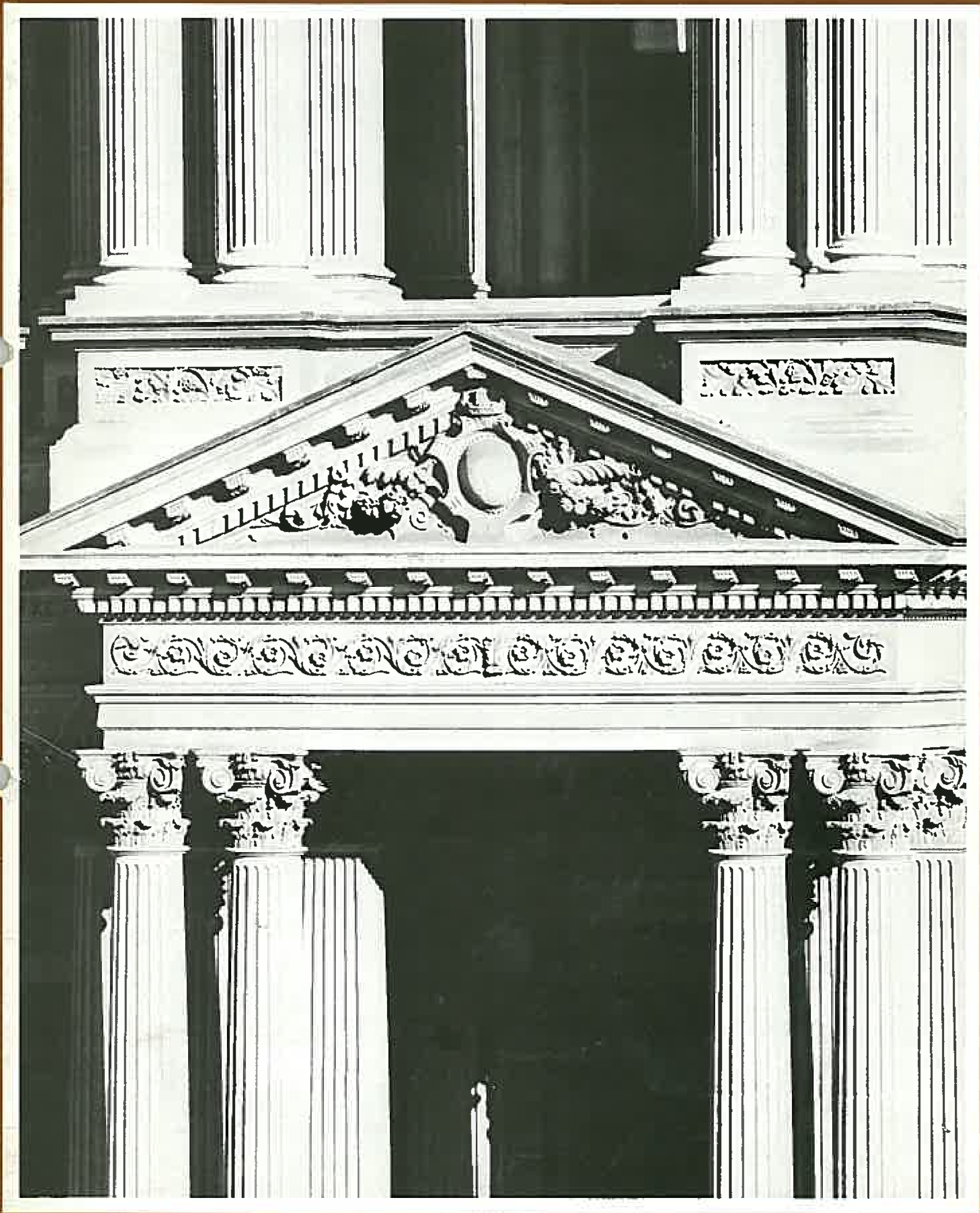
PRINCIPLES OF CLEANING MASONRY BUILDINGS



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COVER
Detail of the Edmund Wright house, Adelaide.

PRINCIPLES OF CLEANING MASONRY BUILDINGS

A Guide to Assist in the Cleaning of Masonry Buildings

Compiled by Dr Alan H Spry, Senior Consultant,
The Australian Mineral Development Laboratories,
for the National Trust of Australia (Victoria)
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the Australian Council of National Trusts.

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FOREWORD

This publication was produced by the Victorian National Trust in 1982 and is the third in a series of Technical Bulletins. It is published under the aegis of the Australian Council of National Trusts and is designed to complement the Conservation Bulletins series. Subjects published and planned to be covered are set out in Appendix B.

The Council records its thanks to Dr Alan Spry, The Australian Mineral Development Laboratories and to the Steering Committee for the production of this Bulletin.

V. H. Parkinson
Chairman
Australian Council of National Trusts

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PRINCIPLES OF CLEANING MASONRY BUILDINGS

by **A. H. Spry***

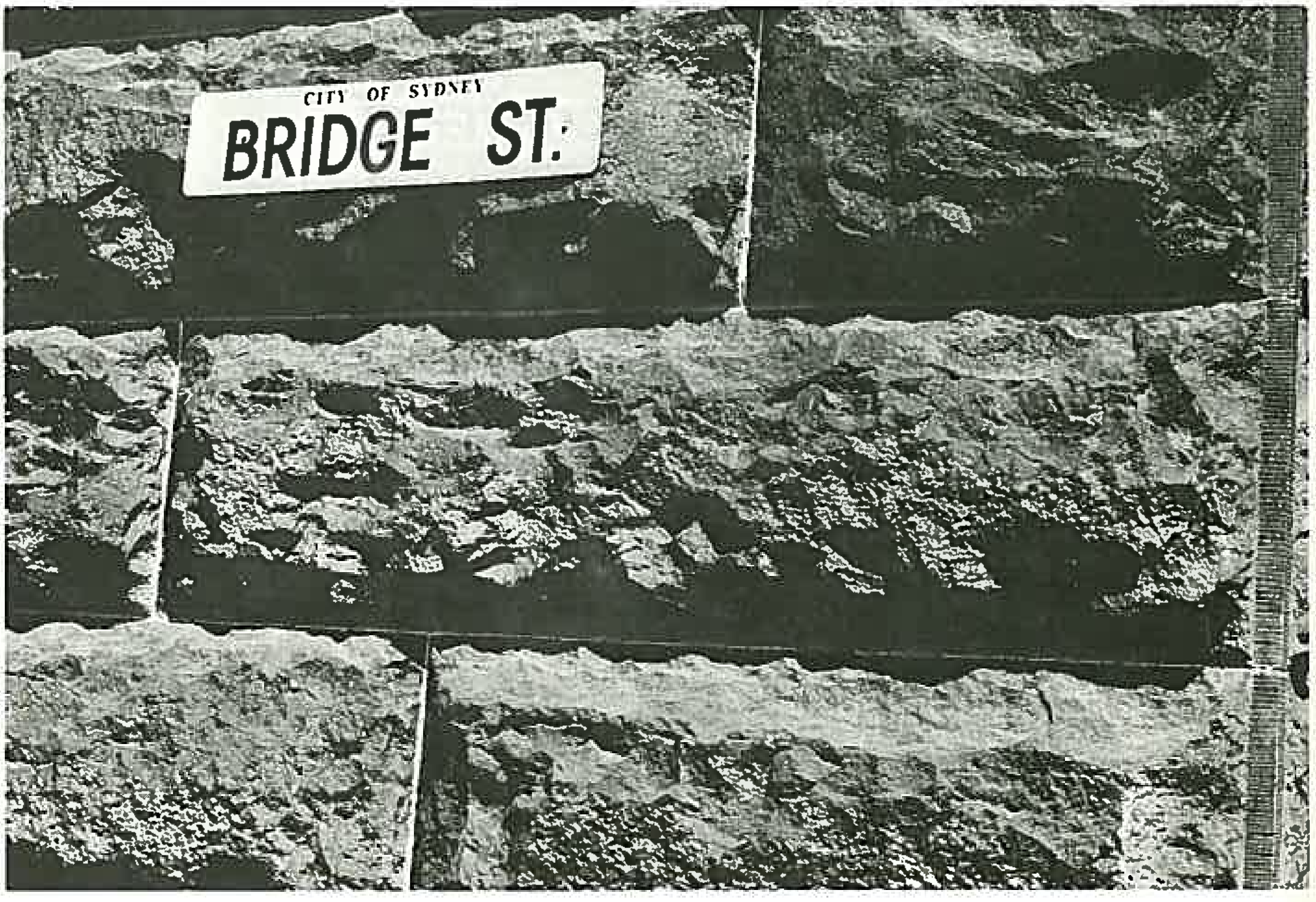

Plate 1: Urban grime in central Sydney. Nearly-white Sydney sandstone is dark grey due to a heavy intractable coat of soot, dirt, hydrocarbons, etc.

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1 INTRODUCTION

Cleaning the fabric of a building (or monument or statue) is generally regarded as an important part of maintenance and of restoration. However, it must be stressed that not only may cleaning be expensive, but it may change the character of the building (by destroying an attractive patina), damage the external fabric and internal decoration, and be of temporary effect only. Cleaning should not be undertaken without strong justification and if soiling cannot be removed without damage to the fabric then it should not be removed at all. In general, strongly abrasive methods such as dry and wet sand blasting and mechanical abrasion cause too much damage to be used for cleaning valuable historic buildings. Alternative, less aggressive methods are preferable.

Techniques to remove any form of soiling from any kind of masonry are available, thus if it is decided to proceed with cleaning then the following must be considered in order to determine the most appropriate method:

(a) the nature of the soiling;
(b) the nature and condition of the fabric;
(c) the finish to be achieved;
(d) the damage likely to be inflicted by the methods available.

Any old building, even one of modest size, contains a number of different materials which will exhibit differing degrees of soiling. Therefore a number of different cleaning methods may be required.

Plate 2: Architectural detailing controls the distribution of soiling. The sandstone parapet is typically stained and the soffit of the cornice with its open joints is decayed and encrusted with a black gypsum-bearing deposit.

2 REASONS FOR CLEANING BUILDINGS AND MONUMENTS

The four reasons normally given for cleaning buildings relate to restoration, surface preparation, appearance and maintenance.[16]

2.1 Restoration

Cleaning may form part of a restoration programme including replacement of decayed materials, repointing, repair, etc. It may be necessary to carry out preliminary cleaning in order to determine the condition of the building, to identify the constituent materials, to allow matching of replacement or patching with original material, to expose architectural details or to identify the best cleaning methods. However, the two processes (cleaning and restoration) should be regarded as largely independent and in fact possibly competitive.

There are examples where an authority has apparently considered that the two are synonymous and has spent a great deal of money on cleaning but has left the building to decay further with open joints, leaking gutters and downpipes, a faulty damp-proof course, inadequate drainage, and decaying stone and mortar. If there is a choice, it is better to make the building sound and leave it dirty rather than make it look attractive temporarily but in an unsound condition.

2.2 Preparation for Surface Treatment

Masonry which is to be sealed, water-proofed, consolidated or painted must first be cleaned for both practical and aesthetic reasons. A greasy, tarry or reactive surface or one covered with loose particles is unsuitable for painting and will retard penetration by a sealant or consolidant so that there may be lifting of the applied material or exfoliation of the surface. Decayed or cracked render or stucco should be cleaned up before patching.

Plate 3: Cleaning may produce a marked improvement in the appearance of a building as the contrast between the cleaned and uncleaned sandstone of the Melbourne Supreme Court shows. However, harsh cleaning may have only a temporary effect in polluted urban atmospheres.

2.3 Appearance

Cleaning is usually undertaken to improve the appearance of the masonry or structure as dark-coloured, grimy, sooty, streaky and encrusted walls are unsightly (Plates 1, 2 and 3) and general soiling may give a building a dull, uniform appearance. However, the degree by which it should be cleaned is a matter of taste and judgement. Correct restoration does not involve cleaning off all signs of age reproducing the original new appearance but accepts that age causes mellowing and produces a pleasing patina which is compatible with the age of the building. Any improvement in appearance must be balanced against possible damage and cost.

Cleaning may reveal original and essential architectural details but it can also be the most aggressive treatment received by the building in its lifetime.

The removal of graffiti is regarded as more than simple cosmetic cleaning.

2.4 Maintenance

Maintenance (the retention of the qualities of the fabric) may include regular cleaning. The belief is held by many authorities[53] that regular cleaning of masonry is beneficial for the following reasons: dirt may contain deleterious deposits which would attack the surface (salts or chemical compounds occur in soot or bird droppings, and tarry compounds give rise to salts); dirt provides a surface condition which may promote chemical reactions involving atmospheric gases; dirty areas remain wet after rain for longer periods than do clean surfaces, so that chemical reaction, freeze-thaw and growth of micro-organisms are promoted; and dust may act as a catalyst for converting atmospheric pollutants to sulphuric and nitric acids which attack the stone. Frequent washing (or rain) reduces the build-up of calcium sulphate (gypsum) in the pores of limestone and sandstone and thus reduces the formation of excessive surface skin ('case-hardening') and later exfoliation.

