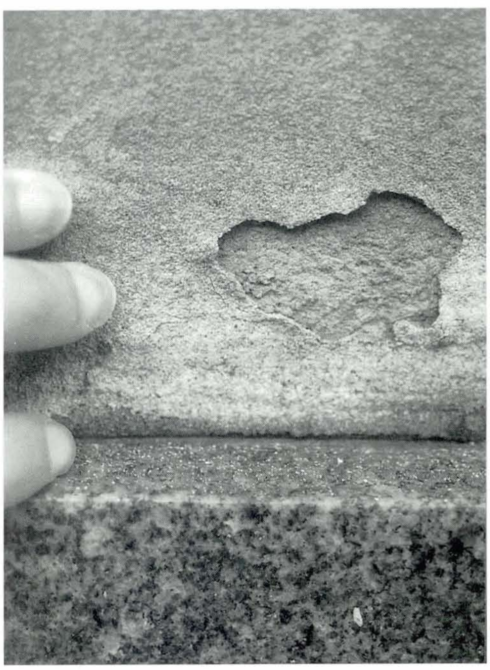

Plate 7 Blistering of sandstone above a polished granite plinth (Glasgow).

3. SOILING AND DECAY OF GRANITE IN BUILDINGS AND STRUCTURES

The soiling and decay of granites are related phenomena since materials deposited as soiling may often become involved in decay processes. The soiling of building facades is a complex process which takes place at or near the masonry surface. Soiling can be divided into two main groups:

- particulate soiling (e.g. soot, aerosols, etc.)
- biological soiling (e.g. algae, lichens, etc.)

In practice, both types of soiling are likely to be present on stone surfaces.

3.1 Soiling of granite building facades

Three distinct soiling forms occur on granite. These are:

(a) a relatively thin, compact particulate soiling layer which is tightly bound to the surface (Plate 2);

(b) a thicker, often millimetres thick, gypsum-rich crust which may be brittle and easily detached from the surface (Plate 2) or may however be more tightly bound where they occur on mortar;

(c) biological soiling.

In south-west Scotland, with a wetter and milder climate, levels of biological soiling, especially green algae, are higher than in north-east Scotland. Generally, there tends to be less biological soiling on granite than on sandstone, due to the lower porosity and water retention properties of granite.

3.2 Particulate soiling and crust formation

3.2.1 Particulate soiling

Particulate soiling materials are a complex mixture of components including natural wind-borne dusts and man-made pollutants. Soot, hydrocarbons and salts (e.g. sulphates and chlorides) are very common. Soot and other pollutants from coal burning were, in the past, the main source of local soiling, and the level of air pollution and its effects on stonework have been recognised for many centuries. More recently, air pollution has come to be a global rather than a local problem. Research suggests that concentrations of some air pollutants (e.g. nitrates and particles from diesel fuel combustion) have increased dramatically in the past century. Oxides of sulphur, in the form of acid rain, have been present for much longer and levels in the atmosphere today may be substantially lower than in the past. However, pollutants deposited in stonework in the past may remain in the stone for many years and contribute to the processes of decay.

Thin, black soiling layers on granite vary in thickness from about 20 to 200 μm. Analysis of these soiling layers has shown the presence of soot, iron oxides and hydroxides, sulphates, chlorides, phosphates and lead compounds along with silicate mineral dust, particles and organic compounds from coal and oil combustion, and asphalt and rubber from car tyres. The soiling is often hydrophobic (i.e. it repels water) and may reduce both penetration of water from the outside of the stone and loss of moisture from inside the stone which can lead to exfoliation of the surface.

Pollutants such as calcium sulphate are able to penetrate into granite. The mechanism for this

Plate 8 Typical example of pattern of soiling on granite. In this case heaviest soiling occurs below the string course in a zone protected from direct water run-off. Note the washed areas below the joints in the string course. The soiling in this zone frequently develops as a gypsum crust. The facade has not been cleaned.

penetration may be micro-cracks in the granite surface. Since granite is a compact stone of low porosity, levels of pollutants present in granite are generally very low and only present in the surface 0-5mm layer, except in very porous, severely weathered granite.

The deposition rates of pollutants on a building facade are not uniform over the whole surface but are influenced by a number of factors including orientation and exposure, slope, stone type, surface roughness, surface moisture levels and the mortar joints (Plate 8). The shape of a building modifies the behaviour of climatic agents, such as rainfall and wind direction, creating different microclimates over the facade.

Soiling on granites is usually heaviest on frequently wetted areas. Soiling is therefore normally heaviest on horizontal surfaces, exposed details or sloping areas of stonework. On these surfaces soiling can accumulate by a number of mechanisms including settling of particulate matter and by deposition of material in water droplets (wet deposition) or as aerosols. Such surfaces also intercept a lot of water during rain showers and this greatly increases the susceptibility of the surface to both biological and non-biological soiling.

3.2.2 Gypsum crusts

Granites, like many other building materials, can accumulate black, gypsum crusts. Gypsum ($Ca_2SO_4.2H_2O$) is a moderately soluble mineral and on areas of facades wetted by rainfall or water run-off, any gypsum formed is dissolved and washed off. However, in sheltered areas (e.g. under sills) gypsum can accumulate and forms a black crust. Soiling in these areas occurs as a result of dry deposition, that is, particulate matter in the air condensing against a cool, moist surface. Gypsum crusts are spongy-textured, complex mixtures of materials from a variety of sources. The mineral gypsum is white in colour but it incorporates other pollutants (e.g. soot, oil, dust, algae, bacteria, salts, etc.) which gives it a black colour. Gypsum crust formation is commonly found on limestones; the formation of gypsum crusts on granites is less well documented. They may be derived from reaction between calcium from mortars and oxides of sulphur in rainwater. Calcium may also be derived from atmospheric deposition and a little from the granite itself (Plates 9, 10 and 11).

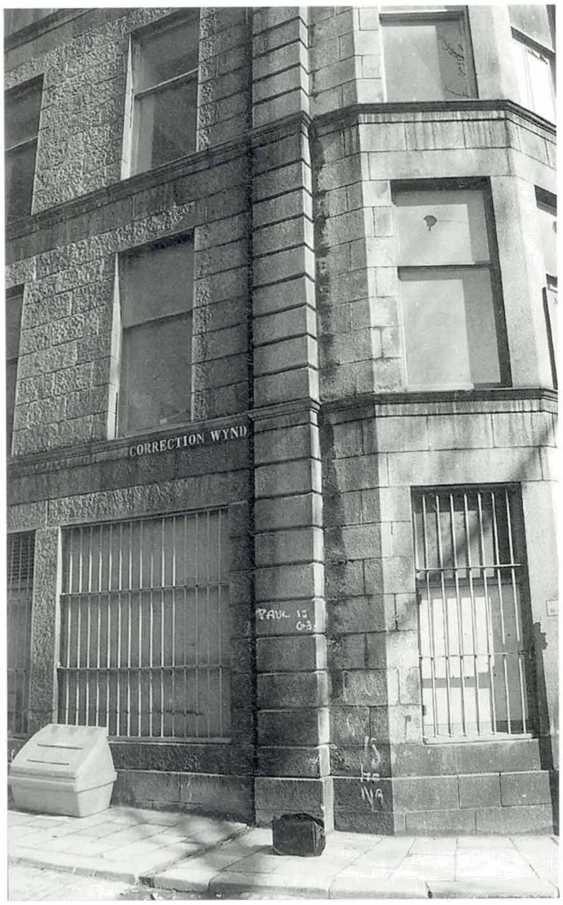

Plate 9 Typical soiling pattern. The soiling streak in the shelter of the projecting pilaster is gypsum which forms at the edge of a run-off zone (Correction Wynd, Aberdeen).

Plate 10 Close view of the soiling in Plate 9. The soiling is in a form of a hard gypsum crust, firmly bound to the granite. The crust is black due to the incorporation of hydrocarbons and other particulates into the gypsum.

At the present time, it is unclear whether gypsum deposits themselves or the effects of certain cleaning methods are more damaging to granite. If it were proved that the presence of gypsum accelerates the decay of granite, then removing the gypsum may reduce the rate of decay. However, aggressive cleaning, either abrasive or chemical, may do more damage to granite than is caused by the presence of the soiling.

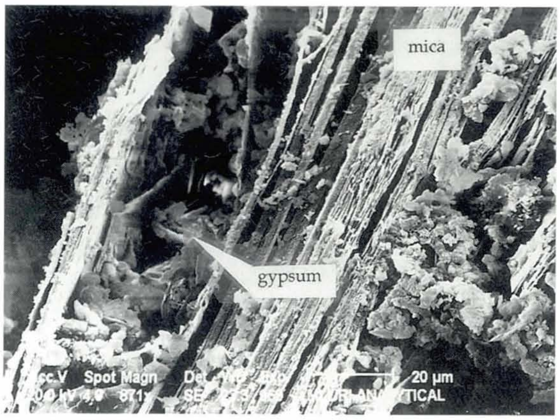

Plate 11 Scanning electron micrograph of granite surface showing the presence of gypsum

3.3 Biological soiling

Algae, bacteria, fungi, lichens and mosses may all occur on granite facades. The conditions required for organic growths to occur vary depending on the type and species of organism. The main factors influencing development of micro-organisms on a surface are water, light, temperature, pH and nutrition.

The most abundant visible growths on granite buildings in urban areas are green coloured algae which colonise a wide range of substrates including stone and mortar joints. Normally, they develop most abundantly on facades with excessive water run-off from leaking gutters and down-pipes or on sloping masonry and other areas of stonework exposed to more frequent wetting. In rural, or less polluted areas, lichens are often abundant. While lichen growths on buildings may be considered aesthetically pleasing, areas of green algae are normally considered to be disfiguring.

Plate 12 Algal soiling of granite. Growths occur on areas of high water availability such as on projecting surfaces and run-off zones below. The low porosity of granite means that the intensity of algal soiling is less than for more porous stones such as sandstone. The granite in this case was cleaned by a chemical method 10 years previously.

3.3.1 Algae

Algal growths are usually green when fresh but darken as the surface dries out (Plate 12). They are very common on the exterior surfaces of buildings and can be found on almost any substrate which remains damp for long enough. Algae are photosynthetic and require light to grow. They may die or become inactive during a prolonged dry spell but regenerate when the surface is re-wetted. Although they are not normally a source of decay, some algae are capable of causing stone decay by chemical action, and by penetrating pores and cracks in the surface of the stone and dislodging grains by mechanical action.

They are an indication of persistent damp conditions and may, if deposits are thick, increase the susceptibility of stone to decay due to long-term moisture retention.

3.3.2 Fungi

Fungi are not photosynthetic and do not require light to grow but they require organic material as a food source. They are generally not visible to the naked eye although they are often a component of the soiling layer. Some fungi secrete organic acids as they grow which are capable of

Plate 13 Lichen growths on Dalbeattie granite and on mortar joints. The presence of lichens is an indication of low levels of atmospheric pollution.

dissolving mineral grains although they are unlikely, in most circumstances, to cause serious damage to stone. The mechanical activity of fungal growth can also contribute to stone decay.

3.3.3 Bacteria

Bacteria are microscopic organisms and therefore not visible to the naked eye. Some bacteria are capable of fixing nitrogen from the atmosphere and may aid the colonisation of a substrate by other organisms through increased availability of nitrogen. Sulphur oxidising bacteria can be damaging to vulnerable substrates through the production of sulphuric acid and may be involved in some gypsum crust formation.

3.3.4 Lichens

Lichens are a symbiotic intergrowth of algae and fungi (Plate 13). They are photosynthetic organisms which require light and mineral salts for growth. They are often grey, yellow or orange in colour. Some of the body of the lichen may penetrate into the surface of the substrate and secrete acids which can damage stone. Lichens are very slow growing and in most cases appear to cause little or no damage to stone, although in some rare cases lichens can cause blistering and decay on stone surfaces.

3.3.5 Mosses

Mosses are small, simple photosynthetic plant structures which appear at the stone surface concentrated in cracks or crevices or on frequently wetted areas. Growths are usually in the form of discrete, often rounded clumps, dark green or reddish in colour. Mosses require some soil on which to attach and obtain mineral nutrients which are absorbed through the roots. Due to their high capacity to hold moisture, these plants lengthen the period of time over which the stone remains damp. Their presence is an indication of persistently damp conditions which are probably more damaging than the organism itself. In some cases, moss can cause some disruption to the stone surface or, more frequently, to mortar joints.

3.3.6 Control of biological growths

Biological soiling may be reduced by control of water run-off over building surfaces and by effective maintenance of gutters and down-pipes. Biological growths may be removed by the use of an appropriate biocide, but even the more effective biocides seldom remain active for more than about a year and regular re-application is necessary if the facade is to remain free of growths in the long term.

3.4 Re-soiling of granite facades

Buildings begin to re-soil immediately after cleaning. The rate of re-soiling is dependent on a number of factors including levels of air pollution, climate, stone characteristics and facade geometry. Some areas of facades re-soil faster than others and re-soiling occurs earlier in or around areas affected by water run-off. In particularly damp areas, biological soiling initially accumulates more rapidly than particulate soiling.

Evidence indicates that following stonecleaning, buildings may be subject to quite rapid re-colonisation by algae. Some constituents of cleaning chemicals, particularly phosphates, may increase the amount of biological growth by acting as nutrients. Even if algal growth is no more abundant after cleaning, any areas of re-established algae will be more visible against a lighter, cleaner surface. Thick biological growths will themselves trap particles and pollutants from the atmosphere, increasing the soiling rate in affected areas.

Stonecleaning may result in surface roughening of a stone due to dissolution of minerals by stonecleaning chemicals or abrasion by grit blasting methods. A roughened surface has an increased surface area over that of a smooth surface. This may result in more water being retained for a longer period, encouraging both biological and non-biological soiling.

If lightly soiled buildings are cleaned, they may resoil to the same level as before cleaning within a comparatively short period.

Consideration of the rate of re-soiling is important since this may lead to a desire to re-clean facades on a regular basis. Repeated cleaning will greatly enhance the likelihood of progressive, cumulative damage being done to the building stone. The effects of repeated cleaning of granite facades have not been investigated and extreme caution is therefore recommended before any second or subsequent cleaning is initiated.

3.5 Decay of granite in buildings and monuments

Granite is often thought of as a strong and durable stone which is not prone to decay. However, granite does weather and decay, although more slowly than many other stone types. Weathering reduces the strength and durability of the granite, and increased weathering is related to changes in the rock structure. Recent reports of crumbling granite exposed to the urban or rural environment for many years indicate growing concern for the condition of many granite buildings.

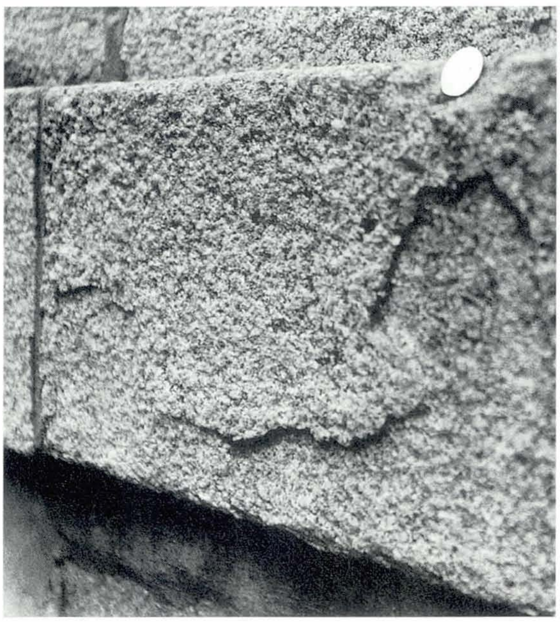

Plate 14 Contour scaling of projecting string course. Scales are several millimetres in thickness. Granite has been cleaned but method is not known.

3.5.1 Forms of decay

The forms of decay observed on granite are similar to those of sandstones, namely: contour scaling, granular disintegration, black crust formation and mineral alteration.

CONTOUR SCALING

In contour scaling, decay occurs by loss of plates or flakes of material from the face of the stone (Plate 14). These may be several tens of square centimetres in area and may be several millimetres in thickness. The scaling surface is unrelated to any underlying texture in the stone and this is not the same as loss of material from face bedded stones.

GRANULAR DISINTEGRATION

Granular disintegration involves loss of grains from the stone surface. Individual mineral grains become detached from the rock and are easily dislodged (Plates 15, 16, 17, 18 and 19).

GYPSUM CRUSTS

Gypsum crusts (Plate 10) form in relatively sheltered areas where the granite is not regularly

Plate 15 Scaling of cleaned Kemnay granite. Note the loss of detail on carved feature and at arrises.

washed by rainwater or run-off. They may be variously coloured but are often black. They are brittle and are often spalling or relatively easily detached from the granite surface. The crust itself is normally composed mainly of gypsum, and the underlying granite surface may be decayed. The spalling of these crusts may be related to differences in the properties of the two materials (i.e. gypsum and granite).

Gypsum is thought to be involved in granite decay through pressure derived from crystal growth within mineral cleavage planes and other cavities in the stone (Plates 11 and 21).

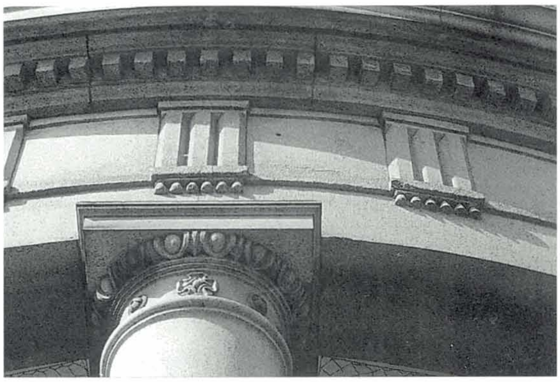

Plate 16 Example of fine detailing on Kemnay granite. This city centre building is known to have been cleaned more than once by unknown methods, possibly chemical. Note incipient scaling on the granite beam features.

MINERAL ALTERATION

Mineral alteration occurs through chemical reactions between fluids and the minerals in stone. Even when it is quarried the minerals in granite are not completely fresh as some alteration occurs due to circulation of ground water. When granite is exposed on a building facade this alteration continues and may be accelerated.

3.5.2 Mechanisms involved in granite decay

Water is the single most important factor in the decay of granite and other stone types. Water is required for biological growths and is involved in frost damage, hydration and de-hydration of minerals, growth of salt crystals and chemical alteration or dissolution of vulnerable minerals. Water can gain access to the interior of stone through exposed faces and by transfer from surrounding stones and mortar joints. Due to

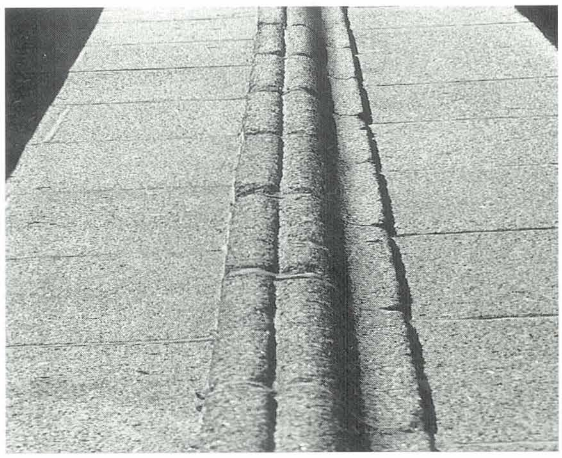

Plate 17 Part of arched opening John Smith Screen, Union Street. Aberdeen. The granite is Dancing Cairns and was cleaned by a chemical method 10 years previously. There is grain loss in association with the mortar joints. This elevation faces south to the street. The similar detail on the reverse of the arch (facing a church yard) remains intact.

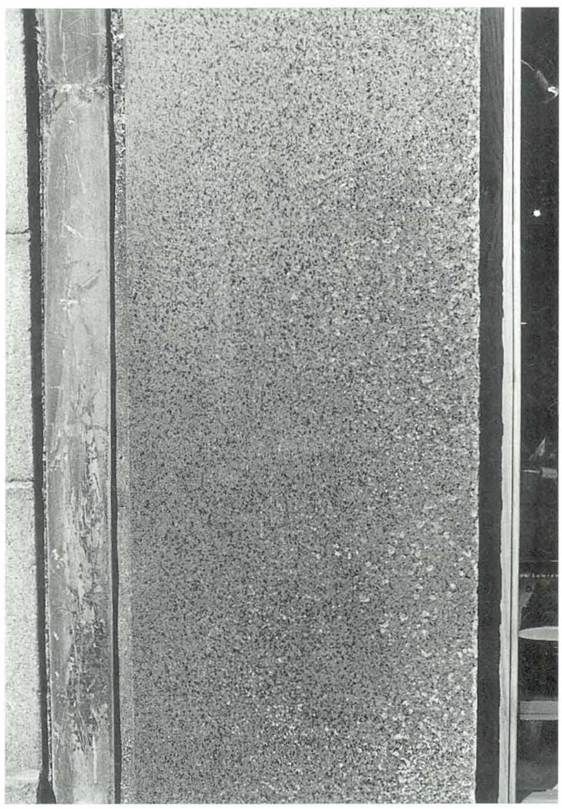

Plate 18 Granular disintegration on the surface of polished pink granite at city centre site. Cause unknown but may be associated with lack of proper protection during chemical cleaning of granite at a higher level on the facade.

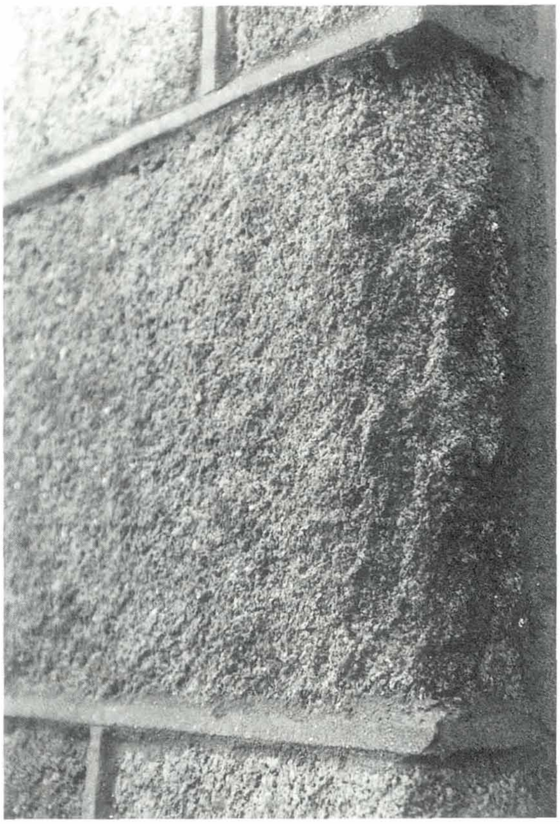

Plate 19 Example of recently cleaned and repointed Loanhead granite. Note the weathered, porous surface texture and significant grain loss. Projecting mortar joint tends to trap moisture, increasing the potential for surface decay of the stone in contact with the joint.

Plate 20 Cleaned facade of porous Loanhead granite viewed after a rainfall event. Generally the darker areas represent moisture retention by the porous surface and reflect varying degrees of surface porosity (Marischal Street, Aberdeen).

their low porosity, water penetration of most good quality granites is very limited. However, moisture may still be trapped in micro-cracks in the stone surface, in pore spaces within weathered mineral grains or in mortar joints. The degree of micro-cracking of the surface is likely to vary depending on the method of surface tooling. Polished surfaces have relatively low levels of micro-cracking. Aggressively tooled surfaces are likely to be more extensively cracked and may therefore be subject to faster decay. Micro-cracking of granites may also occur due to a variety of other mechanisms including stresses before and during quarrying and due to the action of pollutants and other factors on the exposed stone.

Granites consist essentially of quartz, feldspars and micas. Quartz is relatively stable but feldspars and micas are subject to slow alteration in the presence of water. Research has shown that both feldspars and micas can be dissolved and altered to clays by rain water at pH 5. Rainwater in Scotland at present has a pH of about 4.8. The formation of clays and other minerals may lead to micro-cracking due to volume changes on wetting and drying. Once micro-cracks are formed, they will allow the deposition of gypsum which may be the cause of further decay.

Salts can be a major cause of the physical disintegration of granite. Lime and other mortars may act as a source of calcium which, on reaction with pollutants, forms salts. The most common salt to form is gypsum (calcium sulphate), but calcium chloride and calcium nitrate may also form. Water washes the products of dissolution from the mortar onto the stonework underneath and mortars may supply salts to both the upper and lower stones of a joint by redistributing salts through a surface film of water. Salts formed by this mechanism may be implicated in decay of granite. Chlorides are quite common in coastal regions since they are of maritime origin.

Efflorescences are soluble salts, usually white in colour, which crystallise on the surface of a facade due to evaporation of salt-bearing fluids at the stone surface. The salts may originally have been present in the building stone or mortar or they may be derived from pollutants. Efflorescences may also occur on buildings following chemical cleaning due to chemical residues left in the stone.

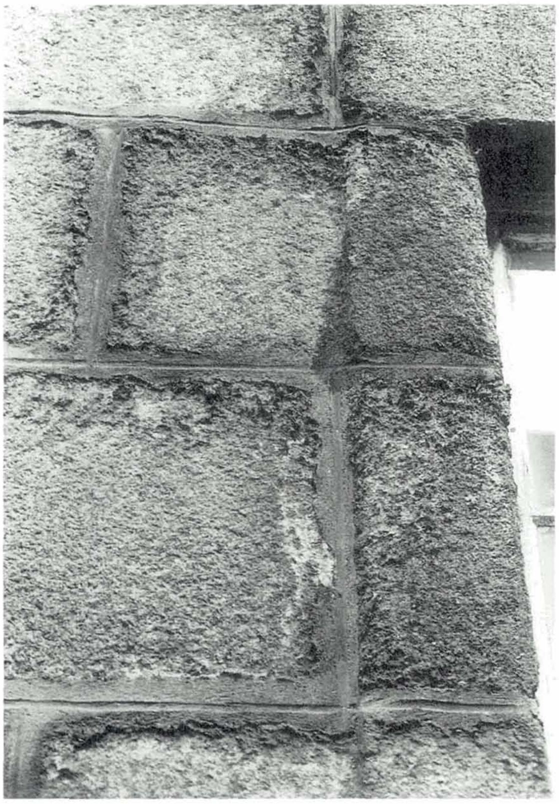

Plate 21 Detail of granite from building shown in Plate 20. Resoiling associated with the development of gypsum crusts around the mortar joints can be seen, with stone loss where crusts have become detached.