It should be borne in mind, however, that this concept has been largely developed in Britain[40] where there is a combination of polluted industrial atmospheres and the use of limestone for building. It does not appear that this approach is justified in Australia, particularly in those examples where the atmosphere is not strongly polluted, the climate is benign and the stone is not porous or reactive. There is no general rule, and any decision on regular cleaning must depend on the prevailing conditions (type and soundness of stone, locality, nature of the building or monument, presence of pollution, etc.) (see Plate 4).

Attention is drawn to the views of Warnes,[72] McLachlan[46] and others who consider that most

3 SOILING

'grime' on buildings contains micro-organisms which attack the stone, hence that cleaning should be regarded as part of preservation (see Plate 5).

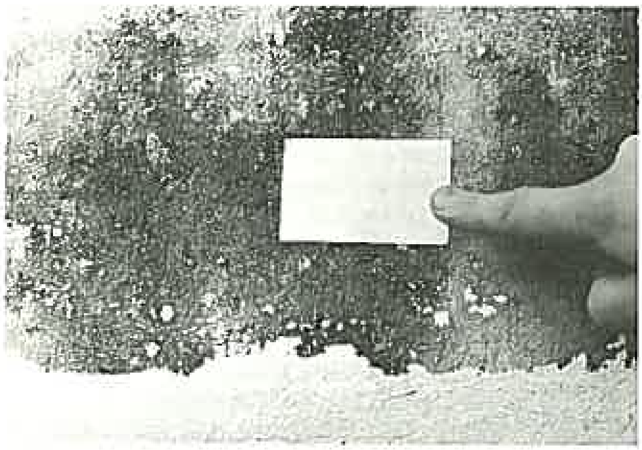

Plate 5: Aspect controls the distribution of organic growths on walls. The surface of the white Mt Gambier, Limestone on the southern wall of the Mt Gambier Hospital is dark grey from algae and fungi.

3.1 Nature of Soiling

Exposure of masonry to the weather over a long period leads to changes which may affect the surface (patina development, colour-change, soiling, efflorescences, etc.), or be penetrating (decay). Some changes are natural (weathering), but others are due to Man's activity, either directly (painting, wear, graffiti) or indirectly (due to pollution). It is essential to determine the nature of the soiling in order to decide the best means of removing it.

The main materials which are required to be removed from masonry are as follows:

(a) dirt, particularly urban grime;
(b) stains (mortar, metallic, food, oil, etc.);
(c) products of masonry decay;
(d) paint, graffiti;
(e) organic growths (plants, lichen, mosses, algae, fungi and other micro-organisms);
(f) salts (stains, efflorescences and crusts).

3.2 Urban Grime

Urban grime is the most common form of soiling in cities. It consists of various mixtures of the

Plate 4: Aspect and exposure control the distribution of soiling. The exposed, west-facing wall of the stucco Adelaide Railway Station (on the left) is light coloured and comparatively clean as the surface is crumbling and self-cleaning. The southern wall (in shadow) is much sounder and more grimy as the dirty original surface still remains.

products of industrial and natural particulate fallout (soot, silica dust, clay, fibres), deposits from aerosols, products formed by reaction between masonry and pollutants (gypsum and other sulphates), hydrocarbons and tarry compounds from car exhausts, rusting iron particles from trains or trams (rails, wheels and brakes), micro- and macro-organisms and others. Grime differs from place to place depending on local conditions. Variations include loose dust or or mud; thin dark grey to black, shiny and greasy films; thin, hard, tough, dark grey to black, sooty layers; and thick, soft to hard, black crusts.

The nature of soiling and the substances involved [39,44,47,49,70,71,73] differ widely in character and in the degree of difficulty of their removal. More rigorous methods are needed to remove more tenacious deposits to achieve a given end product. Some of the more common soiling materials which are required to be removed are ranked in an approximate order of difficulty of removal in Table 1. As a guide, an index (I_T, index of tenacity) from 1 (least difficult) to 10 (most difficult) is suggested.

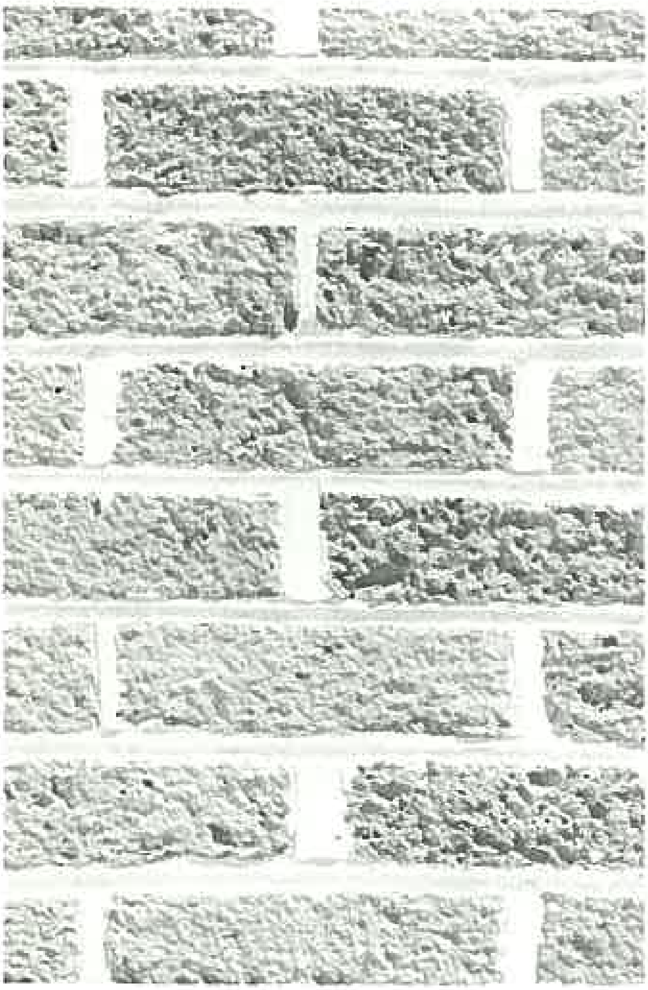

Plate 6: Dry sandblasted bricks in the 1863 Archer Street Police Station, Adelaide, have been deeply eroded. The original surface has been removed and the granular centre exposed.

4 MASONRY MATERIALS

4.1 Introduction

The major external wall finishes which generally require cleaning are natural stone, brick, stucco and render, concrete or portland cement products and painted surfaces. Cleaning may also be required for roofing (slates) and paving.

Historic building materials differ in their tendency to hold grime and in their susceptibility to damage during cleaning because of their wide variation in physical properties (porosity, permeability, hardness, strength, water absorption, texture and structure), in chemical composition, in surface finish (coarsely or finely dressed, polished, smooth, rough), architectural form (smoothed, detailed, carved), and orientation (vertical, sloping or horizontal).

Weathering prior to the proposed cleaning tends to cause considerable loss in surface hardness and coherence, hence the resistance to damage of most old material is substantially less than that of the fresh equivalent. Great care is necessary with crumbling and spalling sandstone, with fragile and porous soft limestones, with underfired bricks, with crumbling lime mortar and with plaster and drummy render.

It should be appreciated that grime on inert stone (such as granite or quartzite) forms a layer or crust on the surface, whereas that which affects reactive material (such as limestone, marble, calcareous or argillaceous sandstone, tuff, some argillites, plaster, render and mortar) becomes part of the masonry surface itself.

Cleaning should not be permitted to affect the surface finish of masonry unless it is a coating which can be readily replaced. Removal of a case-hardened surface may cause a marked reduction in durability.

Stone with a special surface or form such as carved (e.g. window tracery, vermiculated blocks or ornamental capitals), finely dressed (e.g. chiselled or sparrow-picked), smoothly-sawn, rubbed or polished, is most susceptible to damage during cleaning. Rock-faced, seam-faced or quarry-faced stone is least susceptible.

Well-burnt brick is generally easily cleaned, but the soft crumbling surface or exfoliating skin of decayed brick is very susceptible to damage, resulting in rounded corners and exposed granular inner parts and a reduction in the durability (Plate 6).

Stucco and render tends to be self-cleaning in an exposed environment as the surface gradually crumbles away (Plate 3). However, it can develop a dark, hard layer which is difficult to remove without damage. Stringent cleaning may require resurfacing, refinishing with a cement-sand wash, or painting. Old stucco commonly develops cracking which may be due to shrinkage (polygonal crazing) or structural movements (fractures) and also become 'drummy' as it separates from its substrate at the interface. Such material is very susceptible to damage during cleaning.

Some typical masonry materials are ranked in Table 1 with an index figure (I_R) suggesting their degree of resistance to damage: the higher the index figure, the higher the resistance to damage (i.e. the lower the susceptibility to damage). These figures must be taken as a guide only.

4.2 Limestone and Marble

Special attention is given here to the cleaning of limestones and marbles as they are comparatively delicate stones composed of calcium carbonate which is soft and soluble in acids (even rainwater). They are susceptible to damage by physical impact, cyclical heating and cooling, sulphation (conversion to sulphates by oxides of sulphur), smoke, rust, moulds, verdigris, frost, paint, oil, etc. Marble is much tougher than limestone, but polished marble used externally rapidly loses its gloss and becomes dull, pitted and etched. Black marble develops a white or grey film of fine gypsum.

Papers by Kessler[42] and Stambolov[61] on the cleaning and maintenance of marble are very useful. They pointed out that aggressive cleaning chemicals cause damage and that harsh scouring or cleaning agents such as those containing sodium chloride, sodium sulphate, magnesium sulphate, sodium carbonate, sodium bicarbonate, ammonium carbonate and trisodium phosphate should be avoided.

Discolouration, crumbling, cracking and exfoliation of marble steps and of walls just above floor level is commonly due to the use of aggressive cleaning compounds. The removal of stains should not involve the repeated use of acidic compounds (oxalic, citric, hydrochloric, or phosphoric) although these may be used carefully for single cleaning operations if they are washed off quickly.

White marble is prone to brown iron staining (arising from iron pigments in pointing, Portland cement mortar, etc.).

The treatments below may be used as solutions but are best thickened (with glycerine, cornflour, wallpaper paste or carboxymethyl cellulose), mixed to a poultice with whiting or clay or applied as a bandage with paper.

They are listed below in order of increasing aggressiveness:

(a) Sodium citrate solution in water (1:7)

(b) EDTA (sodium ethylenediaminetetra-acetate) 2.5%
Sodium bicarbonate 5.0%
Ammonium bicarbonate 3.0%
Carboxymethyl cellulose (thickener) 6.0% in water

(c) Sodium thiosulphate and EDTA in equal parts, dissolved in water as a 10% solution

(d) Sodium citrate solution followed by the application of crystalline sodium thiosulphate (sprinkled on a horizontal surface or as a paste with whiting and water on steep surfaces)

(e) Potassium-sodium tartrate 15%
Potassium hexacynoferrate 2%
Water 33%
Glycerine 50% in water

Tanner and Cox[63] stated that stains could be removed from marble with a paste of detergent powder plus a small amount of bleach or a paste of quicklime plus caustic soda mixed with melted soap. This is a very aggressive combination and should only be used on small areas and with care.

Special consideration must be given to the cleaning of limestone[47] because it is softer and more porous than marble.

The calcium (and possibly magnesium) carbonate in limestone is slightly soluble in water and hence the stone becomes weaker and more porous with weathering, and thus more susceptible to damage during cleaning. Its reactivity means that it will fail catastrophically if acid cleaning is attempted (although dilute hydrofluoric acid or ammonium bifluoride are effective and leave residual calcium fluoride). Its low strength means that water jetting or sand blasting (wet or dry) will cause scouring. Its high porosity leads to deep penetration and absorption of chemicals used for cleaning.

Limestone develops a case-hardened protective surface after moderate exposure to the atmosphere; cleaning should not remove this surface.

Limestone showing moderate soiling can only be cleaned safely by washing with water. The best procedure is to use a fine spray for some hours or even days, followed by a low pressure wash accompanied by a wipe with a cellulose sponge, or light scrub with a soft brush or gentle scrape with a paint scraper. Highly soiled and sulphated limestone may not respond to this treatment, in which case an abrasive method, with all its deficiencies, may be the last resort.

4.3 Render

Old cement render or stucco becomes carbonated with age, that is, the cementitious components are converted to calcium carbonate. It becomes cracked, drummy and crumbling (sandy) hence many of the precautions pertaining to soft limestone apply.

5 CLEANING METHODS

5.1 Some Relevant Literature

A wealth of information on cleaning of masonry is available in overseas literature, the most important references being: the UK Federation of Stone Industries 'Code of Practice on Stone Cleaning and Maintenance', UK Building Research Establishment Digest 113 (1972), UK Department of the Environment Technical Instruction B10 (1972), Weiss[73] and Rawlins.[53] Others are listed in the Reference Section.

The various methods available differ widely in their effectiveness as cleaners and their ability to inflict damage. *They are discussed below in order of increasing rigour.*

5.2 Radiation

Laser Beam: Asmus[8-14,45] has pioneered a cleaning technique using pulsed laser radiation in the visible and near infra-red portions of the spectrum. It is a very gentle, non-damaging method intended for small areas of delicate material: it is effective in removing black soot-gypsum crusts from marble, lime plaster from murals and paint from leather, but is very limited in its application.