Efflorescences are often transient features and their appearance and disappearance on a facade is highly weather dependent. The salts are easily transported by movement of fluids and tend to concentrate in particular regions of the facade where evaporation rates are highest (e.g. below windows or projecting detail). Efflorescences may be initially concentrated around open joints where cleaning chemicals are trapped and not washed out, or are washed more deeply into the stone during the wash-out phase of cleaning. Ideally, all open joints should be repaired prior to cleaning.

Florescences, apart from their aesthetically detrimental effect, contribute to the decay of stone. Damage due to hydration pressures results from volume changes in salts during wetting and drying. One of the most damaging salts in this respect is sodium sulphate (thenardite; Na_2SO_4) because it undergoes large volume changes on wetting and drying Sodium Sulphate may be formed by reaction between alkaline cleaning agents and pollutants in the stone. Damage caused by crystallisation pressure is similar to that caused by the action of frost. It results from salt crystal growth within the pores of the stone. In good quality granites there is little likelihood of any significant degree of chemical retention or efflorescence; however, in more weathered granites whose porosity is closer to that of sandstones, crystal growth within the surface pores may occur and is known as subflorescence or cryptoflorescence.

As previously identified, the main salt found on an increasing number of granite buildings is gypsum. Gypsum is slightly soluble and may be re-crystallised within the minerals of the granite. Although the porosity of most good quality granites is very low, there is inevitably some weathering of minerals and micro-cracking of the surface. Salt-rich fluids may therefore gain limited access to the interior of the granite. There is evidence that dissolution and re-precipitation of gypsum within some minerals in the granite may, in the long term, lead to the physical decay of the immediate surface. Decay occurs through the physical pressure of the growth of gypsum crystals inside mineral grains. This opens up pathways for the influx of water which may do further damage.

Biological organisms can also cause decay of granite. Lichens, for instance, may cause decay by physical penetration of the surface and through mineral dissolution and alteration.

Many physical and chemical changes within the granite contribute to degradation and all the above processes may act on the stone synergistically to contribute to its decay. It is generally impossible to attribute any observed decay to a single cause.

4. ASSESSMENT OF THE FACADE

Before any decisions are taken regarding stonecleaning a preliminary assessment of facade condition is required as the nature and condition of stonework can profoundly affect the outcome of stonecleaning. A consultant's report covering these issues should therefore be part of any application to clean a building.

4.1 Preliminary examination

The aim of the preliminary visual examination is to provide a detailed site assessment of the building or facade to be cleaned, noting soiling level and distribution patterns, stonework defects, variations in stone type, geometry, micro-climatic effect and any other factors (e.g. poor or inadequate maintenance) which could affect cleaning or the subsequent weathering of the building, should it be cleaned. A systematic examination should be made of the whole area of stonework to be cleaned, taking photographs where appropriate. Much of the information could be recorded on architectural drawings, photographs or sketches of the building facade.

It is important to bear in mind that weather conditions can have a significant influence on the conclusions reached in any assessment of a masonry surface, as it is not possible to accurately assess the level of soiling when the facade is wet. It is therefore essential that a facade should be inspected in a dry condition, since it is very difficult to differentiate between soiling and wet granite, and to grade its severity. Colour testing should always be carried out when the masonry is dry, as wet stonework is significantly different in colour from dry stonework. Colour readings using chroma-meters will be inaccurate on wet stone. However, there are advantages in *additionally* viewing a facade in wet weather, since run-off patterns of rainwater will become clear.

4.1.1 Materials used in the facade

The different stone types and other materials present on the facade must be recorded as this can determine whether particular cleaning methods would be ineffective or inappropriate. Where a variety of materials has been used, more than one cleaning method may be required and some materials may need to be protected from damage while cleaning of other surfaces is taking place.

4.1.2 Tooling and decorative detail

Any variations in surface texture and decorative detail which could affect the choice of stonecleaning method should be noted. Highly abrasive methods, such as high-pressure grit blasting, may cause extensive loss of detail on vulnerable stone types. Abrasive stonecleaning methods may be equally damaging to the appearance of a smooth ashlar surface. It is often the case that decay will be first observed in the loss of grains from the sharp edges of carved detail. Such features therefore require close inspection and recording when the initial assessment is being made.

4.1.3 Soiling level and distribution

Variations in soiling level across the building should be observed and noted as this can affect the cleaning method chosen. Heavy soiling may require more aggressive or different cleaning methods than lightly soiled areas. Ingrained soiling or discoloration due to weathering effects may be difficult or impossible to remove without severe damage to the stone. No stonecleaning method can return stone to its original condition and damage can be done if over-cleaning is attempted.

4.1.4 Staining and discoloration

Some staining may be visible prior to cleaning. Staining is most likely to occur in areas where soiling levels are high, where run-off is concentrated and around metal fixtures. On heavily soiled stonework, cleaning may reveal staining which was not visible prior to cleaning. This is a possible outcome of cleaning which must always be borne in mind. Such discoloration, if it penetrates below the immediate surface, is unlikely to be removed by stonecleaning and may be much more visible following cleaning.

4.1.5 Defects and decay

Defects on the facade such as spalling, general stone deterioration or loss of mortar from joints should be noted. Many stonecleaning methods are likely to cause the loss of any loose or decayed areas of stone. Any areas where stone decay was advanced may require repair or replacement following stonecleaning. Pressure water washing is used in all chemical cleaning methods and in washing down after grit blasting (including dry grit blasting) and open joints can allow penetration of water which can cause damage to the building interior. Open joints may also allow stonecleaning chemicals access to the interior of stonework where they will be difficult or impossible to remove. It is advisable to repoint or temporarily fill damaged joints prior to cleaning.

4.1.6 Salt efflorescences

The presence of any salts (efflorescences) should be noted and samples may be taken for analysis. Salts in stone are frequently involved in decay. Salts differ in their behaviour and some are more dangerous to stone than others. They may be present naturally in the stonework, but may also come from deposition of pollutants. Some stonecleaning chemicals may leave residues of salts in stone or alter existing salts to a more destructive form. In most good quality granites, where porosity is low, salt efflorescences and problems with chemical retention should not occur although problems may still arise in more porous, weathered granites and in joints.

4.1.7 Biological growths

Areas of algal or other biological growth should be identified. On a highly soiled facade, green algal growth is often obscured by the soiling layer but should still be visible on close examination of the surface. Algal growths often occur on frequently wetted areas such as sills, string courses, sloping stonework and exposed decorative detail. They also occur around leaking downpipes or below overflow from blocked gutters. Following cleaning, algae are likely to return in previously affected areas within a few months and may be much more noticeable on the unsoiled stone. Their growth can be controlled by the use of biocides, but these are seldom effective for more than a year or two after application.

4.1.8 Previous cleaning history

Any details regarding the previous cleaning history of the building should be assembled and should include a record of visible damage attributable to that operation. However, it is frequently the case that records from previous cleaning are not available and it is unwise to rely on anecdotal evidence with regard to the methods used. Splash marks on adjacent stonework may sometimes provide evidence of previous chemical cleaning.

4.2 Records and reports

The outcome of the preliminary investigation should be a detailed record of the facade, noting those features which could affect any decisions regarding stonecleaning. It may be possible, at this stage, to rule out some stonecleaning methods from further consideration. On the basis of the evidence gathered from the preliminary examination, a decision can be taken as to whether to proceed with the cleaning of test panels, and if so, which stonecleaning methods should be tested.

5. METHODS OF CLEANING GRANITE FACADES

By comparison with limestone and sandstone, there has been little research done specifically on the cleaning of granite, except for work by the Masonry Conservation Research Group of The Robert Gordon University on which this TAN is based. Consideration of the physical and chemical nature of a building stone is critical when choosing an appropriate cleaning method. Techniques which work well on one stone type may be ineffective or disastrous on another and variations even within stone types can significantly affect the outcome of cleaning.

Granites are similar mineralogically to some sandstones; both commonly contain quartz, feldspars and mica with other minerals in minor or trace amounts. Soiling on granites is likely to be tightly bound in a similar way to that which is encountered on sandstones. Consequently, cleaning methods such as water washing which work well on limestones but have little effect on sandstones are also likely to have little effect on granites.

There is a wide variety of stonecleaning methods, but none are capable of removing the soiling layer from the surface without also having some effect on the underlying stone. It is therefore important when choosing an appropriate method for use on a building to consider not only the effectiveness in removing the soiling, but also its impact on the stone substrate (Plate 22).

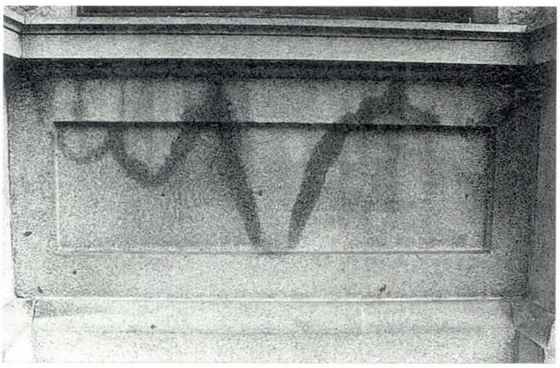

Plate 22 Detail below window on cleaned city centre facade. The clearly defined pattern on the stone (Rubislaw granite) is not soiling but areas of moisture retention at the surface where the granite is more porous. A possible reason for the increased porosity may be as a result of over aggressive chemical cleaning.

The longer-term effects that cleaning methods have on granites with respect to resoiling or decay processes have not been studied in any depth. Research suggests, however, that provided test panels are used to establish minimally aggressive methods for soiling removal, and provided cleaning is properly carried out, many chemical or physical stonecleaning methods can be used on granite facades with little or no damage to the stone, provided it is in a sound condition.

Physical cleaning by grit blasting causes microfracturing on the granite surface, thus leaving granite surfaces more vulnerable to decay processes which are enhanced by the ingress of water and pollutants. Where the granite is spalling, decayed, weathered or otherwise reduced in strength it will be vulnerable to erosion by abrasive cleaning or high pressure water washing (Plate 23). In addition, significant residues of chemical cleaning agents may be left in granites where the porosity has been increased by weathering or decay. Such residues can accelerate decay of the granite.

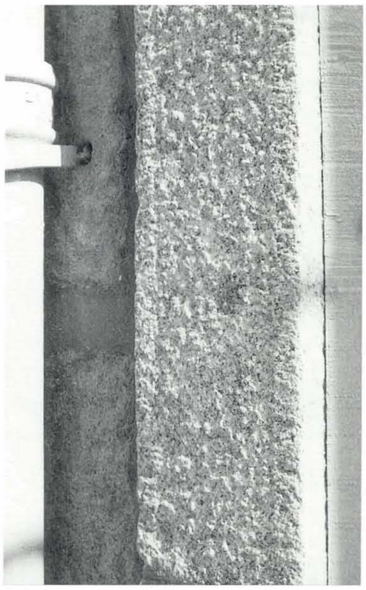

Plate 23 Recently cleaned Loanhead granite. The cleaning method used was a low pressure wet abrasive system (slurry) using olivine grit. The system has proved too aggressive for the friable surface of this weathered granite and a significant quantity of stone has been removed with the soiling.

The nature of the soiling on granite building stone varies within one facade and from building to building. Some cleaning methods (e.g. chemical cleaning) may not be capable of removing some soiling types without resorting to multiple applications or increased chemical concentrations which could result in damage to the stone. It is therefore necessary to conduct sufficient tests on representative areas of soiling to ensure that the chosen cleaning method can cope with all the soiling levels likely to be encountered on the facade. It may be necessary to use more than one cleaning method where small areas of stubborn soiling are not removable by the chosen method.

Stonecleaning may reveal staining beneath the soiling layer which may not have been visible before cleaning. Staining may arise from weathering of the granite or from metal fixtures. It is dangerous to attempt the removal of such stains as excessive cleaning may damage the stone.

On smooth granite surfaces, differences in lightness below 1% can be visible on adjacent facades. Where facades are not adjacent, differences in lightness of a few per cent are probably not visible.

Pollutants in the form of soluble salts (mainly gypsum) are present on many granite facades. These salts have been linked to decay of granite. Stonecleaning by physical or chemical processes can reduce the level of salts present at the surface of the granite. This is likely to have the effect of reducing the rate of decay of the granite. However, more research is needed to establish the long-term effects of gypsum removal.