Visible Light Radiation: Asmus[10] has shown that visible radiation using high-energy Xenon flashtubes (as for electronic photoflashes) can be used for delicate cleaning of large areas. Overprinting of murals in the State Capital Building in Sacramento was removed, but cleaning of crusts from Carrara marble was accompanied by some damage.

5.3 Dry Brushing

Dry hand brushes of various shapes and sizes ranging from a soft paint brush, toothbrush or broom to a hard scrubbing brush may be used to remove soft or loose surface deposits such as dust, salts and weak crusts. The hardness of the fibre is matched to that of the stone. Natural fibre is the softest and nylon bristles can be the stiffest and wear well. Wire brushes are not recommended.

5.4 Water Washing

Water is very widely used for cleaning by virtue of its ability to dissolve, soften, or physically dislodge deposits, its ready availability and its safety. Washing is one of the gentlest processes, is the most versatile method for the sensitive cleaning of delicate materials, has a long history of application and is commonly used as an adjunct to other methods. The force with which the water impacts the surface controls both the cleaning power and the potential for damage (the pressure at the nozzle may range from about 300 kPa (40 psi) up to thousands of kPa). Water alone is not capable of removing the more intractible types of grime and, when under pressure, can penetrate buildings (through open joints, windows, ventilators, etc.) damaging internal furnishings or decorations, damage the masonry itself through unwanted soaking, mobilise soluble salts, and affect passers-by. Adequate sealing, screening and drainage are necessary.

Consideration should be given to the use of very hot water, with detergent, on grime containing grease, oil or tarry compounds. Although the water is chilled rapidly against the cold stone, it may clean old sensitive stone to an acceptable degree.

Cold water may be directed onto stone surfaces from a hand-held hose using mains pressure (which means that through a standard hose the water impacts the surface at virtually zero pressure) or through sprinklers or nozzles.

Spraying may extend for periods of 24 hours, or even up to a week to soften tough deposits. Single or multiple jets may be assisted by perforated hose running along the top of the wall[32]. Fire hoses may be used from ground level.[55] The volume of water should be kept to a minimum as large quantities of water are not necessarily more efffective than small ones and require extra screening to protect the public. Spraying should take place from the top downwards so that the excess water runs down to pre-soften the dirt below.

Urban grime (particularly on limestone and where it contains gypsum) can be softened by subjecting it to a continuous very fine mist of water ('misting' or nebulisation). A hand gun used for paint spraying is effective. It should be noted that gypsum is less soluble in hot than cold water.

Simple water-washing is effective for moderately dirty stone or where complete cleaning is not desired as it is the gentlest method available and may be all that is tolerable on fragile stone. It is generally the best method for limestone. It is suitable where dirt is loosely held, such as dust on polished or dense dressed stone, is effective as a softening process prior to the more vigorous removal by another method such as scrubbing or a moderate pressure water jet, is the preferred method for the removal of hard salt efflorescences from stone surfaces and will remove salt from various depths below the surface of salty porous and permeable stone.

Adequate drainage from the area being cleaned is essential, and some protection for passers-by is required. Precautions against spray and water penetration of the building are not as stringent as for high pressure methods. Penetration of damp and resultant internal damage is a risk. Very porous stone (particularly limestone) or mortar may be softened, paint lifted and timber damaged.

This method has not been greatly used in Australia and is not popular with operators as it is slow. It may not be effective on very grimy buildings (Plate 7), but its importance for restoration is coming to be recognised. It is the best method for small and valuable monuments, statuary or embellishments and may precede or follow 'spotting' or removal of small soiled areas.

Use of a hand-held fibre brush in association with low pressure water from a hand-held hose (with possibly a very little detergent) is an old-established, safe, effective way of cleaning stone. It allows maximum control so that friable stone can be avoided, special care given to intricate carvings, splashing of adjacent areas avoided and personal attention given to specified details. A soft, non-ferrous (bronze) wire brush is one of the most versatile aids.

Hard steel wire brushes are not recommended as they tend to damage the surface (pitting and scratching) and may cause rust stains from lost wires or particles.

Successful examples of gentle water washing include the Gladstone and Eagle Chambers (1979-80), Edmund Wright House and Pilgrim Church in Adelaide and the GPO in Brisbane. Unsuccessful attempts to remove urban grime from sandstone by soaking and washing include the old MLC facade and parts of the GPO facade in Sydney, and the Supreme Court Annexe in Melbourne.

The rate of abrasion by a brush can be accelerated by use of a rotating brush on a hand-held grinding unit in association with a very low pressure water stream (hand-held hose) but does tend to generate a good deal of spray.

A nylon or bristle brush on a portable grinding unit is effective for large areas of stucco or granite and a fibre scouring pad is very useful for polished stone (granite or marble).

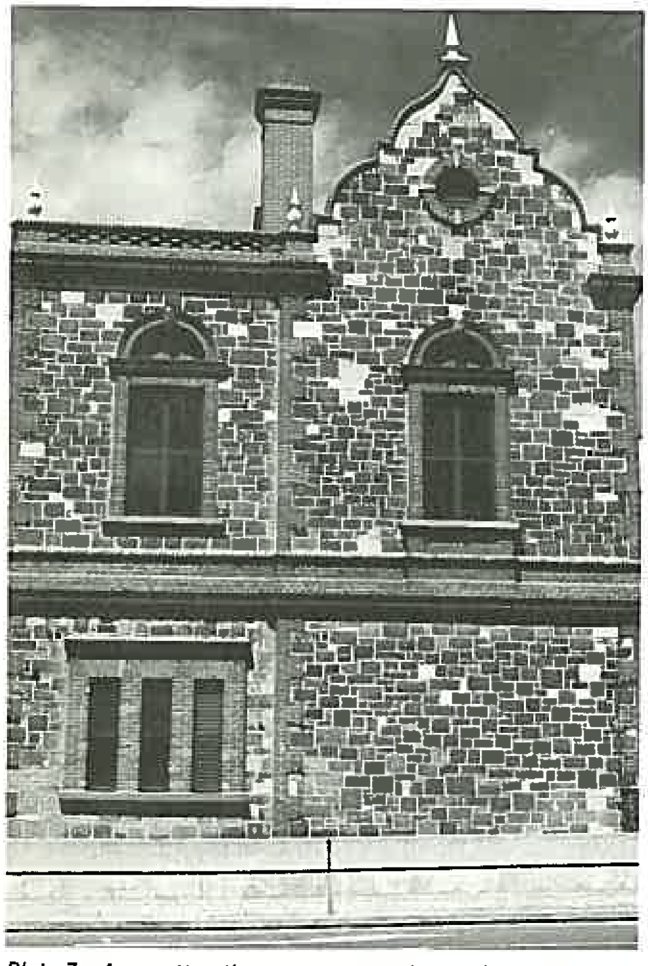

Plate 7: An unattractive contrast may be produced between clean replacement stone and old soiled stone. The original Tea Tree Gully sandstone of the Old Legislative Council Building, Adelaide, is still grimy after washing in 1980. The light blocks are of clean Sydney sandstone.

5.5 Steam Cleaning

Although the term 'steam cleaning' is generally applied to masonry cleaning and many operators are called 'steam cleaners' the process is an old one which is not widely used at present, having been largely replaced by faster methods.

A steam cleaning unit directs thin streams of low-pressure, superheated steam onto a surface. The steam cools in the air so that the surface is struck by a spray of a very small amount of hot water. The nozzle aperture is usually 12 mm, the common pressure range is 70 to 200 kPa (10 to 30 psi) and the working rate is about ten minutes per square metre.[73]

Steam cleaning is not now favoured because it is not particularly effective in removing dirt, is slow, generates large volumes of vapour which make the operation conspicuous, and can be dangerous to a careless operator. It does not generate as large a volume of water as other wet methods, so there is less risk of damage to the interior of buildings by water penetration. Steam cleaning does not damage the masonry unless it is very soft or unless a chemical is used (caustic soda has been widely used in Britain). It is a useful method of softening oily, greasy or tarry deposits, for removing chewing gum from pavements and for killing mould or algae on damp surfaces.

Examples include the pylons of the Harbour Bridge (1968), the Customs House, GPO and Town Hall in Sydney and the Bank of New South Wales in King William Street, Adelaide (where it caused pitting in limestone).

5.6 Water Jetting

A pump unit projects a water jet against the surface to dislodge loosely held material. The method may be used alone but usually follows some kind of loosening process such as chemical application or brushing.[32] Detergent may be fed into the water jet and some units are provided with flash heating devices so that hot water can be used.

Water jetting at various pressures is widely used in Australia and is effective in removing certain types of grime from certain types of masonry. However, if the pressure is raised so as to remove intractable grime it may cause damage to stone, brick, pointing, stucco, etc.

In general, the higher the water pressure, the more effective the cleaning and the greater the damage to the surface.

The pressure of water directed on to the surface can be varied considerably depending on the source, nozzle type and distance from nozzle to the surface. Pressures of up to 55000 kPa (8000 psi) are generated in some mobile equipment, but pumps developing around 20000 kPa (3000 psi) at a 2mm nozzle give pressures of only a few tens of kilopascals at a distance of 50 cm.

The following table gives an indication of the potential for damage and for cleaning by water jets at the more common pressures:

General pressure	Pressure (kilopascals)	Damage	Cleaning ability
Mains to very low	300	Low	Low
Low	up to 1500	Low	Moderate
Medium	1500-3000	Damage to sandstone and limestone	Moderate to high
High	3000-4000	Damage to all but the hardest stone	High
Very high	4000-55000	Damage even to granite	High

Gibbons (personal communication) has shown that the erosive (and cleaning) power of the jet depends on the pressure, flow-rate, jet diameter and shape, and distance from jet to surface. It is proportional to

$$\frac{PQ}{a}$$

where: P = pressure at the pump in kPa
Q = flow-rate in litres per minute
a = area of masonry contacted by the jet.

Bridges[16] stated that Sydney 'yellow-block' sandstone is damaged by presures of less than 3000 kPa and that 4000 kPa will even pit granite. Pyrmont sandstone on the Lands Department building in Sydney was badly pitted with 3500 kPa pressure. Trachyte on the Bank of NSW, George Street, Sydney, was pitted with 2000 kPA pressure. Cleaning contractors in NSW are known to use up to 4000 or even 6000 kPa and even if the jet is kept 15-20 cm from the surface, and is kept moving, damage to the softer parts of stone is a great risk.

Tests by the NSW Public Works Department and the Experimental Building Station at North Ryde, Sydney, confirm that high-pressure water spraying damages Sydney sandstone. However the WA, Public Works Department (personal communication) has been successful in removing dirt from Perth buildings constructed of local limestone using low pressure.

5.7 Chemical Methods

5.7.1 Introduction

Chemical reagents assist in the removal of grime from masonry by virtue of their action as solvents (water, organic liquids), surface activity (detergents), chemical reactivity (acids and alkalis of low or high pH, chelating compounds), their oxidation-reduction potential (bleaches), or their toxicity (fungicides, enzymes, etc.).

Chemical cleaning consists of two parts: the application of an active liquid to soften ('lift') grime followed by washing or some other cleaning process. The general procedure is to wet the masonry surface, spray or brush on a minimum amount of chemical, allow it to act for a short period and then wash it off.

Chemical compounds applied to the surface in the presence of water will penetrate to a degree dependent on the porosity and permeability of the masonry (that is, its water absorption). Granite and similar crystalline rocks (porphyry, trachyte and some slates and marbles) have a very low water absorption (less than 0.5 per cent of their volume, commonly 0.1 per cent) but sandstones may range between about 2 and 20 per cent, some porous limestones are greater (around 20 to 25 per cent) and the Mount Gambier limestone reaches 45 per cent. This means that the applied chemical may penetrate millimetres or even centimetres into the stone and hence may be difficult to remove.

Penetration may be reduced by applying the chemical as a gel, paste, bandage or poultice and its effect at depth may be reduced by pre-soaking the surface. It is a basic rule that all chemicals applied to clean the stone must be completely washed out of the pores.

Chemicals do not subject the stone to such strong physical forces as dry- or wet-grit blasting or abrasion and therefore can be used on comparatively friable stones as long as they can resist the chemical attack. Despite the warning of an authority as experienced as Arthur Warnes[72] that 'never should chemicals be used in cleaning portions of old buildings', their use can be less damaging than some other methods.

General problems include the following:

(a) Special precautions are necessary to protect the operator and the public. Operators must wear special protective clothing to prevent acid burns; glass, painted surfaces, polished marble and metal must be masked. Adequate scaffolding and screening are important.

Plate 8: Chemical cleaning can be effective and non-damaging, but the use of caustic alkali on these bricks in the Bank of New South Wales, Sydney, has left salt staining and efflorescences even after repeated washing.

(b) Gun shading: a horizontal, streaky, blotchy or mottled effect due to uneven cleaning can be produced by uneven chemical action or washing off.

(c) Streak staining: vertical streaking due to uneven cleaning, often the result of applying the chemical from the top down. Application from the bottom up means that excess chemical runs over a surface wetted by the chemical. The effect is minimised by wetting the whole of the face with water prior to application of the chemical.

(d) Mortar attack: although the stone itself may be sufficiently resistant to withstand the chemical, lime-rich mortar is soft, absorbent and chemically reactive and may be attacked seriously, particularly by acids. Mortar may absorb chemicals then slowly bleed out salt efflorescences or stains for a long period.

(e) Chemical staining: great care must be taken to ensure that all of the chemical is removed by copious water washing, otherwise efflorescences of salt will appear on the surface (Plate 8) and salt decay may ensue. A too-active attack by hydrofluoric acid will result in the formation of a white bloom of colloidal silica on sandstone or of calcium fluoride on limestone or render; this is difficult to remove (Ashurst and Dimes, 1975).[7] Iron appears to pass into solution and be transported during chemical cleaning to stain adjacent stone. Wire brushing of acid-treated surfaces before they are washed can generate metallic stains.

(f) Bleaching: the removal of iron-bearing compounds from sandstone may leave the stone in a pale, bleached or over-cleaned condition.

(g) Decay: it has been suggested that the aggressive reagents used in chemical cleaning will attack stone and cause decay, but the limited evidence available suggests that chemical treatments can be less damaging than alternative aggressive methods.

5.7.2 Organic Solvents

Greasy substances such as motor oil, stains from greasy palms in corridors and doorways, dropped or thrown food, etc. can be removed from masonry in some cases by warm water plus detergent. Organic solvents are more effective but are expensive, tend to evaporate or be absorbed, may be flammable, odoriferous or even produce dangerous fumes (particularly the chlorinated hydrocarbons). The solvent may be applied as a liquid or in a 'poultice', or may be swabbed on then washed off with detergent and water with scrubbing.

The more commonly used solvents (used individually or in mixtures) are white spirit, toluol, carbon tetrachloride, methy- and ethyl alcohols, di-, tri or tetra-chloroethylene, benzene, proprietary paint-stripper (methylene chloride), and proprietary dry cleaning agents.

A mixture of 9 volumes of carbon tetrachloride plus 1 volume of benzene plus 1 per cent detergent softened hard, black deposits on

Cleopatra's Needle in London for the 1949 cleaning operation.[21] The deposits were removed by wire brushing after softening. No examples of large-scale cleaning with organic solvents are known but it is applicable to greasy hand marks or food stains.

5.7.3 Detergents

A detergent may be regarded as any material which assists cleaning, but the term is generally applied to a series of synthetic, water soluble compounds used for cleaning, soaps being usually excluded.[37,73]

They are surfactants (that is they affect the surface properties of the material to be cleaned) and promote wetting of the material by water.

Natural soaps are less effective as cleaning agents than the synthetic detergents and have the additional disadvantage that they may produce free alkali and insoluble fatty acid salts;[70] soaps are rarely used for cleaning masonry. Liquid (not powder) detergents only are considered here.

Small quantites of detergent are commonly used to clean masonry in conjunction with washing with cold or hot water (usually at low pressure) or with wet scrubbing. In some cases the detergent is fed into the water jet but it is preferable to apply the detergent first, allow it to remain for a few minutes and then wash it off completely with water (that is until all the bubbles disappear). Several repetitions of washing may be necessary.

Failure to remove the detergent may have three possible detrimental effects:

(a) the stone may be left uneven or patchy in colour;

(b) residual intergranular detergent will promote the entry of rain or other moisture into the stone and thus accelerate rising or falling damp and decay;

(c) the biodegradable nature of most modern detergents means that they are attacked by bacteria and so, conversely, they will act as a support medium for bacterial action in the masonry.

Commercial synthetic detergents are not simple materials but are complex mixtures.[28,58] They may contain any of a very large number of inorganic and organic additives or 'builders' which are aimed at improving their performance but which can be detrimental to stone. The inorganic builders are generally omitted in liquid detergents. Sodium metasilicate (sodium silicate plus caustic soda) is a standard detergent widely used for laundry purposes but now also used for stone cleaning.

It is undesirable to introduce salts (ionic compounds) or harsh alkalis to stone hence the safest detergents are of non-ionic type lacking builders or additives although anionic types are also useful. The most widely used detergents for stone cleaning appear to be anionic Teepol (a Shell product) and Comprox (BP) or non-ionic Lissapol (ICI). These detergents are understood to be neutral and to contain no dissolved salts. Concentrations of 1 to 2 per cent by weight or volume are used; high concentrations are unnecessary and should be avoided.

Detergents are by no means harmless chemicals and many are chemically aggressive. A large number of cases have been documented of the staining or decay of marble or terrazo floors or steps, or of grout between tiles by the detergents used for regular cleaning and maintenance. Examples are common of the corrosion and decay of a band of stone several inches wide above floors and stairs where washing water has attacked.

Mixed aqueous-organic systems can be prepared by mixing surfactants with various solvents such as the chlorinated types (methylene chloride, tri- or tetra-chloroethylene) or aliphatic hydrocarbons (naphtha, stoddard solvent, mineral spirits). The combination of tri- or tetrachloroethylene plus Lissapol in water appears to be very effective.

5.7.4 Acids

Acids used for cleaning masonry include strong types such as hydrofluoric, hydrochloric, nitric and phosphoric and weaker types such as citric, oxalic, acetic and carbonic.

Acids attack deposits in various ways but in general they soften grime and facilitate washing away with water. Unfortunately, they also attack the masonry itself to various degrees. Granite and similar crystalline rocks are resistant to most acids (but not hydrofluoric). Siliceous sandstones such as the Tea Tree Gully sandstone are moderately resistant, those with an intergranular clay bond such as Sydney and Tasmanian, and those with a calcareous cement (including some from Sydney) are attacked. Limestone, dolomite, marble, calcareous slate, travertine, calcrete, calcareous sandstones, concrete and mortar all contain carbonate of calcium and/or magnesium which is dissolved rapidly by acid. The reactive nature of such materials is shown by their effervescence ('fizzing') on the application of acid. Acid will damage such materials by dissolving pits or cavities, opening up cracks or joints, rounding corners and destroying detail. The masonry should be washed until application of a pH paper to the damped surfaces show it to be neutral.

The attack of a carbonate by an acid produces a salt so that (according to the acid) chloride, nitrate, sulphate, phosphate, acetate, fluoride, etc. of calcium or magnesium will be precipitated in pores despite efforts to wash them away. The more soluble types (such as calcium chloride) later pass in and out of solution as the masonry becomes wetted and dried by the weather and crystallisation will cause crumbling, exfoliation and other failure. Deliquescent salts absorb moisture from the atmosphere and cause decay even in the absence of visible damp.

There is considerable resistance to the use of acids[63] in cleaning masonry because of possible damage and risk to the operator and the public. However, it is stressed that cleaning by fluorine-bearing acids may be far less damaging to masonry than wet sand-blasting, high pressure jetting or alkali treatment.

Hydrochloric Acid: Dilute hydrochloric acid (muriatic acid or spirits of salts) is used widely to clean bricks, particularly to remove mortar splashes or lime stains. It is not a particularly effective cleaner, and leaves behind chlorides which tend to be very soluble and hygroscopic and thus promote salt decay. Spirits of salts (1:6 in water) was used to remove stains from porphyry (Brisbane tuff) at the Colonial Stores, Brisbane, apparently without ill effect and tests of 10 per cent acid on robust Tea Tree Gully sandstone at the Adelaide Town Hall showed that it was moderately effective in removing rust stains without damaging the stone. Hydrochloric and phosphoric acid (10 per cent) were equally effective but oxalic acid (100 grams per litre) was less so.

Hydrofluoric Acid: Dilute (5 per cent) hydrofluoric is the most commonly used acid for cleaning stone although it appears that it is being superseded by ammonium bifluoride. Hydrofluoric has been preferred in the past to others because it is a highly efficient cleaner and tends not to leave soluble salts. The acid attacks even highly resistant rocks and also brick, mortar, glass and metal. It will therefore attack and corrode all of the major constituents of building materials. Silica and silicates when so attacked give out white encrustations of amorphous silica; there is some difference of opinion as to the ease by which these may be washed away. Most fluorides (particularly calcium fluoride) are insoluble and thus should not cause salt corrosion due to repeated solution and crystallisation.

The surface is first saturated with water, wetted with the acid solution for about 2 to 4 minutes and then thoroughly washed down with water. The process may be repeated if dirt remains.

It is effective as a pre-washing agent because it attacks and corrodes some of the constituents of the hard, black, soot-dirt layers thus softening and breaking up the deposit.

Hydrofluoric acid is an exceptionally dangerous material even in the hands of skilled operators. Most workmen realise that it will etch glass, destroy the polish on marble or granite, dissolve pits even in durable crystalline granites, leave unsightly marks on windows, paving or footpaths and can cause painful burns. **However, few appreciate that hydrofluoric differs from the common acids in its ability to penetrate skin and flesh to destroy bone.** It must be recognised as highly toxic and dangerous.

Like all acids, it tends to dissolve iron minerals (such as limonite, goethite, or hematite) in stone and thus may cause colour changes such as bleaching or patchy brown staining. The marble steps at the northern entrance of the Treasury Building in Brisbane show brown staining which is alleged to have been produced during chemical cleaning of the walls. UK Building Research Establishment Digest 113 (1972) suggested that this type of staining can be prevented by the addition of phosphoric acid to the hydrofluoric acid; alternatively, a rust inhibitor may be added to the acid.[32]

UK Building Research Establishment Digest 21 (1950) recommended the use of hydrofluoric acid for rough-textured granite and sandstone and considered that it was effective and did not harm the stone if used with care. It also referred to the use of the acid on limestone and quoted a case where no damage had been recognised ten years after its use. Hydrofluoric acid should not be used on any polished stone surface (granite or marble).

Ammonium Bifluoride: An aqueous solution of ammonium bifluoride is used as an alternative to hydrofluoric acid (or as an admixture) as it shares many desirable properties but is somewhat less dangerous and corrosive. The compound is a white deliquescent crystalline solid which is highly corrosive in the presence of moisture and is used as an aqueous solution (as low as 0.1 per cent but as high as 10-20 per cent) which has a pH of about 3½. The solution has a similar behaviour to hydrofluoric acid but its rate of attack is lower and it attacks silica (quartz), silicates (clay, feldspar, mica), carbonates (calcite, dolomite), oxides (limonite, hematite), sulphides (pyrite), metals, glass, mortar, bricks, etc. Silicates when attacked leave a residue of insoluble silica gel and the ammonia may be precipitated as various soluble salts on drying.

The cleaning action is similar to that of hydrofluoric acid but in addition the ammonia liberated tends to emulsify grease and oils. Where ammonium bifluoride alone cannot loosen the grime, its effect may be usefully assisted by the addition of a little hydrofluoric acid. A mixture of 2½ per cent hydrofluoric acid plus 10 per cent ammonium bifluoride has been found effective. Repeated applications of a weak solution may be better than one of a strong solution.

Ammonium bifluoride has been used successfully on sandstone in Australia. Examples include the Treasury Building and Land Administration Building, Brisbane; the Treasury Building, Christ Church St Lawrence, Sydney Hospital, Customs House and GPO tower in Sydney and parts of the Town Hall in Adelaide (Plate 9). The buildings are clean (some persons consider them to be over-clean) and the stone appears to be sound.

The evidence at present suggests that ammonium bifluoride followed by low-to-moderate pressure water washing may be the gentlest method available for the effective removal of urban grime, but it should be appreciated that in no case has a detailed survey been carried out before and after cleaning. Most cleaning only took place a few years ago and any decay may need time to develop.

Phosphoric Acid: This acid (10 per cent) slowly dissolves iron-bearing compounds (rusty stains or natural minerals) and thus tends to bleach the masonry.

Acetic Acid: Dilute acetic acid (vinegar) as a weak acid has been used occasionally to clean stone, particularly limestone (which it attacks and dissolves more slowly than stronger acids) and to remove lime wash or lime plaster. It is cheap, readily available, safe, and useful for cleaning small areas by hand.

Carbonic Acid (Soda Water): A solution of carbon dioxide in water is a very weak acid whose main attribute is the ability to dissolve calcium carbonate. Some soiled surfaces of limestone have been cleaned effectively by soaking in soda water then scrubbing. The acid attacks the surface of the limestone, thus loosening its bond with the grime.

5.7.5 Alkalis

Alkaline substances have been used for cleaning over many years and are used either alone or in various formulations. The use of an alkali instead of an acid for limestone and marble (which dissolve in acid) is an old practice. Caustic soda (sodium hydroxide), caustic potash (potassium hydroxide), soda ash (sodium carbonate) and sodium peroxide were very popular in Britain in the 1920s.[34] Although caustic soda is an effective cleaner of limestone and marble, it should not be used for porous varieties (that is, the majority of limestones) and the general consensus of published opinion is that it should not be used at all for cleaning stone.[69]

A 'caustic gel' (apparently caustic soda plus caustic potash thickened with cornflour) has been used to strip paint from the Sydney Mint and also for cleaning sandstone (test panels on the Sydney Railway Station), trachyte (test panels on the bank, 345-60 George Street, Sydney) and brick at the Bank of NSW, George Street (Plate 8).

Plate 9: The tower of the Adelaide Town Hall in the centre of the photograph has been cleaned safely and effectively with a combination of water washing, bronze-wire brushing and chemical (ammonium bifluoride and hydrofluoric acid) treatment (on the more highly soiled parts). The tower of the GPO on the left has been cleaned by dry grinding which has left the surface of the sandstone and limestone damaged and spotty.