5.1 Physical cleaning methods

Physical cleaning methods embrace a wide variety of techniques. Most work by abrading the surface layer of stone to which soiling is attached. However, there can be considerable variation in the effects which different techniques have on stone. Many abrasive cleaning methods can cause roughening and erosion of the stone surface. Any damage which results from physical cleaning is usually apparent at the time of cleaning although surface roughening or erosion may not always be obvious to the untrained eye. The extent to which this occurs is dependent on a range of factors including the nature and state of decay of the stone, the pressures used and the nature and size of grit blasting particles. The skill and training of the operative employed on the cleaning task is of vital importance as it is easy to cause damage to stonework. Pressures to clean buildings quickly and within a limited budget can lead to the abuse of many physical cleaning methods with resulting damage to stonework.

5.1.1 Water washing and steam cleaning

Water washing is most effective on limestones or other stone types where much of the soiling is water soluble. On granites, however, water washing is generally ineffective and is only able to remove loosely bound surface debris. Water washing may be done at a range of pressures from fine, nebulous sprays through to high pressure water jets (up to 14,000 kPa (2000 psi) or more). Even at high pressures, water washing alone is not capable of removing substantial amounts of soiling from granites as it is only able to remove loosely bound surface debris or biological growths. Water acts both to loosen soiling deposits and to wash them away. The effectiveness of the technique is enhanced by the additional use of gentle scrubbing (using non-ferrous brushes). It also has some cleaning effect on mortar. Since water washing at low pressures can be effective at removing some organic growths such as algae and moss, water washing and brushing is often used as a preliminary to chemical cleaning. Loose or water soluble material removed by water washing reduces the amount of chemicals needed. Water washing is also used for rinsing to remove chemicals after chemical cleaning and to wash down after grit blasting.

When using water jetting, the spread of the nozzle is important as it influences the pressure of the water at the surface of the stone. Straight ahead nozzles with 0 to 15 degrees of spread are to be avoided on vulnerable stone since the concentrated energy can be damaging. Nozzles with 15 to 50 degree spreads are commonly used. The distance that the nozzle is held from the surface and the angle of attack also strongly influence the water pressure on the stone. The volume of water used may range from 4.5 L/min. for delicate work up to 36 L/min. It is normal for the water to be heated to improve the cleaning action.

Where chemical cleaning agents are added to the water used in pressure jetting, it has been suggested that the application pressure should be kept below 350 kPa (50 psi)), and that the stone should be pre-wet to reduce infiltration of chemicals into the stonework. However, little research work has been done in this area and it is unclear whether pre-wetting is likely to reduce or increase chemical penetration in general. On granites, which have very little porosity, fluid penetration of the stone is unlikely to occur beyond the immediate surface, although penetration into mortar or open joints is possible.

Most of the problems associated with long duration water washing methods are related to the dangers of water penetration into the stonework. Water penetrating through cracks and defective pointing can cause damage if it comes into contact with timbers, iron fixings, electrical wiring and internal fixtures and fittings. Water can also collect in voids within the walls and elsewhere which may lead to direct damage or future problems with rot. Freezing of water during cold spells can cause frost damage. Water containing pollutants dissolved from the soiling layer may be absorbed into the stone and later mobilisation of salts in the stonework may lead to efflorescences.

Steam cleaning is infrequently used today. Steam cleaning works by the combined action of moisture and heat which swells and loosens soiling. When used in conjunction with mild detergents it can remove grease and oil. It has the advantage that relatively little water is used. The steam is directed at the surface in a jet at pressures of 70kPa to 480kPa (10 to 80 psi). This method may be useful in situations where other methods are difficult to use (e.g. on irregular surfaces). Steam cleaning should be followed by scrubbing. It is effective at removing organic growth but is slow, expensive and potentially dangerous for the operative. It is considered by some to be little better than cold water washing and it is ineffective at removing severe staining. On granites, steam cleaning is likely to be only minimally effective since much of the soiling layer is chemically bound to the surface.

Non-ionic detergents are sometimes used in cleaning. Ionic detergents should not be used as there is the danger of causing efflorescences if residues remain in the stone or mortar. Detergent washing in conjunction with brushing can remove greasy or loosely bound soiling but is generally ineffective on granite.

5.1.2 Abrasive cleaning (grit blasting)

Pressures used in abrasive cleaning range from the extremely low (20kPa (3 psi)) to high pressures of 560 kPa (80 psi) or more. The higher the pressure, the greater the potential for erosion. The effective pressures and amount of erosion at the stone surface depend on a number of factors including pressure, working distance, flow rate and grit size, shape and hardness. The grits used are generally amorphous alumino-silicates, but other materials including olivine, aluminium oxide (corundum), calcium carbonate, sodium bicarbonate, silicon carbide or dry ice (solid CO_2) are also used. The erosive power of a grit is related to its hardness. Softer substances such as calcium carbonate or sodium bicarbonate are less erosive than silicate slags. The sizes of grits range from the very fine (50 to 100 μm diameter) up to coarse (about 1mm diameter). Coarser grits are more abrasive than finer grits.

Grits such as quartz and sand, which contain free silica, are no longer permitted (Health and Safety at Work Act, 1974) as they release dust which can cause lung damage (silicosis). Depending on the degree of soiling, softer grits such as calcium carbonate or sodium carbonate may leave some residual soiling on the granite surface.

Abrasive cleaning may be done either dry or, if water is added to the abrasive stream, wet. Dry cleaning has the advantage that there is no danger of water penetration into stone or mortar but it is extremely noisy and produces a great deal of dust. Even where grits are used which do not release free silica, erosion of a stone surface which contains silica in the form of quartz (e.g. granite) is likely to release silicon dust into the atmosphere. Although no water is used in the cleaning process surfaces should be washed down after cleaning to remove any debris adhering to the stonework.

Wet grit blasting (Plate 24) is slightly less noisy and the inclusion of water in the grit stream keeps down the amount of dust produced. However, wet grit blasting tends to be very messy to use, since it leaves deposits of slurry on the surface being cleaned. The surface requires careful washing down after cleaning, to avoid leaving a stone-soiling grit-paste on the surface. This paste, if not washed off, will harden onto the stone. The difficulty for operatives of seeing how the work is proceeding can result in an uneven clean (gun shading).

Plate 24 Wet grit blasting using an olivine slurry.

Ideally, abrasive cleaning should only remove the outer soiling layer. In granites, unless they are highly weathered, soiling does not penetrate below the immediate surface so the amount of abrasion necessary to remove soiling should be minimal. In practice, however, the amount of abrasion is difficult to control. It should be noted that staining (e.g. from iron fixings) may penetrate more deeply than the soiling layer. It is dangerous to attempt to remove such soiling by abrasive cleaning since removal may entail an excessive degree of erosion of the stone surface.

Generally, dry grit blasting at 10 to 40psi tends to be both more effective in removing soiling and more damaging to the stone surface than wet grit blasting at the same pressures. Successful cleaning requires a balance which can achieve maximum soiling removal with minimum stone abrasion. A cleaning method which works on one stone type may not necessarily work equally well on another since even granites may vary quite widely in their hardness. Harder, unweathered granites may be quite resistant to erosion, allowing relatively abrasive methods to be used. However, on softer or weathered granites even gentle cleaning methods may result in relatively large degrees of surface loss.

This may be of little consequence in circumstances where the stone is hard or has a rough, rustic texture, but it can be very damaging to the appearance of smooth faced ashlar or polished stone. Light tool marks or surface patina are easily lost. Soft, weathered or decaying stone is unlikely to survive abrasive cleaning and on such stonework severe loss of surface texture may result.

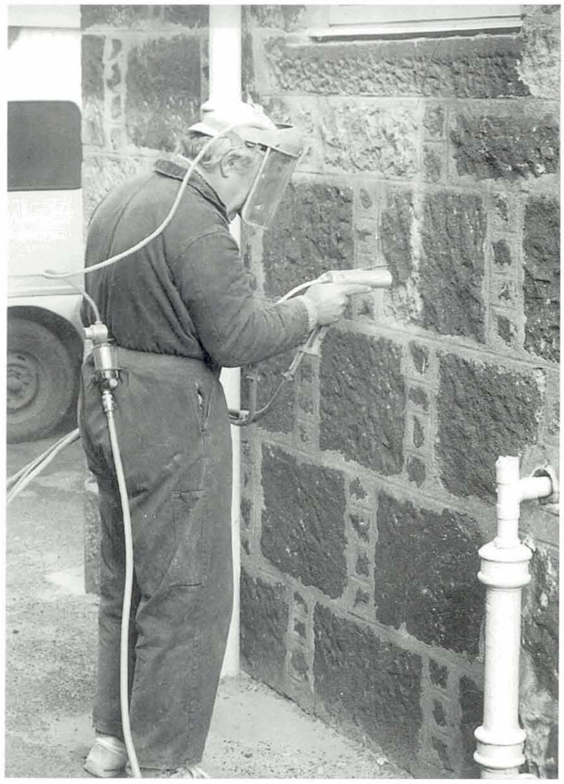

Plate 25 Very low pressure cleaning of a heavily soiled rock faced granite test panel using a fine aluminium powder abrasive.

Very low pressure abrasive systems (of the order of 20 kPa to 35 kPa (3-5 psi)) which use extremely fine abrasives such as a powder of aluminium oxide may, under ideal conditions, be capable of removing soiling with little or no damage to the stone surface. Under some circumstances the patina has been retained on the stone (Plate 25).

The erosion caused by abrasive cleaning methods generally results in a dulling and/or scoring of the granite surface. More extreme erosion can blur or soften previously sharp corners or remove tool marks. Roughening is undesirable aesthetically and may increase the resoiling rate of the stone after cleaning. The rougher surface may also be more susceptible to algal growth due to reduced water run-off rates. The amount of erosion can be reduced by using lower grit blasting pressures or softer grits.

Abrasion of the surface of quartz-rich stones (including all granites) will produce fine quartz particles which could be hazardous if breathed in. Operatives involved in cleaning must always wear appropriate safety clothing and respiratory protection.

5.1.3 Mechanical cleaning

Mechanical stonecleaning methods are seldom used nowadays. Such methods include a variety of techniques, including the use of brushes, discs, abrasive block and needle guns. Most of these methods (with the exception of brushing) work by abrading and removing the surface of the stone, removing the soiling layer and thereby exposing fresh stone. The use of some of these methods can be particularly damaging since they remove the surface patina and blur tooled detailing on the stone surface. In the past, considerable damage has been caused by these methods. While virtually never used today as the principal method of cleaning a building, they are occasionally used to remove stubborn stains which remain following other cleaning treatments.

DISC CLEANING

Disc cleaning involves the use of carborundum discs and brushes attached to power tools and applied directly to the surface of the stone. A range of different discs and brushes are available to suit the work being undertaken. Undoubtedly this is the most damaging form of mechanical cleaning, particularly as the considerable abrasive power of the machines is very difficult to control, even in the most skilled hands, and such damage is irreversible. Typical forms of damage include the distortion of straight arrises and loss of original surfaces on flat stones and carved details. Mechanical grinding can result in the scouring of facade surfaces and the 'imprinting' of the disc as a series of curved, shallow hollows on the stone surface. Disc cleaning results in the re-dressing of the stone, which is not recommended in terms of good conservation practice particularly because the loss of historic fabric is inevitable with this process.

DRY BRUSHING

This involves manually brushing the facade with a stiff bristle or nylon brush to remove organic growth and loosely bound surface dirt. Sometimes a commercial grade vacuum cleaner is used to take away the debris as it is removed. This method removes relatively little soiling but consequently causes little or no damage to the facade. It can be effective on rubble and rock-faced ashlar buildings where soiling is less noticeable or where only a low level of cleaning is required.

ABRASIVE BLOCKS

Abrasive blocks have occasionally been used to remove stubborn areas of soiling. Their use is not recommended since they can cause excessive, localised erosion if used in an attempt to remove ingrained soiling.

NEEDLE GUNNING

Needle gunning is a technique which involves abrasion of the stone surface by the impact of bunched metal rods or needles. This method is rarely used and can cause a great deal of damage to a surface.

5.1.4 Precautions and good practice

Abrasive cleaning methods are not recommended on polished granite as this will result in loss of the polished surface. Pressure water washing and detergents may be used where test panels indicate that the pressures used do not cause damage to the surface.

While physical cleaning methods (unless used at higher pressures) may cause relatively little damage on most good quality granites, weathered granites are more friable and are more susceptible to damage. Some granites may be damaged simply by pressure water washing. Such weathered granites are unsuitable for cleaning by any abrasive method.

In situations where the pointing is in poor repair there is a danger of water penetration into the building fabric where wet cleaning methods are used. Even dry abrasive cleaning methods require the use of water washing to remove dust from the facade after cleaning. In such situations prior repair or temporary filling of joints should be considered.

5.2 Chemical cleaning methods

Chemical cleaning methods work by chemical reaction between the chemicals, soiling layer and the stonework (both stone and mortar). A wide range of chemical cleaning agents is available commercially, but all can be categorised into a few groups according to their chemical and physical properties; most are strong acids or alkalis. The active ingredient may be a single component material or a mixture and can vary considerably in concentration and strength. Inert materials or detergents may be added to control the viscosity and action of the cleaning agent. Technical literature from the manufacturers is usually supplied with the cleaning agent. However, modification of chemical strengths or dwell times may be necessary if indicated by analysis of test panel results.