The main concern with caustic soda is its high solubility and its aggressiveness in causing salt crystallisation decay of porous stone. It is very difficult to wash out of stone (salt staining is visible at the last two localities in the previous paragraph) and comments[7,15,55] have been made on its dangerous nature and an inability to remove it from stone even after prolonged and repeated washing. Sodium carbonate (soda ash) apparently assists in washing out caustic soda but is itself an even more dangerous salt. Treated surfaces should be tested with pH paper for the presence of alkalis after washing.

Caustic soda has been found very effective as a paint stripper (parts of the Old Legislative Council Building in Adelaide).

It is not permissible to neutralise alkalis used for cleaning with an acid (such as vinegar) nor to neutralise excess acid after acid treatment with alkalis as the reaction between acid and alkali produces salts in the pores. Inadequate washing-off of the alkali may leave white stains and treatment of these with dilute acid may result in salt efflorescence.

One of the mildest chemical treatments proposed[65] consists of a jelly based on mildly basic salts (sodium or ammonium bicarbonate, with a complexing agent for calcium with water and methyl cellulose).

Liquid ammonia (ammonium hydroxide) has been used on light coloured limestones.[73]

5.7.6 Bleaching Compound

Calcium oxychloride (bleaching powder) and sodium hypochlorite (household bleach) are well known and effective cleaning and bleaching agents for many purposes, but should be used with great care because of the generation of dangerous salts, visible efflorescences and because of the possiblity of overcleaning.

5.7.7. Toxic Washes (Biocides, Fungicides)

Organic growths on masonry range from the larger climbing plants such as ivy and creepers, through the lithophytes (lichen and moss) to the micro-organisms (cryptogams), algae, mould, fungi and bacteria[5,19,27,46,54] (Plate 5). These may be torn down (in the case of creepers) or removed with a wire brush (lichen and moss), although this is time consuming and may damage the masonry. Algae, moulds and similar small types can be removed by steam cleaning but the simplest, most effective and long lasting method is to kill the organisms with a toxic wash. Organic staining (black, brown or yellow) remaining after removal may require further cleaning such as bleaching.

A large variety of toxic washes[54,64] are available, many being listed in the UK Building Research Establishment Digest 139 (1972) and although considerable attention has been given to them in Europe (proceedings of the 1978 UNESCO-RILEM Conference in Paris) there has been little interest in Australia.

The more effective toxic washes are as follows:

(a) household bleach (5 per cent sodium hypochlorite);

(b) formalin (5 per cent);

(c) phenols (pentachlorphenol or orthophenyl): commercial examples include Brunosol, Brunobrite, Cuprinol, Hepta-San, Protim, and Santobrite;

(d) quaternary ammonium compounds ('quats'): commercial examples include Gloquat C and Thaltox Q;

(e) organo-metallic compounds such as the silicofluorides;

(f) boron compounds such as Polybor;

(g) solutions of copper sulphate or copper ammonium carbonate – used but not recommended because they may stain and are aggressive towards masonry;

(h) commercial formulations such as Penacide, Chlorea, Emphigen BAC, Resco 70009, etc.

Appropriate care should be exercised in using some of these toxic materials to protect the operator and the public. Also pollution of the surrounding environment needs to be considered in the case of some of these chemicals.

5.7.8 Poultice and Bandage Methods

A useful variant to spraying or painting of masonry with a reagent (or solvent) used for chemical cleaning involves covering the area with a layer of reagent-soaked absorbent (poulticing). The reagent attacks the unwanted material within the masonry and is drawn out of the pores and through the bandage or poultice as the solvent evaporates out of the outer surface. The soiling material is left in or on the bandage or poultice after drying. The bandage is generally easier to apply but the special absorbing quality of the material of the poultice (high suction) and its closer contact make it more effective.

The poultice procedure is to mix an absorbent solid with a solution of the reagent (or the solvent) as a thick paste, wet the surface of the stone with the reagent, then apply the paste in a layer about 1 cm thick and allow it to dry. It may be necessary to support the poultice in position by wire or plastic mesh, hessian, paper or other material. When the mass is dry (it shows craquelure or open, intersecting cracks or is powdery) it is removed and the surface brushed clean or washed with low pressure water. It may be necessary to repeat the process several times.

The techniques have been discussed in detail[7,42] and are appropriate for circumstances in which:

(a) the unwanted material is located deep within the pores of the masonry and is to be drawn out;

(b) the soiling has a low solubility and requires to be kept in contact with the reagent for an extended period then drawn out;

(c) the solvent has a high volatility.

Solvents include water, solutions of chemicals in water and organic liquids. Solutions may be thickened with glycerine, cornflour, wallpaper paste or carboxymethyl cellulose. Solid media used in poultices include the following in a finely ground condition:

whiting (appropriate for marble and limestone), pulped paper, common clay (kaolin), absorbent clays (sepiolite, palygorskite, attapulgite, fuller's earth), talc or diatomaceous earth (diatomite).

The absorbent clays and diatomite are most effective whereas whiting and kaolin are cheapest.

Bandages may be made of cloth or cotton wool but white absorbent 'butchers' wrapping paper or smooth absorbent paper towels are effective. 'Japanese' paper has also been used. Clean white paper may be overlaid with many thicknesses of newspaper.

Bandage and poultice methods are used for small objects or valuable areas as, although useful, they are too cumbersome for applications to large areas of walls.

5.8 Manual Abrasion

Small areas of intractable grime are effectively attacked by a hand-held abrasive such as a block of carborundum, a file, 'wet and dry' sandpaper or various types of scraper.

The nature, particle-size (grade or grit) and hardness of the abrasive should be matched to the masonry. Coarse carborundum is suitable for hard sandstone but fine carborundum, a brick or hard sandstone block is safer for soft sandstone, limestone or marble. 'Wet and dry' emery paper of various grades is very useful for small areas or for details. Pumice stone is very soft and can be used on small areas of soft stone, particularly marble (not polished).

An abrasive block may be used dry, but the presence of water assists by washing away fine powder which tends to clog the block, by preventing shiny patches developing, by avoiding overheating, and by preventing ingraining fine (perhaps coloured) dust. The method is very useful for cleaning up small, highly soiled areas, such as carved detail. However, it is slow, laborious and damaging to the surface (Plate 10).

It is not suitable for polished, dressed (chiselled, picked, etc.) or deeply pitted surfaces as the dirt is not removed from the depressions. It is most appropriate for hard stone, and for special cases such as sandstone with a crumbling surface but a hard interior. Examples of its use include the Helidon sandstone of the Old Colonial Stores and of the Anzac Memorial (Brisbane), and the Sydney sandstone cornices and mouldings of the Bank of New South Wales, George Street, Sydney.

Dirt, paint, decayed stone, moss, algae, soot, salt, etc. may be removed from small areas (particularly in ornamentation or in areas which are difficult to reach) by standard tools or specially constructed scrapers of various types. For safety, the hardness of the scraper should be greater than that of the deposit but less than that of the stone, and hard metal scrapers must be used with care and skill.

5.9 Wet Sand (Grit) Blasting

This currently popular high speed method of cleaning consists basically of directing onto the surface a high pressure stream of water into which is fed abrasive particles. Water pressures appear to range between 300 kPa (40 psi) and 55000 kPa (8000 psi) although 20000 kPa (3000 psi) is common. The abrasive is generally hard (quartz sand, crushed slag, carborundum, garnet powder, or steel shot) but may be soft (crushed limestone, eggshells or almond shells).

The water is generally cold but some equipment is able to produce hot water.

Overseas practice[79] is apparently to use very low pressure 150 to 700 kPa (20 to 100 psi

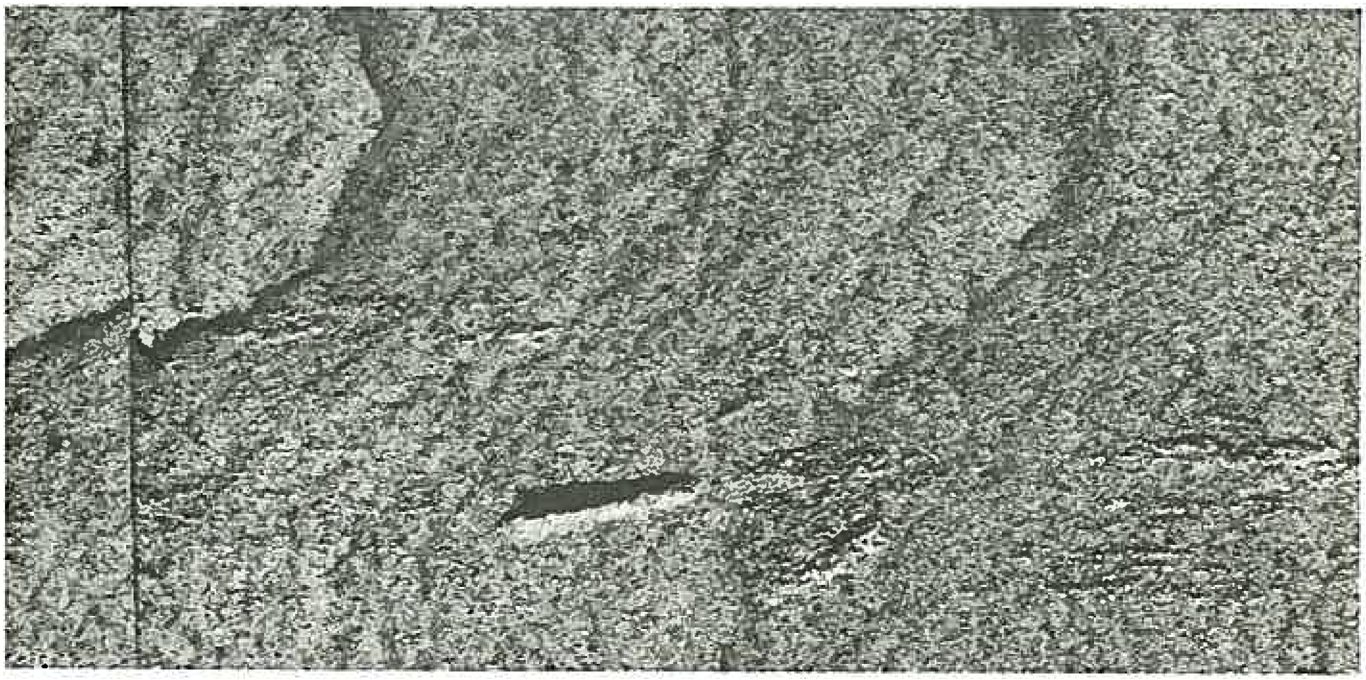

Plate 10: Manual abrasion (carborundum block) of sandstone can leave the surface scratched and pitted. The surface of this Helidon sandstone on the Anzac Memorial, Brisbane, has been badly damaged.

measured at the nozzle), but in Australia much higher pressures are used. Wet sand blasting does not produce dust as does dry sand blasting and this is favoured on health grounds. The results of wet or dry blasting are said to be comparable,[73] but the wet method has a number of disadvantages despite its almost complete replacement of the dry process. It generates water spray and run-off and thus requires sealing of openings such as windows, doors and ventilators, requires precautions to prevent drains clogging, and will damage soft stone and paint unless used with extreme care. Unskilled operators may produce a mottled finish. The process tends to be messy, as it generates water spray and abrasive dust, leaves heaps of abrasive on the ground and results in streams of run-off water. Considerable amounts of slurry which are generated tend to obscure the vision of the operator by covering the visor of his mask and also collect on ledges, in mouldings and on masonry surfaces. Imprecise use of the wet blast caused differential cleaning and produces a mottled effect, called 'gun shading', and requires considerable skill by the operator. Brown stains may appear on stone.

Use of wet sand blasting at the Duke of York Hotel, Currie Street, Adelaide, in February 1980 to remove thick hard paint from Stirling sandstone masonry is considered to have been too rigorous (Plate 11). The surface of the sandstone has been removed generally by 1 to 2 mm, with 3 to 5 mm in softer parts. Arrises have been rounded, the dressing texture removed and the surface given an eroded appearance. The surface of the stone is now hard but its appearance is not attractive.

Wet sand blasting on the Hobart Town Hall (Plate 12) has damaged the soft Tasmanian sandstone. The surface is pitted, arrises rounded and dressing marks and vermiculated carving has become blurred. Similar results were obtained on a test panel of Tasmanian sandstone used for the Supreme Court in Melbourne.

Plate 11: Wet sandblasting of Stirling sandstone in the Duke of York Hotel, Adelaide, has removed between 1 and 5 mm of stone, eroded grooves along the bedding and destroyed most of the original dressing marks.

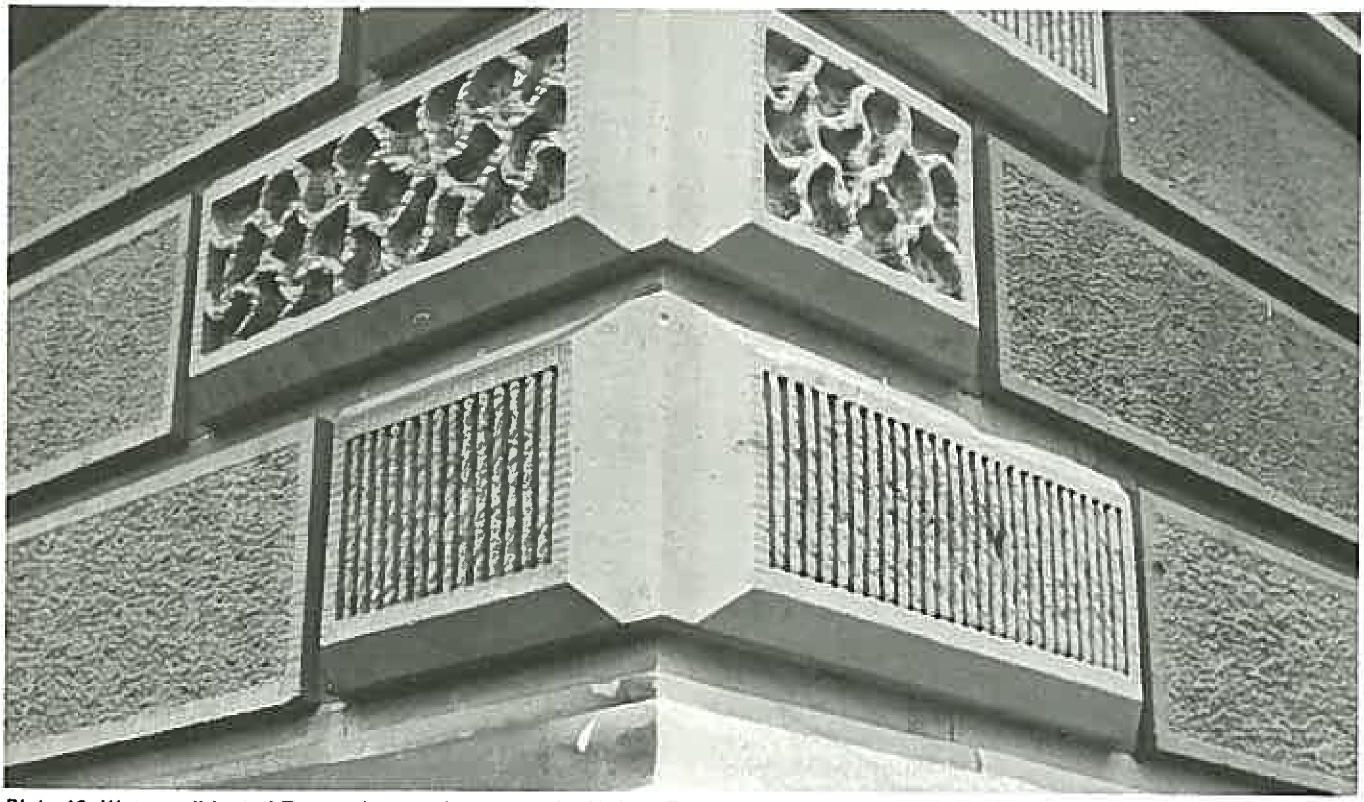

Plate 12: Wet sandblasted Tasmanian sandstone on the Hobart Town Hall. The lighter coloured section on the right has been cleaned, the left-hand section is uncleaned (the lighting is uniform). The surface of the sandstone has been damaged, arrises rounded, vermiculated and picked dressing has become blurred.

Plate 13: Dry sandblasting of the Sydney sandstone in the piers of Knapsack Gully Bridge, New South Wales. The method is effective but damages the surface. Protection from airborne silica dust for the operators is inadequate.

A recent variant of this method (Kue Process) is capable of producing much less damage. An air jet containing abrasive is accompanied by a small amount of water.

5.10 Dry Sand Blasting (Grit Blasting, Shot Blasting)

This high speed method was originally developed for removing rust from iron and steel but was adapted for use on masonry in the 1960's.[22] It uses a compressor, hose, abrasive feeder and a nozzle system and consists basically of a compressed air jet into which is fed granular abrasive such as sand, coarse quartz grit, garnet grit, carborundum grit, crushed slag, steel shot, etc. (Plate 13).

The jet is highly abrasive and scours surface deposits (plus the masonry surface itself) by impingement of the abrasive particles.

The method is comparatively fast and cheap but has such disadvantages that it is rarely used today on restorative work and it is understood to be unacceptable on health grounds to most Australian authorities. It may be acceptable for tenacious soiling on hard, unweathered, rough stone surfaces such as granite and has been used successfully on the Moruya Granite pylons of the Sydney Harbour Bridge. However, sand blasting will damage weathered, exfoliating or crumbling masonry, brick or plaster, or indeed fresh sandstone, limestone or brick (particularly on arrises and details) if they are soft, and also adjacent painted surfaces, glass, polished marble, brick, etc. unless the operator is extremely skilful.

The method is very damaging to old bricks whose external surface is removed to reveal the softer interior which takes on a high-pitted aspect (Plate 6). Although the appearance is not unattractive as a textural device (perhaps in a recycled building), the original appearance is destroyed and the process is completely opposed to the principles of restoration. Old sand-stock bricks (about 1860) in Campbell's Storehouse, The Rocks, Sydney, those at the Archer Street Police Station (1863) in North Adelaide, at 73 Webb Street, Fitzroy and Gordon House (1884), Little Bourke Street, Melbourne, show pitting and erosion due to dry sand blasting.

The operation is hard to control, noisy and generates a large volume of unsightly dust which is, at the least, unpleasant for the operator and, at worst, a health hazard if the grit or stone is siliceous or if lead paint is being removed.

5.11 Mechanical Abrasion

A rotating carborundum wheel (disc or cone) on a portable grinding machine is one of the most effective methods for cleaning grime from masonry. However, it also removes the surface itself and is therefore one of the most damaging methods and hence generally unacceptable for valuable or historic materials. The method is fast and capable of removing intractable urban grime, decayed stone, paint and render. A range of sizes and shapes of wheels and grades of carborundum are available. The grinding machine may alternatively be fitted with a wire brush which is a little more flexible. Stone is 'cut-back' to present a fresh surface hence the method is only suitable for smooth, sawn or fair-faced material, not for rock-faced, dressed, carved or polished surfaces. The removal of a superficial dirt layer may only take off a millimetre but the removal of grime-impregnated sandstone may take several millimetres, and of a decayed and hardened crust, about 10 to 20 mm or more.

Surface grinding is not practicable on very hard stone such as granite but may be particularly appropriate for very soft limestones which are sulphated or which cannot be cleaned by a wet process.

Grinding has a number of disadvantages in that it is highly damaging to the surface which is left bruised (containing many microcracks and shattered grains) with pores clogged by fine rock flour. A high degree of skill is necessary to avoid scoring the surface and leaving curved scratches, grooves or light-coloured patches. The work is noisy and fatiguing to the operator. A great deal of dust is generated and as this will be siliceous (if sandstone or granite is being cleaned) or lead-bearing (from painted surfaces) and thus a health hazard, the operator and the public require protection. Dust may penetrate openings even in adjacent buildings or vehicles. The patina or darker coloured aged surface of stone is removed and thus it becomes lighter in colour so that differential abrasion produces patchy colouration.

Streaky, tarry or sooty deposits tend to foul or 'bind' the carborundum and reduce the cutting rate. Such deposits should first be removed by some form of washing with hot water or steam.

Where the surface of the stone is crumbling, hence is softer than the interior, the dry grinding exposes clean stone which is harder than the original. However, where the stone has a hardened skin (as do many limestones) grinding will remove the protecting surface and expose soft, easily erodible stone.

Examples of dry grinding include some bricks of the Court House at Windsor, Melbourne, and sandstone at the Supreme Court, Melbourne. An apparently successful example is the smooth ashlar sandstone of the ANZ Bank (corner of Exhibition and Bourke Street, Melbourne).

The GPO tower in Adelaide illustrates an inappropriate use of the method on dressed (picked, chiselled) Tea Tree Gully sandstone and carved (capitals, mouldings, string courses) of soft Bath limestone (Plate 9). Grinding has partly obliterated the interesting and historically valuable dressing textures, has left dirt in depressions (giving a spotty appearance) and has removed the protective outer skin from the limestone.

5.12 Redressing

Redressing the surface of stone or brick (by hammer and chisel or similar) to remove loose fragments or exfoliating surfaces may be necessary for reasons of safety (as on the Old Zoology building at Melbourne University). It is not normally regarded as a cleaning method, but may be the only feasible means of removing strongly adherent material such as render, plaster or paint. However, the surface may be left in a damaged and unsightly condition which requires correction, e.g. the cement render on the lower part of the sandstone wall of the Metcalfe Bond on the waterfront at The Rocks, Sydney, was removed this way by the Sydney Cove Redevelopment Authority and the surface then covered with sandstone veneer.

Correct restoration of both carved details and simple smooth-surfaced stone requires finishing with a chisel in the hands of an experienced mason.

Hand-held pneumatic chisels and related devices are used to remove substantial deposits of hard material from large areas of masonry. The deposits may be of decayed stone, cement or plaster render, thick paint, disfigured stone, etc. The surface of the stone is inevitably extremely damaged and may require complete cosmetic surface treatment such as stone veneering, plastering, rendering or painting.

A needle gun was used to remove paint from sand-stock bricks on St Luke's Church (1819) in Liverpool, New South Wales. The method is slow and damaging.

5.13 Blow Lamp

A blow lamp has been used to clean very soiled stone by thermal spalling of the surface,[70] but there appears to be no justification for the use of such an extreme method.

5.14 Some Special Cleaning Problems

5.14.1 Introduction

Special techniques[17,23,38,44,52] are required for certain types of intractable soiling, chiefly gypsum crusts, paint and various stains.

5.14.2 Gypsum Crust Removal

Gypsum is a common constituent of urban grime and is particularly prone to form crusts (mixed with soot, hydrocarbons and dust) on the undersides (soffits) of sills, cornices, string courses and parapets. The material is slightly soluble and is not very hard, but its removal is time consuming and tedious.

Methods suggested for its removal are as follows:

Water Soaking: It is common practice in England to soften the crusts on limestone by prolonged (up to a week) spraying with water then brushing them away. This method is time consuming and has not been effective with some gypsum crusts in Australia, particularly those combined with urban grime on sandstone.

Dry Abrasion: The crusts can be readily removed from plane surfaces by rubbing with a carborundum block, metal scraper or wire brush, then washing with water. However, dry abrasion is very difficult on intricate dressings or even on soffits with their shaped 'drips', and dry grinding can be very damaging.

Heat: Application of a blow lamp is said to cause the crusts to spring off. Gypsum will dehydrate on strong heating but this is likely to damage the stone and experiments with the method by the author have not been successful.

Chemical: Gypsum is more soluble in potassium acetate or EDTA solutions than in water and formulations such as the following have been suggested: 25 per cent disodium EDTA, 3 per cent ammonium bicarbonate, 5 per cent sodium bicarbonate and 6 per cent carboxymethyl cellulose. Experiments by the author have not been particularly successful.

Some success has been obtained[98] on statues with poultices containing urea and glycerine or ammonium bifluoride.

5.14.3 Paint Removal

Many old buildings have been painted; some as an original condition and others at some later date in order to protect the walls, prevent crumbling, water-proof the surface or to improve the appearance. Graffiti present related problems. That paint which is part of the original (as at Elizabeth Bay House, Sydney) or which cannot be removed without damage should remain or be replaced. Removal of paint from rock art presents similar problems.[25]

Selection of the most appropriate method for paint removal depends on the nature of the masonry substrate and of the paint but the matter becomes complicated where many layers of paint of different ages and types are present. Economic and other restrictions generally demand a single treatment which is capable of removing all of the types present.

Old lime wash or distemper can usually be removed by washing and scubbing but tiny patches left in pores may give a spotty appearance. Careful use of acid (acetic acid, that is vinegar, or very dilute hydrochloric acid) followed by copious washing should be effective.

Old shellac and varnishes may still be soluble in acetone or methylated spirit. Scrubbing may be necessary and residual stains may require bleaching with sodium hypochlorite. Modern polymer-based lacquers are more difficult to remove but generally respond to paint strippers, as do most modern paints. Alcohol tends to soften acrylic paints. Casein-based paint, old limewash or distemper made with milk or animal fat may soften by treatment with an enzyme.

The more intractable types of old, hard, lead and oil paints or modern types may need to be attacked more vigorously. Chemical treatment is preferable to abrasion as it damages masonry less and wet sand-blasting is a last resort. The following methods are used:

Commercial Paint Stripper: Proprietary paint strippers have not been designed for use on masonry but are effective on some surfaces. They commonly contain methylene chloride and benzene, even phenol and suffer from the disadvantages that they are expensive, dangerous, unpleasant to use, caustic and thus possibly damaging to stone, are not effective on old, hard, thick paint, and evaporate rapidly. They are useful for small areas, particularly for the removal of graffiti. Residues of paint and chemicals may be left in pits and cracks and hence such treatment should be followed by thorough cleaning by water jet or similar.

Chemical Formulations: Other methods of removing paint include scraping and rubbing with household scouring powder and steel wool, or scrubbing with one of the following solvent mixtures; methanol plus triethylamine, pyridine or morpholine (3:1); methanol plus polyethylene glycol (Carbowax); methyl acetone (10 parts), benzene (25 parts), denatured alcohol (18 parts) and ethylene dichloride (8 parts).