The effects of stone porosity are especially important in chemical cleaning. Porous stone is capable of absorbing and retaining a large amount of applied chemicals. Granites, having low porosity, do not usually absorb much chemicals although residues of chemicals may be left in joints since mortar tends to be more porous than stone.

Chemical cleaning methods are generally capable of removing soiling, even when the soiling is very heavy. The only case where chemical cleaning methods may not be sufficient is on areas of stonework that are covered in black crusts. There appears to be little significant difference in the effectiveness of any of the chemical cleaning methods available.

5.2.1 Alkaline cleaning agents

Alkaline chemicals may be applied to heavily soiled surfaces as degreasing agents before the application of acidic cleaning agents. Degreasers vary in chemical composition but many contain sodium hydroxide (NaOH). These chemicals soften greasy or oily deposits on the stone surface which might otherwise repel acidic cleaning

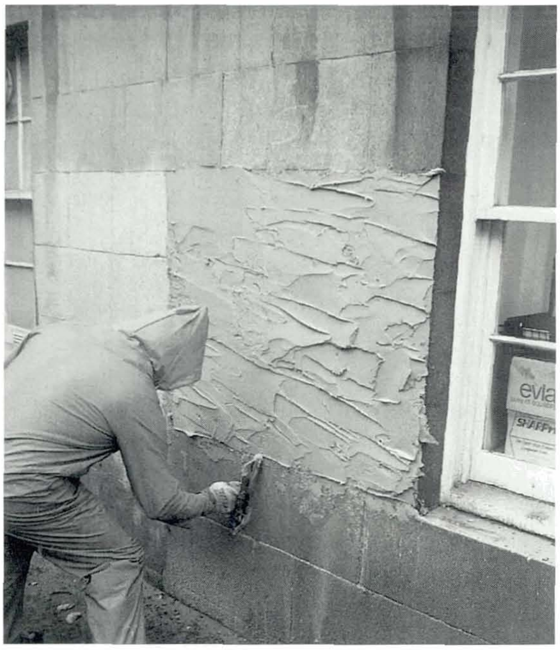

Plate 26 Applying alkaline poultice to Rubislaw granite test panel.

agents. These cleaning agents are normally brushed or sprayed onto the stone surface. Often the surface will have been pre-washed with a water jet to remove any loose debris or soiling. Some degreasers contain a thickening agent designed to aid the adhesion of the degreaser to the surface of the stone. In an extreme form the degreaser may be mixed with clay to form a poultice. This can then be trowelled onto the stone (Plate 26) Plastic film is placed over the poultice to prevent it from drying out.

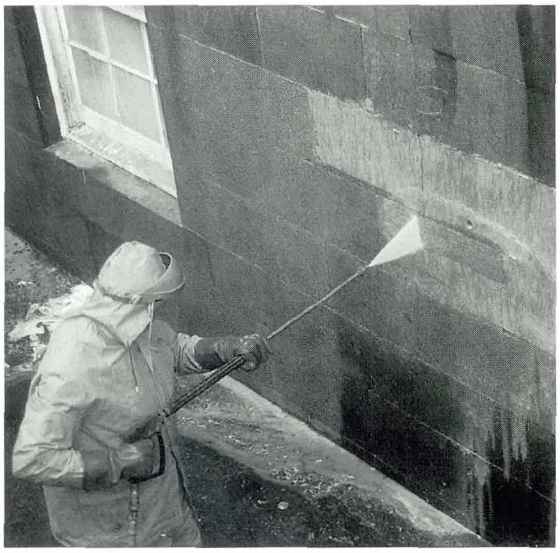

Plate 27 Wash off of poultice with water at a pressure of 1500 psi and at 80°C following scraping. Note protection to window.

Dwell times for liquid degreasers vary depending on their chemical composition and the nature of the deposits to be removed, but usually they are in the region of 20 minutes to 3 hours. Dwell times for poultices tend to be longer (up to 24 hours). After the relevant dwell time the degreaser is washed from the surface by a high pressure water spray. In the case of a poultice it is first scraped off before undergoing the wash procedure (Plate 27). Poultices may be difficult to remove from carved or intricate areas of stonework.

Although pressure water washing is often used to rinse off the cleaner, this wash-off process is unlikely to be any more effective than low pressure water washing at removing chemicals that have been absorbed into the stone. Chemicals that remain in the stone can be a cause of decay.

Alkaline pre-cleaning agents may remove much of the soiling from the stone surface. This does not however imply that an alkaline treatment alone should be recommended for granite cleaning. The use of alkali alone, without neutralisation or very thorough washing, runs the risk of alkali (i.e. sodium) being retained in the stonework or, more likely in the case of granite, in the mortar joints.

The use of sodium-based chemicals may lead to the formation of potentially dangerous salts in stonework if substantial amounts of the chemical are left in the stone or joints. The sodium salt thenardite (sodium sulphate, Na_2SO_4) is considered to be particularly dangerous in stonework.

Alkaline cleaners are not recommended for use on stones with relatively high iron content as this could result in iron staining on the surface.

5.2.2 Acidic cleaning agents

Hydrofluoric acid (HF) is the most common active ingredient in acid based cleaning agents although other weaker acids (e.g. acetic acid) may be used where the acid is intended for neutralisation of a previous alkaline treatment rather than for its cleaning action. Hydrofluoric acid based cleaners work by dissolving the bond between the soiling layer and the stone, allowing the soiling to be washed off. The dilution and dwell times of acid cleaners should be kept to the minimum which achieves an acceptable level of cleaning. The penetration of acid based chemicals into the stone seems to be more dependent on dwell time than on concentration.

Hydrofluoric acid based cleaners are normally applied by brush after the alkaline degreasing stage (Plate 28), although some (e.g. ammonium bifluoride based cleaners) are used without a degreasing stage. Dwell times for liquid cleaners can range from 5 to 30 minutes. Ammonium bifluoride based cleaners come in gel form, and need a longer dwell time (e.g. 1 hour). The chemicals are washed off with high pressure water.

Dark, iron-rich minerals which occur in small amounts in granite may be attacked or dissolved by some acidic cleaning chemicals. Dissolved iron may be re-deposited at the stone surface appearing as orange or brown staining. If, on the other hand, dissolved iron is washed out of the stone this will result in bleaching of the surface. Staining and bleaching may be the result of application of chemical cleaners at too high a concentration or for too long a dwell time. Where chemical cleaning is properly controlled, problems with bleaching or staining need not arise.

Plate 28 Application of hydrofluoric acid based cleaner to Rubislaw granite test panel.

5.2.3 Effects of chemical cleaning on granite facades

Where chemical cleaning was done under controlled conditions, no evidence was found of any immediate physical damage to the granite surface.

The effects of chemical applications are generally predictable. There tends to be very little chemical penetration into granite and levels of chemicals retained tend to be much lower than those found in sandstone. However, there is evidence to show that long contact methods cause some increase in chemical penetration. It is therefore safer to use methods that involve the shortest possible dwell times with the most dilute chemicals. This should result in very little detectable penetration of chemicals from the cleaning process.

The low porosity of good quality granites means that in most cases chemicals applied to granites remain on the immediate surface and cannot penetrate to any significant depth. Residues of cleaning chemicals in good quality granites are normally too low to be of concern. More weathered granites may have porosities closer to those of sandstones and may suffer similar levels of chemical retention with the danger of salt formation and accelerated stone decay. Significant retention of cleaning chemicals may also occur in mortar joints, especially where the mortar is decayed or lost. The point of contact between the mortar and the neighbouring granite block tends to allow greater access for pollutants (and therefore chemicals). Residues in mortars could give rise to problems at a later time. The long-term effects of chemical retention in mortar joints are unknown.

Weathered granites may be relatively soft and such granites can be damaged simply by pressure water washing. Building facades containing highly weathered granites are considered unsuitable for chemical cleaning.

Direct physical damage has been observed after the chemical cleaning of highly weathered granite. The chemicals may increase the erosion of the stone surface, but the main damage is clearly caused by the pressure of the water used in the rinse stages of the cleaning process.

Chemical cleaning agents are generally able to remove most soiling from granite, except where the soiling is particularly heavy or encrusted.

A substantial increase in the level of lightness can be achieved by the most effective cleaning methods. The degree of colour change obviously depends both on the degree of soiling and on the underlying colour of the weathered surface of the granite. The most highly soiled granites may have lightness value below 30 when measured on a scale 0-100 (where 0 equals black and 100 equals white). Fresh granites, depending on their colour and surface finish, have lightness value between about 55 and 70. Cleaning generally cannot return a granite to its original level of lightness, and values achieved tend to be more in the region of 40 to 60.

Different cleaning methods can produce variations in colour (chroma). If, for example, various properties in a terrace are cleaned at different times or by different methods, this can lead to marked difference in colour along the terrace.

In field trials there was no evidence of any bleaching or staining on chemically cleaned granite surfaces, indicating that while such problems can arise through improper cleaning, they need not occur if care is taken.

The effects of chemical cleaning agents on mortar are somewhat different from that on granite. This is to be expected, since mortar is softer and more porous than granite. Pollutants can gain access into the mortar to depths in excess of 10mm. The permeability of fresh mortar is dependent on the amount of sand present in the mix. The more sand-rich the mortar, the greater the porosity. In relation to chemical uptake during a cleaning process, the more sand a mortar contains the more applied chemicals would be retained. Mortars which contain a higher proportion of cement or lime appear to withstand a chemical cleaning process more easily.

5.2.4 Precautions and good practice

The correct procedure for testing, selecting and applying chemical cleaners is described in section 6 below. The points raised here are general recommendations and suggestions which may be helpful.

- Chemical cleaning should not be carried out when there is any risk of freezing. It should also be noted that when air temperatures are low the cleaning action will be slowed down and that the surface temperature of the stone may be below that of the ambient air.
- Acidic chemical cleaning methods (especially hydrofluoric acid or ammonium bifluoride based methods) must not be used on polished granite as this will result in loss of the polished surface.
- In some cases, using an alkaline pretreatment followed by an acid cleaner has been found to be no more effective than using the acid treatment alone. It may therefore in some cases be advisable to remove soiling from granite using only an acidic cleaning agent without the prior use of an alkaline degreaser. A single stage cleaning process would have the advantage not only of being cheaper and easier than a two stage process, but it also avoids the dangers inherent in the application of alkaline materials to stonework. However, it must be noted that thicker soiling deposits may not be removed by acidic cleaning alone.
- There is some indication that long contact methods increase chemical penetration. It is safe to assume that one would be better advised to use methods that involve the shortest possible dwell times with the most dilute chemicals.
- Most chemical cleaning methods are capable of removing soiling at concentrations lower than those recommended or provided by

manufacturers. The risk of damage to the stone face may be reduced greatly by the application of more dilute chemicals and an end result of comparable cleanness to a full strength cleaning regime could be achieved.

- It has also been noted that the dwell time (time of application contact to the stone) of many chemicals could also be greatly reduced from that recommended by manufacturers. In general, dwell times should be kept as short as possible. This again may reduce the risk of damage caused by the chemical cleaning agents and still provide a satisfactory degree of cleanliness that would be indistinguishable from that of a full dwell time cleaning regime. It may be possible to produce a satisfactory level of clean when chemicals are only in contact with the stone for a period of little over 5 minutes.
- In situations where mortar has decayed, stonecleaning chemicals may gain access to the interior of the wall where they will be difficult to remove in the wash-off stage of cleaning. There is also the danger of water penetration into the building fabric. It is therefore important to ensure that mortar joints are in good condition, and open or decayed joints should be repaired prior to chemical cleaning in order to minimise the ingress of chemicals into joints. If mortar is to be raked out and replaced at the same time as cleaning takes place, the old mortar should be left in place or the new mortar be put in before chemical cleaning takes place. If chemical cleaning is carried out on a facade where the mortar has been raked out it is likely that large amounts of chemicals will be left deep in the masonry wall.
- Chemicals should be brushed on and not sprayed. An agitation by brush should be applied to the chemical-soaked surface approximately half-way through the total contact period of the chemical.
- The chemicals used in stone cleaning can cause serious damage to skin, eyes or the respiratory tract. Adequate precautions to safeguard both the operatives and the general public are therefore essential. Whenever hydrofluoric acid is used, hydrofluoric acid burn gel should be available for treating small burns. Serious hydrofluoric acid burns require immediate medical attention.
- Strong alkalis will attack metals and plastics, therefore all vulnerable areas (e.g. window frames) should be covered and sealed before cleaning commences. Hydrofluoric acid will etch polished stone surfaces, metals and glass, therefore all windows and areas of polished stone must be covered and sealed before cleaning commences. Airborne chemicals can cause damage to property (e.g. etching of glass, damage to car paint work).
- Any regulations regarding the discharge of effluents into the public drainage system should be checked with the local water authority. Effluent run-off from the building should be controlled so as to minimise any local environment damage.
- In situations where the pointing is in poor repair there is a danger of water penetration into the building fabric where wet cleaning methods are used. In such situations prior repair or temporary filling of joints should be considered.

5.2.5 Removal of efflorescent salts

A number of different salts may be present on and within stone. A surface salt deposit is known as efflorescence and, whilst it may be visually intrusive, it may not cause damage. Salts which form in pores and fissures below the surface (subflorescence or cryptoflorescence) are potentially very damaging to some porous materials. Granite is less vulnerable in this respect than, for example, some sandstone.