Caustic Soda: Caustic soda (25 per cent solution) is a cheap, traditional paint stripper which is generally very effective. It requires precautions to protect the operator and may cause great damage to porous stone, but it is likely to be less damaging than harsh abrasive methods.

Wet Grit Blasting: This is a rapid and effective method for removing even thick layers of old paint from masonry. It is widely used and comparatively inexpensive, but it is too damaging except for the hardest masonry or for surfaces which are to be later painted or plastered.

Dry Sand Blasting: This is a rapid and effective method of removing paint, but it is so damaging to masonry that its use is rarely warranted. The colour and surface texture of the masonry are changed and the area cleaned is usually left a lighter colour.

Steam Cleaning, Water Jetting: Steam-cleaning, or better still very hot water under pressure, will remove modern paints whose film blisters and breaks up or old paints which are loosely held. Low-to-moderate pressure water jetting can remove whitewash, distemper, degraded and blistered old oil paint, or paint which has been chemically softened.

Burning Off: Unwanted paint can be removed from many surfaces by the use of a blow lamp to 'burn off' (break down the paint film which is scraped off), but such a procedure is rarely used for masonry and is not recommended. Volatile oily compounds can be driven into stone to leave stains and the heat will tend to chip, fret or exfoliate weak stone. The surface remaining after cleaning is only suitable for repainting.

Hand or Power Tools: Paint can be chipped off with hand or mechanically operated equipment such as chisels, needle guns, etc. This method normally is slow, not effective in removing paint unless the masonry surface is also removed and leaves the surface in a damaged, bruised and unsightly condition.

Mechanical Abrasion: The use of carborundum stones, wire brushes, etc. is satisfactory in some cases. Abrasive grinding is only suitable for smooth surfaces and is possibly the only method applicable to soft stone although great care is necessary. Wire brushing can be used on rough surfaces but may leave paint in cracks.

5.14.4 Graffiti Removal

Graffiti are generally applied with paint spray cans (enamel and metallic paints), lipsticks, felt-tip markers or crayons. Paints are the major problem and different formulations require different treatments.

The nature of the material surface or substrate is important. Many graffiti removers are effective on smooth non-porous surfaces, but few on rough, porous stone or concrete.

If the graffiti can be treated before the paint dries, much can be removed by patting with absorbent cloth or paper, dampening with solvent or wiping with a cloth, followed by washing with hot water plus strong detergent. Care must be taken with solvents on wet paint as the paint may spread and penetrate the pores. If the paint is dry, then the first treatment should be with commercial paint stripper. The most effective procedure[36] has been to use three different specified strippers in a certain order. Brushing with a hard nylon or soft, fine non-ferrous metal brush will assist. Any remaining residue will require more drastic treatment such as with a paste of caustic soda, soda ash and water (thickened). The approach should be strictly chemical, using known procedures and mechanical processes such as wet or dry sand blasting or abrasion should be used as a last resort only after all else fails. Faint residual staining may be treated with bleach. Acids are rarely useful; they may fix the stain more firmly and deeply or cause additional staining by reaction with the masonry.

A detailed examination[36] has been made of the problem and 99 potential graffiti-removers have been tested, mainly on paints applied to limestone and sandstone substrates. The potential removers were mainly commercial paint strippers.

Acids, alkalis and other chemicals are commonly applied to graffiti in Australia without knowledge of the paint used or the substrate. Such treatment is generally ineffectual or accentuates the problem.

5.14.5 Salt Removal

The removal of salt from stone is an important aspect of cleaning and preservation[7,15,41,42,72] as intergranular and subsurface salts accelerate decay and prevent remedial treatment.

Salts (mainly chlorides, sulphates and nitrates of sodium, potassium, ammonium, magnesium and calcium) accumulate in the lower part of walls due to rising damp from saline soils, in places where salt has been stored, and are also derived from old concrete, bleeding mortar, sea spray, splash from paving or from falling damp.

The ease of removal depends mainly on the size, shape, abundance and degree of interconnection of the pores of the masonry, and to a lesser extent on the composition of the salts and their distribution and concentration in the wall. Levels as high as 20 per cent of salts are known and proportions greater than 0.5 per cent may cause appreciable decay. It is desirable to reduce the level to below 0.5 per cent.

Surface salt should be brushed off as a dry powder then the salt level reduced by continuously sprinkling with a fine mist of water.[15,63] Less than 200 litres per hour of water are sufficient to feed six sprays covering about 7 square metres and washing may be carried out for as long as 14 days.

Continuous wetting of a porous stone, however, may cause deep penetration of the salts which may emerge on the inside surface or later return to the outer surface as the water dries out, hence the application of a poultice may be more effective in reducing the salt content.[15]

Hot, near-boiling water is more effective for most salts but not for gypsum which is more soluble in cold than in hot water. Alkaline efflorescences and calcite crusts can be attacked with dilute acid (acetic or hydrochloric) to soften hard deposits but the resultant soluble salts still need to be flushed away. The salty run-off must be collected and directed away from the building, not allowed to soak into the soil at the base of the wall.

5.14.6 Stain Removal

Porous masonry is susceptible to coloured staining, the most important being due to metals (iron, copper and bronze), asphalt, tar, chewing gum, smoke, perspiration, oil, grease, wine, bird droppings[49] and organic growths.[53]

Iron: Rusty iron stains may be due to rusting steel reinforcing, fixings, rails, pipes or roofing, to decay of iron minerals (for example pyrite in the Tynong granite of the Shrine of Remembrance in Melbourne) or to iron particles from trains or trams.

The general principle of removal is to reduce the compound from the ferric to the ferrous state (from the insoluble to the soluble) by a reducing compound (bleach) or alternatively to disintegrate the rust with potassium hexacyanoferrate. The iron is then removed in the soluble form by means of a complexing (chelating, sequestering) agent such as the alkali salt of an organic hydroxy carboxylic acid (sodium citrate, tartrate or gluconate) or sodium ethylenediaminetetra-acetate (EDTA) in an alkaline condition.

A simpler but usually less effective alternative is to remove the iron as a colourless soluble complex by attack with hydrofluoric, oxalic, phosphoric or formic acid (5-10 per cent) or sodium or ammonium bifluoride. A solution of sodium citrate (15 per cent) mixed 1:1 with glycerol as a poultice is simple; diammonium citrate is sometimes more effective.

Deep stains on concrete can be attacked with a 15 per cent solution of sodium citrate, followed by a sprinkling of sodium hydrosulphite crystals and completing with a poultice.

Copper and Bronze: Copper and bronze are corroded by water, acids derived from polluted air or from solutions containing organic acids (from rotting wood), salts such as chlorides (corrosive under acid conditions), acetates (corrosive under neutral conditions) and ammonia (from organisms). The initial tarnish on copper is bluish and composed mainly of copper sulphate derived from aerosols containing oxides of sulphur or basic sulphates (particularly ammonium sulphate) from polluted urban atmospheres. With time the tarnish becomes the common green colour and contains more basic and less soluble compounds such as brochtite (probably basic nitrate and chloride).

Commercial grade sheet (AS1566, alloy 122) commonly used for flashing is a phosphorus deoxidised copper; it differs in its patina and corrosive behaviour from high-conductivity copper used for lightning conductors, or from bronze.

The metals copper and bronze can themselves be cleaned with mixtures such as a whiting plus ammonia, pumice powder in mineral oil, nitric acid and gum arabic, orthophosphoric acid and sodium nitrite or commercial metal cleaners (e.g., Silver Dip, Brasso). Coarse abrasive should not be used, nor should steel wool (some contains a corrosion inhibitor which stains copper). Very heavy crusts can be softened with Calgon then attacked with sulphuric acid which leaves the copper a pink colour. This can be treated with silver nitrate, then the silver powder brushed away.

Surface run-off from rain carrying acids will pass from the metals to become absorbed by the masonry below, where it can cause coloured stains and decay. Known treatments for bronze and copper stains include the following:

(a) **Bronze stains:** ammonium or aluminium chloride with a little liquid ammonia in water, thickened to a paste with talc (or similar) to make a poultice.

(b) **Copper stains:**
1. Ammonia or ammonium chloride + ammonia, as liquid or poultice
2. Formic acid (10 per cent)
3. Caustic soda + detergent + sodium boroglucamate + sodium ethylene diamine
4. Hydrofluoric acid (0.2 per cent applied only for a few minutes)
5. Sulphamic (amidosulphuric) acid, 10 per cent aqueous. Acid treatment may be neutralised with alkali before intensive final washing.

Other stains: The removal of stains from stone, brick or concrete poses special problems and a very large number of treatments (many patented) exists in the literature. Treatment generally consists of the application of a solution (followed by washing) or the application of a poultice or bandage. Stain removal is facilitated by first degreasing the area with solvent, applying solutions which are hot, using repeated applications of dilute solutions rather than a single concentrated solution, rinsing with water before and after each treatment, and combining the active solutions with an absorbent poultice.[61]

The following table shows reagents which have been used.

Nature of Stain	Treatments
Asphalt, bitumen, tar and brown stains under soot	1 If thick, freeze with ice or dry ice, chip off. Wash with petrol, benzene. 2 Liquid, bandage or poultice;kerosene, carbon tetrachloride, trichloroethylene, toluene or benzol. 3 Benzene + ammonia + methanol; 1:1:1. 4 Carbon tetrachloride (9 parts) + benzene (1 part) + detergent (1/10th part).

Nature of Stain	Treatments
Chewing gum	1 Freeze with dry ice and pick off (small areas). 2 Steam clean (large areas of paving). 3 Scrape off, treat residue with a solvent such as denatured alcohol, carbon tetrachloride, carbon bisulphide or chloroform, then wash with hot water plus detergent, Calgon or scouring compound.
Smoke or perspiration	1 Scrub with dilute glycerol. 2 Trichloroethylene poultice. 3 Trisodium phosphate (Calgon) + bleaching powder + talc poultice.
Urine	1 One kilogram of trisodium phosphate (Calgon) in 5 litres of hot water, added to a paste of 350 grams of bleaching powder in water, mix, dilute to 10 litres , allow to settle. Apply poultice of liquid plus talc.
Stains left after removal of cryptogams (mould, lichen, moss or bacteria)	1 Trisodium phosphate and laundry bleach. 2 Household bleach. 3 Bleaching powder (calcium hypochlorite). 4 Dilute ammonia. 5 Formalin (40 per cent solution of formaldehyde). 6 Oxalic acid (5 per cent plus household bleach). 7 Citric acid (15 per cent). 8 Proprietary acidic rust-removing concrete cleaner. 9 Brush on sodium nitrate solution (15 per cent) cover with a layer of sodium dithionite crystals covered by a poultice of whiting and water. Wash. 10 Proprietary fungicide (e.g. Santobrite).
Grease, oil, food stains, hand marks	1 If wet, cover with dry clay absorbent or Portland cement. Dry, brush and wash with hot water and detergent or solvent. 2 Scrape, scrub with hot water and detergent, Calgon or scouring compound. 3 Application of a solvent as a liquid (with scrubbing) or as a poultice. Follow by a scrub with hot water and detergent. Solvents include benzene, white spirit, kerosene, petrol, carbon tetrachloride, proprietary dry cleaning agents, di-, tri-, or tetrachloroethylene. 4 Proprietary alkaline degreasing agent. 5 Poultice of trisodium phosphate (1 part), sodium perborate (1 part), talc (3 parts) in a hot soft soap solution in water.

6 SELECTION OF CLEANING SYSTEM

6.1 Principles

Cleaning masonry is complex and expensive because consideration must be given to the type of building material, to its degree of weathering, to the type and degree of soiling, to the degree of cleaning required, to the safety of the operator and of the public, to the protection of the surroundings and to requirements of time and costs. The risks in cleaning and the need for proper planning are emphasised.[1,73] The number of possible variables applying to each building generally means that a cleaning *system* which is a combination of *methods* must be devised (Plate 14).

An inappropriate procedure may be ineffective, may cause irreversible damage (which may not be apparent until months or years later) or may be unnecessarily expensive. The improvement due to cleaning may be disappointingly brief in polluted environments; use of an aggressive cleaning method on a building in a very dirty environment is not good practice as the necessary repetition of cleaning causes damage.

The Code of Practice on Stone Cleaning and Restoration (1974) produced by the Federation of Stone Industries, London (the 'FSI Code') is useful, but overseas experience should not be applied to Australian masonry exposed to Australian conditions without due consideration. Methods appropriate for London and Paris (limestone buildings in a polluted environment with high rainfall and occasional freezing) may not be suitable for sandstone, bluestone, brick or stucco walls in Australia, especially in clean environments with a low rainfall and temperate climate.

6.2 Degree of Cleaning Required: The 'Neat and Tidy Syndrome'

It is acceptable that an old building which is recycled by conversion to shops, a restaurant or other commercial activity will be given an appropriate appearance, that is, it will be clean, bright, neat, tidy, possibly eye-catching and with durable surface and other finishes. However, the aims and techniques of *restoration* differ from those of *adaption* in that they must conserve a valuable part of the heritage, preserve a fragment of history and retain certain qualities of the building.

A clean, new appearance is generally incompatible with restoration. The 'neat and tidy' syndrome (the 'whiter than white' or 'New Blue Omo' school[16]) which is expressed as a desire to make an old building clean and new is common in Australia and is an indication of a lack of understanding of restoration (Plate 15).