The source of the salts should be identified. Efflorescences are crystalline deposits on the surface of the stone or mortar and should be removed quickly as some can be reabsorbed into the masonry. Removal of surface salts can be achieved by gentle brushing, with the powder collected and disposed of. However, surface efflorescences will gradually reduce over time.

The removal of salts from within the stone or mortar is a specialist operation, often utilising an appropriate poultice, and is only practical on small areas and areas of fine detail.

6. TESTING METHODOLOGY

Before any building facade is cleaned, a programme of testing is necessary to establish the best method. The method chosen should be one which can produce an *acceptable* degree of soiling removal whilst causing minimal damage to the stone. It is recommended that test cleaning should be conducted separately from, and in advance of, the main stonecleaning contract. A properly conducted program of test cleaning and analysis of results can be time-consuming. It should therefore be commissioned well in advance of the anticipated date for the proposed stonecleaning contract.

No stonecleaning method exists which is capable of removing the soiling layer without also having some effect on the underlying stone. This will be governed by the cleaning method and the characteristics of the stone. In choosing an appropriate cleaning method it should always be the aim to use the minimum possible pressures, chemical concentrations and dwell times necessary to achieve a satisfactory level of soiling removal. It should be recognised that it may be necessary to use more than one method of cleaning on a facade. It is not acceptable to use only the most aggressive method that cleans the most heavily soiled stone, when a less aggressive system is appropriate for other areas of stonework.

It must be accepted that no cleaning method can return a stone to its original appearance. Some residual soiling and staining is inevitable in most cleaning situations, and building owners should not have unrealistic expectations of the outcome of cleaning. In some situations it may not be possible to remove soiling without causing potentially serious damage to the stone. **In assessing the likely outcome of stonecleaning the option not to clean should always be considered.**

6.1 The decision to clean

It is always recommended to consider whether a building does in fact *need* cleaning. Many buildings give a pleasantly weathered impression which stonecleaning would destroy. In addition, stonecleaning may expose the building to damage from the cleaning process, and possible accelerated decay. The effects of the cleaning may also be short-term. Particularly after chemical cleaning, some facades may be quickly recolonised by biological growths.

Thought should also be given to where to start and stop cleaning. A piecemeal approach to cleaning a property will inevitably produce a patchwork effect which will significantly affect the architectural integrity of a building or group of buildings.

Cleaning should never take place where the precise nature of what is to be cleaned and its possible response to the method and materials to be used are not fully understood. Proposals to stoneclean, if they are acceptable in principle, must be considered with extreme care. Where there is any doubt about the basis of a cleaning proposal, consent should not be given.

6.2 Need for tests

Following an initial selection of potential cleaning methods, test panels should be cleaned by each of the chosen techniques and the results analysed. Analysis of the effects of stonecleaning should include qualitative and quantitative assessment based on on-site and, where appropriate, laboratory analyses. There are a number of techniques which may be employed in this analysis, and a few notes on each technique are given at the end of this section.

It is likely that lightness variations below 0.5% are detectable by eye on adjacent areas, especially on relatively smooth stone surfaces. On rougher surfaces such small differences are more difficult to perceive. This has important implications for the cleaning of adjacent properties or terraces since it emphasises the care which must be taken when cleaning is carried out, if unsightly variations in lightness value are to be avoided on stonework whose appearance is intended to be homogeneous. Where facades are not adjacent, differences in lightness of a few percent are probably not noticeable.

6.3 Identification of test panels

If, following the preliminary assessment, the decision is taken to proceed further, locations need to be selected for test panels. These test panels (normally at least 1 m^2) should be on representative areas of each stone type, preferably on unobtrusive parts of the building. It may be necessary to test clean areas with different levels of soiling, surface texture, degree of decay or any other variations present on the facade. Carved or moulded work must be included and the tests may confirm that different methods are required for these elements.

Procedures for the monitoring of test panels using physical and chemical cleaning techniques differ in some respects and are dealt with separately. The procedures outlined below represent a comprehensive range of tests which would ideally be carried out. In certain situations some of these tests may be omitted.

6.4 Physical cleaning test procedures

The aim of test cleaning should be to establish the minimum grit or washing pressures necessary to achieve a satisfactory level of cleaning with minimal damage to the stone. The method or methods chosen should be based on the general level of soiling on the facade. More heavily soiled areas may require special treatment, but the whole facade should not be subjected to a treatment designed to remove exceptionally heavy soiling deposits where these only exist in a few locations.

All procedures should be recorded and photographed in detail.

6.4.1 Before test cleaning

Prior to test cleaning, assess the state of the stone and mortar (sampling and taking photographs where necessary) with particular reference to:

- existing decay
- soiling level
- colour
- roughness
- efflorescences
- biological growths
- permeability (unnecessary on good quality granite)

In especially sensitive situations it may be necessary to take stone samples for the following analyses:

- petrographic analysis (unnecessary on good quality granite)
- scanning electron microscope examination of surface (not always necessary)

Following this, proceed with test cleaning, recording the process in detail.

6.4.2 Immediately after test cleaning

Assess the state of the stone and mortar (sampling and taking photographs where necessary) with reference to:

- any loss, damage or alteration to the stone or mortar
- residual soiling
- colour changes (including bleaching or staining)
- roughness changes
- permeability (unnecessary on good quality granite)
- any visible residues of cleaning materials

Take stone samples where appropriate for the following analyses:

- petrographic analysis (unnecessary on good quality granite)
- scanning electron microscope examination of surface (not always necessary)

Any abrasive cleaning method used to clean a building facade should be carried out at the lowest effective pressure and using the least abrasive grit to achieve an acceptable level of soiling removal. The cleaning method chosen should be one capable of removing the general level of soiling prevalent over much of the facade rather than one which is capable of removing localised heavier soiling. Use of too aggressive a treatment on areas of stonework which are less heavily soiled risks causing unnecessary damage to the stone. Where some soiling remains after cleaning, careful re-treatment of the area may be necessary provided that no damage is caused to the stone surface. Alternatively a different cleaning method may be employed to remove the heavier soiling in affected areas.

6.5 Chemical cleaning test procedures

The aim of test cleaning should be to establish the minimum chemical concentrations and dwell times. The method or methods chosen should be based on the general level of soiling on the facade. More heavily soiled areas may require special treatment but the whole facade should not be subjected to a treatment designed to remove exceptionally heavy soiling deposits where these only exist in a few locations.

All procedures should be recorded and photographed in detail.

6.5.1 Before cleaning

Prior to test cleaning, assess the state of the stone and mortar (sampling and taking photographs where necessary) with particular reference to:

- existing decay
- soiling level
- colour
- roughness
- efflorescences
- biological growths
- permeability (unnecessary on good quality granite)

Undertake on-site trials or take stone samples for the following analyses:

- depth profiling for chemical residues (unnecessary on good quality granite)
- porosity (unnecessary on good quality granite)
- petrographic analysis (unnecessary on good quality granite)
- scanning electron microscope examination of surface (not always necessary)

Following this, proceed with test cleaning, recording the process in detail.

6.5.2 Immediately after test cleaning

Assess the state of the stone and mortar, sampling and taking photographs (Plate 29) where necessary, with reference to:

- any loss, damage or alteration to the stone or mortar
- residual soiling
- colour changes (including bleaching or staining)
- roughness changes
- efflorescences
- permeability (unnecessary on good quality granite)
- pH of surface (to test for neutralisation of cleaning chemicals)
- any visible residues of cleaning materials

Plate 29 Test panels to assess three chemical cleaning systems for Listed Building Consent (Rubislaw type granite).

Take stone samples for the following analyses:

- depth profiling for chemical residues (unnecessary on good quality granite)
- scanning electron microscope examination of surface (not always necessary)

6.5.3 At a later date after cleaning

In the case of buildings of significant historic value it may be considered necessary to leave test panels to weather for a period of time following cleaning (up to a year). The test panels may then be re-assessed for changes which have taken place since the previous examination. Record changes to:

- state of decay of stone and mortar
- soiling level
- colour
- surface roughness
- efflorescences
- biological soiling

On porous surfaces (but not on good quality granite) it may be necessary to take further stone samples adjacent to the original locations for depth profiling for chemical residues.

Wherever possible the chemicals used to clean a building facade should be at the lowest possible concentration and use the shortest possible dwell time to achieve an acceptable level of soiling removal. The cleaning method chosen should be one capable of removing the general level of soiling prevalent over much of the facade rather than one which is capable of removing localised heavier soiling. Use of too aggressive a treatment on areas of stonework which are less heavily soiled risks causing unnecessary damage to the stone. Where some soiling remains after cleaning, careful re-treatment of the area may be necessary. Alternatively a different cleaning method may be employed to remove the heavier soiling in affected areas.

6.6 Special features and finishes

Where the facade contains special features, these should be included within the testing framework since they may present a different cleaning problem from the rest of the masonry. Examples of special features are carved work, polished surfaces, interfaces with other materials, panels in other stone types, granite walls with sandstone arrises etc.

Tests on special features should be small-scale and performed in an unobtrusive position. In some instances, it may be necessary to adopt different test cleaning methods for specific features.

6.7 Reporting results of test cleaning

Evaluation of cleaning trials should begin with a visual examination of the test panels noting the extent to which biological and non-biological soiling has been removed. The extent and location of any residual soiling or efflorescences should be noted, taking into account its effect on the appearance of the facade. Any bleaching or staining, whether from the cleaning process itself or revealed following the removal of soiling, should be noted. An examination should also be made of any visible changes to the surface texture of the stone and mortar, including loss of weathered or decayed areas or loss of surface patina. Results from the various laboratory tests carried out on the stone need to be considered along with the visual and on-site data.

A comprehensive report (including photographic documentation where appropriate) covering the results of the examination and testing procedures should be prepared. Any changes that may have occurred in the period following cleaning should also be documented. This is especially important where chemical cleaning has been carried out as efflorescences may take some days or weeks to become visible.

The report should provide clear guidance on the most appropriate method or methods of stonecleaning. In particular, it should provide conclusions detailing the proposed intentions and prescriptive specification of the stonecleaning method or methods to be adopted. Evaluation should always be approached on a damage-limitation basis; if doubts persist, the option not to clean should be considered.

6.8 Analytical techniques

6.8.1 Colour measurement

Portable electronic colour meters are available which allow the reflected light colour from masonry to be quickly and accurately measured. Colour measurement may be used as part of the assessment of the degree of soiling removal from test panels and can also be used to detect bleaching or staining as a result of chemical cleaning.

6.8.2 Depth profiling

Depth profiling allows the presence of soluble salts in stone or mortar to be measured. It is used to establish whether chemical cleaning has left any residues in the stonework. The stonework is either cored or drilled to a series of depths and any soluble material is extracted and analysed. On good quality granite, depth profiling should not be necessary as the low porosity of the stone means that there is very little chemical retention. Chemical retention may occur in more weathered granites and in mortar joints.

6.8.3 Efflorescences

Efflorescences (surface salt deposits) present before or after cleaning may be damaging to the stone and should be analysed. The simplest method for the identification of salts is by X-ray diffraction (XRD).

6.8.4 Roughness

Unless samples of stone with the surface intact or suitable imprints can be taken for analysis, it is generally only possible to make an assessment of roughness by visual observation *in situ*.

6.8.5 Petrological analysis

Petrological analysis involves the preparation of thin sections of stone on glass microscope slides. It is most useful to take sections perpendicular to the surface of the stone so that data may be obtained regarding the thickness or penetration of the soiling or weathering layer. On good quality granites where soiling and weathering effects are confined to the outer surface of the stone the analysis of thin sections should not be necessary.

6.8.6 pH

Testing of stone pH is conducted after chemical cleaning to ensure that neutralisation of cleaning agents has taken place. This is done by applying litmus paper to the stone surface while it is still wet. This will only give an indication of pH at the stone surface. Care with interpretation is required as the water used to rinse down the facade may not be neutral in terms of pH. More complex procedures would be required to test pH levels within the stone itself.

6.8.7 Scanning electron microscopy (SEM)

The scanning electron microscope enables examination (and often chemical characterisation) of an object at a very small scale. Areas as small as a few thousandths of a millimetre across can be examined and photographed. SEM can be used to look for microscopic changes to the stone surface (e.g. etching or damage to minerals). A small sample is required for this laboratory-based analysis.

6.8.8 Porosity

Porosity (the amount of empty space in a rock) can affect a stone's moisture retention and its ability to absorb applied chemicals. Porosity can be measured by mercury porosimetry. Testing of stone porosity is expensive and in practice is generally omitted. Most good quality granites will have very low porosities (1-2%).

6.8.9 Permeability

Permeability affects the ability of a stone to absorb applied chemicals and also its ability to retain moisture. Permeability can be measured using a simple device in the form of a graduated tube with an open sided, bulbous base. This is attached to the stone face and water is added through the upper, open end of the pipe until the column reaches the zero graduation mark. The rate of water absorption by the stone can be determined by noting the time taken for the water meniscus to pass each graduation mark. Most good quality granites will have extremely low permeabilities which are not measurable by this technique.

6.9 Appointment of cleaning contractor for test cleaning

A programme for test cleaning should be established before the award of the main cleaning contract. The purpose of test cleaning is to establish the most appropriate specification and cleaning method/s for the granite facade. It is therefore important that an experienced specialist stonecleaning contractor be appointed.

7. CLEANING SPECIFICATION

7.1 Sources of information

Specifications for stone cleaning should be based on evaluation of the test panels. It is important that the specification gives clear and precise instructions on the nature and scope of the work to be undertaken because, traditionally, such specifications have tended to be unsatisfactory in content and may thus militate against the knowledgeable and competent contractor, with the work being awarded to the lowest tenderer who may lack the necessary experience.

Recognition should be made of the historical significance of the property to be cleaned and the demands of the specification need to be set at a level that gives appropriate attention to vulnerable areas of stone and the condition of the stone surface. However, it may be inappropriate to demand the same level and detail of specification for a facade that has no real historical or architectural merit.

Inspection of the facade should be carried out (as specified in Section 4) by a competent practitioner experienced in the inspection of facades for cleaning purposes. A masonry contractor's report alone is not adequate for a full assessment of the facade.

The specification should stipulate whether test panels will be used to assist in the selection of the most appropriate cleaning method. Where there is clear evidence of satisfactory cleaning on an adjacent property where panel tests have been conducted and where the stone is of the same type and surface finish, then it may be appropriate to dispense with the need for test panels and the same specification may be adopted.

Where test panels are required, the number of test panels should be stated along with specifications of the cleaning methods to be used. Unless otherwise specified, test cleaning should be carried out using manufacturers' recommended strengths, dilutions and dwell times for chemicals and approved equipment, media and pressures for physical cleaning systems.

The specification should stipulate whether analytical tests on stone and mortar are required before and after cleaning. If this is the case, the tests should be carried out by an approved laboratory.

Records of test cleaning should be kept by the supervising agent, together with any on-site adjustments necessary to achieve the desired level of cleaning.

7.2 General recommendations

The current British Standard BS 6270, Part 1, 1982 (with amendments) 'British Standard Code of Practice for Cleaning and Surface Repair of Buildings, Part 1, Natural Stone, Carved Stone and Clay and Calcium Silicate Brick Masonry', is widely recognised as being out of date. A revised BS 6270 is currently in preparation, but no date is available for its publication. A specifier should not, therefore, base a specification on the 1982 edition of the BS. A specification for stone cleaning which consists only of a statement that 'stonecleaning should be carried out in accordance with BS 6270' should not be accepted as an appropriate specification for any stone cleaning work.

7.3 Content of specification

The content of a specification needs to include a number of key items. The following list identifies the main headings and a more detailed list may be obtained from the book Cleaning Historic Buildings (vol. 1, pp. 40-43) by Nichola Ashurst, Donhead, 1994.

- Scope of the work
- Standards to be achieved and panel tests to be carried out by the contractor
- Materials and equipment
- Compliance with statutory requirements
- Notification to local authority
- Access and scaffolds
- Protection of work, property and persons
- Experience and qualifications of contractors, operatives and supervisors
- Weather conditions for cleaning
- Environmental protection
- Cleaning procedures to be used
- Notification of stages of work to permit inspection by Supervising Officer or Architect
- Procedures on completion, wash down, final inspection of stone and surrounding site.

8. CONDUCT AND SUPERVISION OF STONECLEANING WORK

8.1 Selection of contractor

The selection of an appropriately experienced contractorlactor is vital to the success of a cleaning contract. It is the knowledge, skill and care of the contractor, his supervisors on site and the operatives undertaking the cleaning operation that determine the outcome of cleaning. There are many examples where the responsibility for specification and method of work has been left entirely up to the contractor, leaving the architect or agent little choice but to accept the often disastrous results. The following guidance points provide recommendations to ensure that the contractor selected can bring the necessary expertise to bear. The selection of a stonecleaning contractor is further complicated by the fact that this work is often undertaken by small firms.

- It is important that the client, professional advisers, planning officers, historic building inspectors and Local Enterprise Company officers are fully conversant with the risks involved in this work and are aware of the need to ensure that sufficient funds are available to support all the necessary works, from test panels through to the main cleaning operation. All parties and prospective contractors should also be aware that the award of the stonecleaning contract will be based not just on price but on the technical competence of the contractor.
- It is recommended that the contractor should be a member of the Stone Federation (82 New Cavendish Street, London W1M 8AD). The current situation is that such membership will not necessarily ensure that the contractor is capable of dealing with all the technical complexities of many stonecleaning operations, but it will mean that as a member of the trade organisation he would have a proper commitment to the success of the operation.
- A selected contractor should be able to demonstrate a past history of successfully completed contracts on similar stone types and involving similar architectural features. It should be appreciated that stone type, condition and architectural detail can have a major influence on the conduct of the work. Independent evidence should be sought to substantiate the success of past cleaning contracts.
- The contractor should be experienced in the use of the specified cleaning techniques and should be prepared to demonstrate his abilities using appropriate trial panels. The contractor should be required to demonstrate that he is capable of meeting the specification requirements in full. The contractor may suggest changes to the specification based on his past experience. However, any changes to the specification should be avoided and made only when the original specification is shown to be impractical in a given situation and where there will be no lowering of performance standards, and only after reference to the stonecleaning consultant (cf. Section 8.3 below).
- It is not sufficient that the contractor has prior experience on similar projects using the specified techniques. The operatives and supervisor who will be employed on the project must also have relevant experience, training and skills and the contractor must be prepared to provide documentary evidence in support of the key site personnel. It is also recommended that a suitably experienced site supervisor be named in the contract documents.
- When the contractor has been selected and before stonecleaning work on the facade commences, trial panels should be prepared using the specified techniques and by the personnel who will be employed on the cleaning project. Areas suitable for use as trial panels should be selected by the supervising agent, after consultation with the stonecleaning consultant (cf. below, 8.3) where appropriate, and the results of the trials approved by a competent person.

  Note: the trial panels in this context should not be confused with the test panels which are used to determine the stonecleaning specification. The trial panels are to ensure the competence of the operatives in the use of the specified technique/s

- It is recommended that in the case of the selected contractor being unable to achieve a suitable standard of workmanship on trial panels, there should be a clause in the contract documentation which permits the termination of the contract, without cost to the client.
- In the absence of a national register of approved stonecleaning contractors, all prospective contractors should be interviewed by the supervising agent to determine the experience, knowledge and skills available to the contractor in the conduct of the work.
- In addition to the above technical requirements, the contractor should provide the following information:

  i. Details of how the work will be supervised, e.g. will there be a full-time supervisor on site? A method statement should be prepared and submitted for approval.

  ii. Confirmation that adequate public and employer's liability insurance is in place.

  iii. Details of how compliance with health and safety regulations will be achieved.

8.2 Training of operatives

No operative should be permitted to undertake cleaning of stone without having received appropriate training.

Until 1993, no national qualification was available for stonecleaning operatives, therefore such operatives were, at best, only likely to have received on-the-job training, either through a training programme devised by the employer or simply through experience picked up in carrying out the work with or without supervision. The knowledge and skills base of operatives is thus likely to be extremely variable.

Since 1993 a qualification in Facade Cleaning has been available as either a Scottish Vocational Qualification (SVQ), offered through SQA, or in England as a National Vocational Qualification (NVQ); both of these at Level 2.

A contractor selected for a facade cleaning contract post-1993 should therefore be required to employ only operatives with the above qualifications for this work. Alternatively, operatives with proven skills and knowledge in stonecleaning who have not been able to undertake the course of study leading to the qualification may be employed, based on evidence of past successful work on similar stone types.

8.3 On-site supervision

In the case of listed buildings or other granite facades of significance to the architectural heritage, it is recommended that a supervising agent be appointed to oversee the stonecleaning operation on site. Where stone cleaning is part of a building refurbishment programme, the supervising agent may be the project architect or building surveyor where the agent has relevant experience of stone cleaning work. Should the project architect / surveyor lack the necessary experience to supervise the stonecleaning operation, or stonecleaning is to be carried out in isolation, it is recommended that for important and/or vulnerable facades an independent stonecleaning consultant be appointed to undertake the supervision of the cleaning operation.

In the case of facades of limited architectural merit, the expense involved in the appointment of a specialist supervising agent is unlikely to be justified. It is also likely that the services of a professional agent will not be available when stonecleaning is to be carried out as an isolated activity. Under such circumstances the client should be aware of the potential risks to the facade, the stonecleaning operatives and the general public and seek the advice of an experienced stonecleaning contractor, who is a member of the Stone Federation, before initiating the work. The contractor in this case will be responsible for the supervision and conduct of the work.

Where cleaning of test panels is a necessary prerequisite to determining the stonecleaning specification this should be done under the direction of the supervising agent.

In addition, clients, supervisors and contractors need to be aware of their responsibilities under the relevant health and safety regulations and, in particular, the duties and responsibilities imposed by the Construction (Design and Management) Regulations 1994 with regard to the appointment of a project supervisor.

In supervising the work, it is important to recognise that the potential for damage to the masonry can be due to activities other than the cleaning process. In particular, there are many examples where careless erection and dismantling of access scaffolds had caused damage to stone. Supervisors should therefore ensure that contractors and scaffolding sub-contractors are made fully aware of the risks to the stone. Scaffold tubes should not rest in, or come in direct contact with, vulnerable stonework and care must be exercised in raising or lowering of scaffold members to avoid damaging the surface of the building. All pole ends must be capped.

8.4 Assessment of masonry joints

The state of the joints over the whole facade should be assessed before any chemical cleaning takes place as open joints can allow penetration of chemicals into the stonework. Joints should not be raked out prior to chemical cleaning unless they are to be repaired prior to cleaning. If possible, joints should be left in place until the chemical cleaning has been completed and any repairs or replacement done after cleaning. This will avoid any problems with retention of chemicals in the joints themselves. Any repointing must be to the architect's specification

8.5 Dealing with special features

Special features of a building may require particular attention and care, and possibly different treatment from the rest of the facade. Where a building contains such features, this must be recognised and work conducted accordingly. In such a case, it is likely that a higher level of supervision and control on site will be required.

- Carved stonework is vulnerable to erosion of fine detail if abrasive cleaning methods are used. Care should be taken when applying poultices since these may be difficult to remove from more intricate carvings. Refer to Section 5 for more detail.
- Polished surfaces will be damaged by the application of acid cleaners or abrasive cleaning methods and will have to be protected from the cleaning process.
- Strong alkalis will attack metals, therefore all areas of vulnerable metalwork (e.g. window frames) should be covered and sealed before cleaning commences.
- Places in which the granite interfaces with other materials (e.g. mortar, limestone, sandstone) have to be treated with caution.
- Panels composed of stone types other than granite are likely to require a different cleaning regime.
- Seriously eroded and friable granite surfaces can disintegrate if subjected to high-pressure water washing or abrasive cleaning methods. Such surfaces should not be cleaned.

8.6 Maintenance of records

The vast majority of stonecleaning work carried out to date has been conducted without the preparation and maintenance of appropriate records. The lack of a proper record of stonecleaning intervention means that a critical evaluation of the condition of the stone, mortar and joints at a later date may lead to inappropriate decisions being made on future action. It must be recognised that many facades have now entered a cycle of cleaning and re-cleaning which makes the need for records increasingly essential.

It is recommended that the supervising agent or, in the absence of such a person, the stonecleaning contractor, keeps a detailed record (including photographs and laboratory reports) of all relevant factors as identified in previous sections. This record should be passed to the client on completion of the work and a copy retained by the supervising agent or contractor. In the case of a listed building subject to planning permission, a copy of the record should be lodged with the local planning authority.

9. HEALTH AND SAFETY ISSUES

9.1 Contractual arrangements and legislation

Contractual arrangements will have an important bearing on how statutory health and safety responsibilities are managed and discharged. They should define how the parties involved should fulfil their requirements, and fill out the particulars of the general statutory arrangements for provision of accommodation, welfare facilities, first aid, fire prevention, protective clothing, reporting and recording of accidents, etc.

Proper planning for health and safety should be an integral part of the overall preparation for the efficient running of the project.

It is important that consideration for such work should only involve contractors who are able to demonstrate their competence in management of health and safety matters.

The Construction (Design and Management) Regulations (1994) are now in force and need to be recognised. These Regulations will affect some cleaning projects and impose new duties upon clients, designers and contractors which require them to re-think their traditional roles in construction work.

The aims of the Regulations are to improve the overall management and co-ordination of health, safety and welfare throughout the project. They do this by assuming the existence of a client and a planning supervisor for each project. They then require the planning supervisor to co-ordinate and manage health and safety during the design and early stages of preparation and to prepare a pre-tender safety plan. The principal contractor is required to develop a health and safety plan prior to the project commencing. Everyone involved in the construction process is required to take into account the general principles of prevention and protection which are set out in the Regulations. On completion of the project, the Regulations require the preparation of a health and safety file about the project itself, which is to be passed to the client.