Most old buildings benefit aesthetically from cleaning during restoration as unsightly blemishes are removed. The architectural unity may be returned, and valuable details, colours

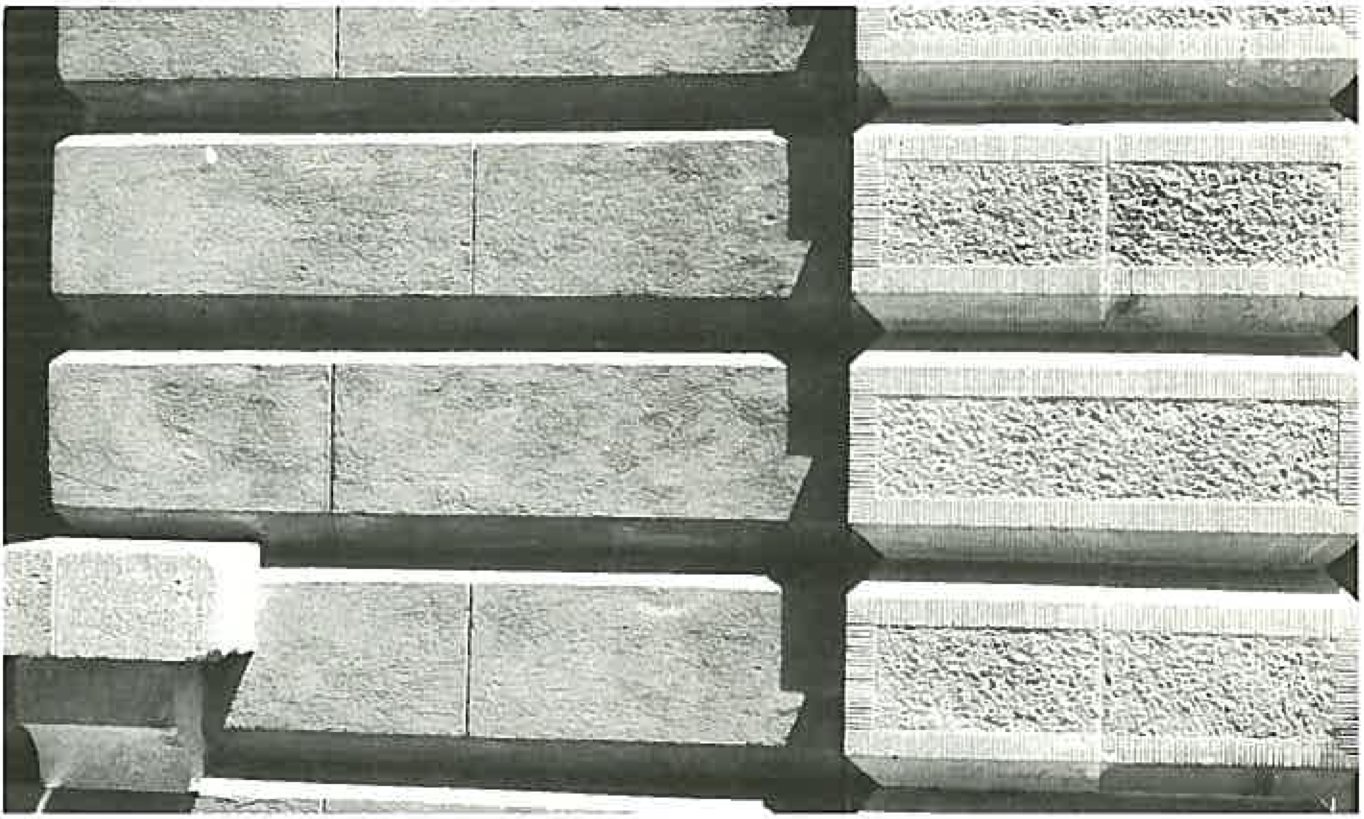

Plate 14: Correct cleaning may be complex. The sandstone quoins of the Eagle Chambers (Adelaide Town Hall) were so defaced as to require replacement in newly dressed stone. The stucco on the left was discoloured and patched. Hence it was washed, then given a cement-sand wash to give a uniform finish.

Plate 15: The degree to which cleaning is taken is a matter of judgement. The Old Legislative Council Building in Adelaide after 'restoration' in 1979-80 no longer looks 130 years old.

and textures revealed but overcleaning must be avoided. Those responsible for restoration must be able to resist uninformed criticism from those who consider that an old building should look new.

6.3 Selection of a Cleaning Method

Table 1 is a guide to assist in the selection of an appropriate cleaning method. It considers four variables:

- I_R, the degree of resistance of the masonry to damage;
- I_T, the tenacity or degree of difficulty of removal of the soiling;
- I_S, the severity or potential of the method for damaging the masonry;
- I_C, the cleaning ability of the method.

The table emphasises the following points:

1. Cleaning methods differ widely in their ability to remove soiling and to cause damage.
2. Different types of soiling differ widely in their tenacity.
3. In general, the more aggressive the cleaning method, the more tenacious the soiling it can remove, but at the price of a greater degree of damage.
4. Less tenacious soiling can be removed by the less damaging methods.
5. If a single effective cleaning method is chosen, then considering the range of materials in most buildings and the range in type and degree of soiling, it would have to be one of the more aggressive in order to be effective.

Table 1 can be used as a *general guide* to the selection of a cleaning method in the following way:

(a) The masonry material and type of soiling are identified then the tenacity assessed (I_T).

(b) A number of cleaning methods are provisionally selected on the basis of cleaning ability, that is, I_C must be as high as I_T.

(c) The method should be selected such that I_S does not exceed I_R and is as small as possible.

It is emphasised that the index figures are subjective and act only as guides.

As an example, consider removing soft urban grime ($I_T = 3$) from moderately hard sandstone ($I_R = 3$). Methods which have I_C of 3 or 4 are considered and manual scrubbing with cold water selected ($I_C = 3$). This has an I_S of 2 to 3 and therefore should not damage sandstone with an I_R of 3. The method should therefore be tested; if not successful, a method with higher I_C should then be considered. However, if high pressure water jetting plus wire brushing were selected ($I_C = 6$) then this has an I_S of 7 and would damage masonry with an I_R of 3.

The basic principle to be followed is that the *cleaning method must not damage the fabric.* Therefore the least damaging method or combination of methods must be sought to remove the soiling to an acceptable degree (this may mean that it is not removed entirely).

The basic principle in selecting a safe, effective method is to carry out tests in secluded areas, beginning with the least aggressive procedures (such as water washing and scrubbing), then testing those which are increasingly rigorous (such as chemical) before considering the intensive methods. The aim, is generally for a high I_C with a low I_S, but over-cleaning and an 'as new' appearance should be avoided and the method with the lowest intensity capable of removing grime to the degree desired should be selected for each unit of the building, bearing in mind practical factors such as cost, speed and the availability of labour. Thus a cleaning *system* can be formulated to range from mild methods for sensitive or lightly soiled areas to more aggressive *methods* for the highly soiled parts.

Planning of the cleaning operation or calling of tenders then follows close specification of the method; this is efficient and economical.

6.4 Preparation for a Cleaning Programme

Any programme of building conservation should be preceded by a survey in order to allow correct planning, scheduling, costing and tendering as well as to avoid ineffectual or damaging treatment. A pre-cleaning survey will determine the following:

(a) The identity and condition of the various masonry types and associated materials (in order to estimate their resistance to damage).

(b) The identity of the soiling and staining.

(c) Possible cleaning methods. The tenacity of the various types of soiling is first estimated by a graduated series of small-scale tests involving washing, and scrubbing with various solvents and the application of a few simple chemicals.

If commercial cleaning operators are to be used, a number should be invited to carry out demonstration tests on a square metre or so of selected surfaces, using the survey data as a basis for the selection of methods. The decision as to the method or methods to be used for the total programme will be based on the acceptance of a certain degree of cleaning coupled with a requirement for a minimum amount of damage.

Access to the building during the survey is a problem and detailed examination of some parts may need to wait until scaffolding for the whole job has been erected. The cost of scaffolding can be a significant proportion of that for cleaning a building.

In general, cleaning should be one of the last parts of restoration and should follow repair and replacement. However, in some cases it may be necessary to clean a building (at least in a preliminary fashion) in order to identify materials and reveal details and faults.

(d) Attention must be given to the protection of other parts of the building, the public and the operators. Scaffolding must be screened with heavy duty plastic sheeting, preferably surrounded by wire mesh (for the safety and weather-protection of the workmen and the safety of the public). If wet methods are to be used, provision must be made for adequate draining (a temporary gutter should be constructed against the base of the walls and the run-off taken well away), and openings (ventilators, windows, doors, etc.) sealed up.

6.5 Operator Safety During Cleaning

Many cleaning processes are unpleasant for the operator and some are dangerous, but observations of cleaning practice in Australia suggest that adequate safety precautions are commonly not observed.

Care is necesary with handling and use of many chemicals used in cleaning; these include hydrochloric acid, caustic soda, chlorinated hydrocarbons, benzene and fungicides.

The application of acids (particularly of hydrofluoric acid or ammonium bifluoride) is very dangerous but it would appear that the excessive toxicity and danger of these chemicals is not appreciated. United Kingdom Building Research Establishment Advisory Service TIL (1975)[20] provides useful information. Reference should be made to a work such as Driesbach[30] (pages 4-7, 164-7) before operators are allowed to use these chemicals, and details of first aid and medical treatment, including instructions to employees as given by Mitchell[48] (undated) should be noted. Operators using these chemicals should be supplied with appropriate protective clothing. Scaffold tubes should have their ends sealed before use, scaffold boards should be lifted as soon as possible using gloves, and all scaffolding components thoroughly washed during dismantling.

Dry mechanical grinding and sand blasting (particularly of sandstone and granite) produces fine siliceous dust which produces a dangerous risk of silicosis. Such processes are not permitted in some places by health and industrial regulations and protective equipment such as face masks or ventilated helmets are specified. The author has observed many instances where operators produce a visible haze of dust and grossly exceed levels permitted under regulations issued by Departments of Health and of Labour and Industry. Employees of State and Commonwealth Government Departments have been observed to work under unsatisfactory conditions and without due regard for health.

Dry grinding or dry sand blasting of old painted surfaces may produce fine particles of lead paint which can be a hazard if inhaled.

SELECTION OF A CLEANING METHOD

TABLE 1

(1) Masonry Material	I_R (Index of Resistance to Damage)	(2) Soiling	I_T Index of Tenacity
	0		0
Lime mortar, limewash, old & soft Limestone or plaster, soft Lime mortar, hard Paint, old, soft Brick, underfired, sandstock Cement render, stucco, old Weathered sandstone or bluestone, soft		Loose dust Climbing plants, moss Fungi, algae Lichen Loose flaking paint Salt efflorescence	
	2		2
Concrete, old, soft Composition mortar Sandstone, moderately hard Brick, moderately burnt Paint, old, hard Cement-rich mortar, concrete Limewash, hard		Salt staining Old limewash Hard limewash, distemper Oil, grease, foodstains Soft urban grime	
	4		4
Marble, soft Brick, well-burnt Limestone, hard Marble, hard		Bird droppings Metallic stains Plaster Soft decayed stone Soft gypsum crusts Tar Old hard paint	
	6		6
Sandstone, hard Slate, hard and sound		Damaged stone Soft cement droppings Moderate urban grime Hard, black gypsum crusts	
	8		8
Bluestone (blocky argillite), hard Bluestone (basalt) Clinker brick Granite Quartzite		Modern plastic paints Hard cement droppings Heavily pigmented old paints Hard urban grime	
	10		10

(3) Cleaning Method	I_S (Index of Severity) I_S should not exceed I_R	(4) Cleaning Method	I_C (Index of Cleaning Ability) I_C must be as high as I_T
	0		0
Light radiation Dry brushing Laser Water misting Very low pressure water washing Organic solvents, paint stripper Steam cleaning		Light radiation Dry brushing Laser Blow lamp Very low pressure water washing	
	2		2
Manual scrubbing, cold water Manual scrubbing, hot water & detergent Low pressure water jetting Mechanical scrubbing Chemical (HF, NH_4F_2, alkali)		Steam cleaning Organic solvents Low pressure water washing Manual scrubbing, hot or cold water, detergent Water misting Needle gun Soft, abrasive sand blasting	
	4		4
Soft, abrasive sand blasting Medium pressure water jetting		Medium pressure water jetting Mechanical scrubbing Paint stripper Manual abrasion (carborundum block) Manual wire brushing Chemical (HF, NH_4F_2, alkali) High pressure water jetting	
	6		6
Manual abrasion (carborundum block) Manual wire brushing High pressure water jetting Very high pressure water jetting Wet sand blasting		Dry mechanical grinding Very high pressure water jetting	
	8		8
Needle gun Dry sand blasting Blow lamp Manual redressing Dry mechanical grinding Mechanical redressing (pneumatic chisel)		Dry sand blasting Wet sand blasting Redressing	
	10		10

General Guide to the Selection of a Cleaning Method

(a) Deduce I_T by investigation.
(b) Select I_C based on I_T so that:
(c) I_S does not exceed I_R.

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APPENDIX A

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