Whichever cleaning method is specified, all parties involved in the project, whether as owners, clients, professional advisers, principal contractor, contractors and operatives, have certain responsibilities and duties placed on them by the Health and Safety at Work Act 1974, and other relevant legislation.

Under the Act employers have a general duty to ensure, so far as is reasonably practicable, the health, safety and welfare at work of their employees and, where appropriate, the general public. This duty includes the provision of safe plant and equipment, a safe work place, and all necessary information, instruction, training and supervision. In addition, employers should consult safety representatives appointed by recognised trade unions.

When employing five or more employees the employer is also required to prepare and issue a statement of safety policy, outlining the arrangements they are making to satisfy these duties, including how they intend to ensure that the necessary safeguards are adopted. The contractor should be asked by those managing the project to provide a copy of their safety policy, with evidence of ability to put it into practice.

In addition to those directly employed the employer must ensure, so far as is reasonably practicable, that persons not in his employment are safe and without risk to health, and to provide such information as is necessary to avoid risks. In stonecleaning projects such persons would include occupiers of the premises, visitors to sites and premises and any member of the public who might be affected by the work activities.

Employees have a duty under the Act to take reasonable care of their own safety and the safety of others who may be affected by their actions. They should co-operate with their employer so far as it is necessary to enable their employer to comply with the Act. Every self-employed person is required to conduct their undertaking so as to ensure that they and other people who might be affected are not exposed to risks to their health and safety.

Duties are also imposed on those who have to any extent control over non-domestic premises which are used by people (not their employees) as a place of work or as a place where they may use machinery, equipment, etc., or substances which have been provided for their use. The person having any control over the premises, the means of access, or of any plant or substance in the premises, has a duty to ensure that so far as reasonably practicable, they are safe and without risks to health.

Any person who has, through a contract or tenancy, an obligation of any extent in relation to maintenance or repair of the premises or the means of access, or for guarding against hazards from the plant or substances there, will be regarded as the person who has control of the premises, and who has the above duty to the extent of their obligations.

Manufacturers, which means any person or company who designs, makes or supplies (including hiring) anything for use at work, are required to ensure that the product is safe and without risk to health when properly used. This requires paying attention to design and arranging for any necessary testing. Importantly, it also means that users are entitled to necessary information concerning the proper use and other conditions required to ensure safety and absence of risk to health in connection with the use of the product at work.

The requirements of the Act and related legislation are in their respective spheres enforced by the Health & Safety Executive, certain local authorities and other agents acting on behalf of HSE. The methods of enforcement available to the authorities include prohibition and improvement notices and prosecution. As enforcing authorities they provide advice and information, as well as taking enforcement action when necessary.

9.2 Hazard information

Central to the Management of Health and Safety at Work Regulations 1992 is the requirement on employers and the self-employed to make and maintain a sufficient and suitable risk assessment to identify the means of complying with health and safety law. The decisions reached will reflect the various roles of those contributing to the development or execution of a construction project. The requirements of the CDM regulations expand the more general requirements of the Management of Health and Safety at Work Regulations to give them practical effect for construction work.

The Control of Substances Hazardous to Health Regulations 1988 (COSHH) define in general and specific terms how employers are expected to safely manage the use of potentially harmful substances.

For workers who expect to handle a variety of toxic substances there are a number of guidelines laid out in the Health and Safety Executive COSHH publication of Approved Codes of Practice. The COSHH Regulations apply to substances that have already been classified as very toxic, toxic, harmful, corrosive or irritant under the Chemicals (Hazard Information and Packaging) Regulations 1996 (CHIP) and substances which have maximum exposure limits (MELs) or occupational exposure standards (OES) (e.g. carcinogens, mutagens or teratogens).

The Regulations require employers to make an assessment of all work which is liable to expose any employee and other persons to a substance hazardous to health. Most chemical and physical cleaning methods on masonry surfaces require to be assessed as they involve the use of hazardous solids, liquids, dusts, fumes or vapours depending on the method selected.

Managing hazardous substances and complying with the requirements of the COSHH Regulations requires:

1. Identification of the hazardous substance involved.
2. Assessment of the risk to health arising from the work and identification of precautions necessary.
3. The introduction of appropriate measures to prevent or control the risk.
4. Checks to ensure that control measures are used and that equipment is properly maintained and procedures observed.
5. Where necessary, exposure to be monitored to ensure that methods and control measures work.
6. Employees to be informed, instructed and trained about the risks and precautions to be taken.

Assessment means evaluating the risks to health and then deciding on a course of action needed to remove or reduce the risks with the details recorded in writing. The responsibility for assessment should be allocated to a competent person who is adequately trained with access to appropriate levels of advice and professional support as required.

Guidance Note EH40 from the Health & Safety Executive lists the occupational exposure limits which should be used in determining the adequacy of control of exposure by inhalation, as required by the COSHH Regulations.

Persons managing the site / contract have a responsibility to ensure that contractors and others have adequate information to safely plan their work. There is also a responsibility to ensure that they have carried out their COSHH assessments, that they are adequate, and have in place a management system for checking on the suitability of the assessments for the work being carried out and to ensure that precautions and controls are being implemented.

The use of masonry biocides is also covered by the above Regulations with approval for use made under the Control of Pesticides Regulations. An Approved Code of Practice has been prepared on 'The safe use of pesticides for non-agricultural purposes' which provides practical guidance on the COSHH Regulations as they apply to pesticides in such situations.

9.3 Precautionary measures

9.3.1 Preventing exposure to chemical cleaners

It is recommended to choose the most dilute solution which is effective. Where possible, proprietary brands of cleaner which are diluted by the manufacturer/supplier should be used to avoid handling concentrated chemicals.

9.3.2 Controlling exposure to chemical cleaners

If concentrated cleaners have to be handled and diluted, this should take place in a well-ventilated area off-site and concentrated cleaners transferred in sealed containers. When diluting concentrated acids, cleaner should always be added to water, never water to cleaner. The dilute material should be transferred to site in properly sealed and labelled containers.

Spray application should be avoided, i.e. the cleaner should be applied with a brush or roller with a splash guard.

9.3.3 Personal protection

It is essential that operatives using chemical cleaners wear protective clothing to protect skin, face, eyes etc. from the corrosive material. This includes eye protection, gauntlet gloves, protective, chemical proof and waterproof boots, protective overalls, and in some cases a protective apron and approved respiratory protective equipment may be necessary. Plates 25 - 28 show examples of suitably protected operatives, excepting that face masks should be used in all works involving hazardous substances.

It is recommended to check with the manufacturer or supplier of protective equipment that it is suitable for the particular corrosive material being used and for the particular working conditions of the job in hand.

It is important always to ensure that protective equipment is thoroughly cleaned with water after use, checked for any deterioration and renewed where defective.

9.3.4 Protecting the public

Members of the public and workers who are not directly involved in cleaning must be protected against exposure to the cleaner. For the steps to be taken, refer to HSC Construction Sheet No 24 *Chemical Cleaners*.

9.3.5 Protecting the environment

Great care should be exercised to avoid contact of chemical cleaners with the wider environment. Most cleaners are toxic to plants, although larger plants may be resistant. It is important to ensure that excess run-off from application of a cleaner does not come in contact with other plant life.

Chemical cleaners or cleaner run-off fluids should not be discharged to rivers, ponds, surface waterways or drains or sewers. It is possible that some dilute solutions may be discharged into the local sewerage system in accordance with Water Authority Regulations, after consultation with the Water Authority.

9.3.6 Disposal of grits

The residue from grit blasting should be collected and placed in appropriate containers for removal from the site to a disposal point agreed with the local authority.

9.3.7 Emergencies

Dilute all spillages with water unless concentrated acids are involved, which have to be neutralised with slaked lime. Tools and equipment which may be contaminated should be treated similarly.

Anyone appearing to be affected by the chemical should be taken at once into the fresh air to be given first aid and referred to medical care. In most cases, first aid will involve drenching the affected parts with plenty of cool, clean water.

9.3.8 Noise abatement

Noise from construction sites is subject to The Control of Pollution Act (1974) (COPA) and the Noise at Work Regulations for Employees. The COPA is enforced by the Local Authority who may serve a notice on the contractor specifying the manner in which the work is to be carried out. The purpose of the notice is to provide protection against noise for other people who live or work in the area. The notice may impose constraints on the machinery used, limit work hours or specify acceptable levels of noise. Application for prior consent can be made to the Local Authority with proposals to minimise noise on site. Consent, when given, will greatly reduce the likelihood of such problems, but not altogether eliminate the risk.

The Noise at Work Regulations require employers to assess the risks whenever they reach the 'Action Levels' defined in the Regulations, and implement appropriate control measures.

9.3.9 Electricity

The Electricity at Work Regulations 1989 apply to construction sites and place duties on contractors, employees and the self-employed in so far as they relate to matters which are within their control.

They require the electrical system to be sound, properly installed and maintained (the installation standards set out in the IEE Regulations for Electrical Installations are considered acceptable in this respect). The IEE Regulations set down all the requirements to follow regarding protective devices, cable sizes, etc. These form the basis for any electrical system and do not vary whether the installation is permanent or temporary. They also refer to British Standards, and BS7375 Code of Practice for 'Distribution of Electricity on construction and building sites' provides further guidance on the type of electrical apparatus and wiring for site installations.

All persons carrying out electrical work must be competent to do so and expert advice should be sought in order to establish satisfactory arrangements for inspection and maintenance.

9.4 Work at heights

Most cleaning projects will involve work at heights with access provided by scaffolding or mobile work platforms. Having selected the system to be used, the design stage will be influenced by the site location, public access, method selected for cleaning, containment sheeting, lifting operations, loading of the scaffold and site security. In certain chemical applications the ends of scaffold poles must be plugged to prevent ingress of chemicals.

The construction of all scaffolds must be carried out within the requirements of the Construction (Health, Safety and Welfare) Regulations 1966 and any local authority requirements. All scaffolds including mobile towers require to be of sound construction and erected, maintained, and inspected by a competent person. Where scaffolds are provided by the main contractor for common use, the onus is on the user to ensure that it is fit for its intended use by their employees. Scaffolds should be inspected weekly to see that they remain in a safe condition and in compliance with the regulations, with details of inspections recorded in a scaffold register.

Scaffolding must be erected on a safe foundation (sole and base plates) and it should be perpendicular without the uprights leaning away from the building. It must be suitably braced and tied and all components properly spaced. The working platforms must be fully boarded out (600mm width minimum) and must always include toeboards, intermediate rails and guardrails, with brickguards and containment sheeting fitted where necessary. The access ladders must project 1 m above the landing platform, should be angled 4:1 to the vertical and should be secure tied.

In certain circumstances, the need for mobile scaffolds may arise. They must be of sound construction, never be less than 1200 mm minimum base dimension, and the height limitations are $3^1/_2$ times the shorter base dimension for internal work and 3 times the same dimension for external work (these dimensions are inclusive of outriggers). Mobile scaffolds should, where possible, be tied into the building. The working platform must be fully boarded and equipped with toeboards, guardrails and an internal secured ladder. The wheels should be no less than 125 mm in diameter; they must be secured to the standards and fitted with brakes. Mobile scaffolds should only be used on level, firm ground and must never be moved until all persons have moved to ground level.

Mobile work platforms are sometimes used to provide temporary working places for minor cleaning work, giving access to localised areas above and below ground level. They provide an alternative to scaffolding and must be used in accordance with the manufacturer's and other guidance. The use of cradles is not recommended for stonecleaning work.

10. STATUTORY CONSENTS

In Scotland, under the terms of the Town and Country Planning (General Permitted Development) (Scotland) Order 1992, there is a requirement, in some cases, to obtain either listed building consent or planning permission for stonecleaning. The Order states that stonecleaning is not a permitted development where the building is listed or within a conservation area. Therefore all proposals to stoneclean listed buildings require listed building consent or, in the case of unlisted buildings within a conservation area, planning permission.

An applicant should always be advised that cleaning may reveal plastic repairs, indents and pointing, the colour of which was specifically selected to match that of the soiled stonework. Where a cleaning proposal is acceptable in principle it is important that, before consent is given, the applicant should confirm that such work, if found, will be removed and replaced with correctly coursed and pointed indents in carefully matched natural stone and without further damage to adjacent masonry.

Proposals to clean should be based upon and supported by analysis of the geological make-up and present condition of the surface of the stone and of the effect that various cleaning processes may have on these. The onus should be firmly upon the applicant to satisfy the planning authority that it is in the best interests of the building to clean and that the methods and materials to be used will prolong, and not reduce, its life. Where there is any doubt about the basis of a cleaning proposal consent should not be given.

There will be cases where stonework should under no circumstances be subject to possible damage. Planning authorities are advised to have a policy which clearly states where cleaning shall and shall not be viewed favourably. The policy should also make clear that one cleaning method may not be acceptable for use over a whole building, and that parts of the structure may require special treatment.

It is important that planning authorities, when considering applications to clean stone or any other masonry material in respect of listed buildings and those within conservation areas, give consideration to the Memorandum of Guidance on Listed Buildings and Conservation Areas 1993, published by Historic Scotland. Planning Authorities are required to notify Historic Scotland of applications for proposals to stoneclean buildings listed at Categories A and B, as this is considered to be an alteration which would affect the character of the building.

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