Canal & River Trust

APPROVED PROCESS

Approved Process: HERITAGE WORKS

Management Brief

This Approved Process describes 'best practice' standards for works of repair to heritage assets (i.e. historic waterway buildings and structures).The purpose of these standards is to ensure a consistent, approved approach to practical heritage conservation on the Canal & River Trust estate.

The process forms the third tier in the Trust's hierarchy of heritage management documents and should be read in conjunction with the Mandatory Standard: Heritage, and the Approved Process: Heritage Management.

This Approved Process should be drawn to the attention of anyone maintaining, repairing or specifying works to heritage assets.

This process supersedes the former BW Heritage Standards (2001).

Status

This process should be followed by default and is effective from 1 March 2011. It will be reviewed annually and will apply until an updated or revised version is formally issued.

Responsibility

It is the responsibility of all heads of departments and functions and all Trust managers and supervisors who deal with heritage assets to ensure that this approved process is followed. It is especially important that Trust staff working on heritage assets communicate with heritage advisers before and during works, particularly where unforeseen circumstances arise.

Performance monitoring

- Routine checks – Z4 and ZQ notifications will be checked each quarter by heritage advisers to identify issues and record incidents of non-compliance.
- Operations Score – the quarterly scorecard will report on general compliance for heritage.
- State of the Waterways Heritage report – the head of heritage will produce an annual report summarising progress in meeting the objectives of this process.
- Internal audit – will periodically look at the effectiveness of this process.

Authorised by:

Operations Director **Date:** 17.09.2012

Custodian: Nigel Crowe, Head of Heritage.

Amendment Record

Issue No.	Issue Date	Changes
1	Feb 2011	Supersedes Heritage Standards 2001 to become Approved Process AP-OPS-93.
2	Sept 2012	Updated in line with Canal & River Trust standards

CONTENTS

1. Heritage Assessments & Management Agreements

1.1 Types of assessment

There are a number of different heritage assessment tools that can be used in different situations. Almost all works to heritage assets, apart from minor repair or maintenance will require some form of assessment, including an Environmental Appraisal with supporting photographs (before, during, after). An appraisal may well point the way to further assessment, including one of the following.

1.2 Rapid heritage audit

A rapid heritage audit is a brief written overview of a site. It may be required as part of an indicative development proposal, a disposal, or a package of engineering works. The intention is to raise early awareness of the importance of a site and to flag areas that may need more investigation.

A rapid heritage audit is quick and basic, but it should include the following information:

- background history – existing sources of information, maps, surveys
- site visit observations – free text and/or annotated sketch drawings
- photographs of the site and its setting
- short assessment of significance
- further work requirement

1.3 Heritage impact assessment

A heritage impact assessment is a response to a proposal to develop, alter, or otherwise modify a heritage asset. It may be no more than a memorandum or a letter relating to a proposal, or it may take the form of a short written report. Either way, it should come to a judgement on whether a proposal will conserve or diminish the value of a heritage asset. In order to come to such a judgement it will be necessary to assess and understand the significance of a heritage asset. A heritage impact assessment should do the following:

- explain why an asset has heritage value
- describe how proposed works will affect its significance
- explain why a particular approach is adopted
- recommend conservation measures where necessary

A heritage impact assessment may not necessarily be conservation led, but where a heritage asset is likely to be impacted negatively then it must make a case for the impacts being the only viable solution. Under such circumstances it must also recommend mitigation measures and these must be considered in relation to the significance of the asset.

1.4 Heritage assessment

A full-blown heritage assessment (sometimes referred to as a heritage study or heritage survey) is an in-depth analysis of a heritage site or structure. It establishes a site in its wider historical context and assesses its significance in detail. It systematically examines a site and lists out, usually in gazetteer form, those elements of it that are significant.

A heritage assessment also makes practical recommendations for managing and conserving heritage elements of a site. Depending on circumstances, it should include all or some of the following:

- documentary research – using primary & secondary records, maps and surveys
- photographs of the site and its setting
- fieldwork records
- site surveys
- plans showing phasing and zoning of the site

- an assessment of significance
- recommendations for any further work

Heritage assessments will usually be prepared in advance of development works that may be commercially driven or for engineering projects or other purposes.

1.5 Conservation statement

A conservation statement is essentially an outline conservation management plan. It is based on currently available knowledge and provides an overview of a heritage asset. It should be short and concise and should identify the following:

- key features
- significance
- main conservation issues
- outline policies
- further actions required

Conservation statements are not intended to be closely researched definitive documents. But they can usefully highlight essential heritage conservation information at the outset of a project.

- A conservation statement might follow on from a rapid heritage audit of a site or structure and will often point the way towards a full-blown conservation management plan.

1.6 Conservation management plan

A conservation management plan is a crucial document that looks in detail at ensuring the future viability of a heritage site or structure and conserving its heritage significance in future development proposals. It can be used to convince others that a heritage site can and should be conserved. It is also a key to unlocking funding.

A conservation management plan contains three main elements:

- a statement of significance
- a conservation policy
- management guidelines

It is a written document that essentially does the following:

- identifies and describes why a heritage site is significant and worth conserving
- sets down policies for conserving the significant heritage values of a site
- defines the process of practical management necessary to conserve and deal effectively with a heritage site
- sets a timescale for consultation, implementation and review of the plan

A conservation management plan does not always need to be a long document. Sometimes a shorter conservation statement will suffice.

1.7 Management & heritage partnership agreements

Management agreements for the Trust's historic sites take two forms. The first is the scheduled monument management agreement (permitted under section 17 of the Ancient Monuments and Archaeological Areas Act, 1979). This type of management agreement relates specifically to a scheduled monument and its boundaries. The second type is the Heritage Partnership Agreement that BW and the Trust have been instrumental in pioneering for a number of sites and linear lengths of waterway. HPAs are not yet enshrined in law but in England and Wales it is likely that such agreements will form part of the forthcoming changes to the heritage protection system. They are basically a written understanding between the owner of a designated asset or series of designated assets and the regulators; namely the local planning authority and sometimes English Heritage or Cadw (in Wales).

A heritage partnership agreement should include the following:

- an agreed framework for conserving a heritage asset
- an agreed conflict resolution process
- avoidance of the need for misunderstanding and lengthy consultation procedures

In the waterways context HPAs can be applied to complex sites like boatyards or maintenance yards, or large buildings like warehouses, but they are likely to be most beneficial when applied to lengths of waterway or even entire canals.

HPAs are at best a set of agreed indicative guidance rather than a set of 'binding rules'. All parties need to agree to them and they may change and need re-drafting over time.

PREPARATION

Performance Criteria

1. The need to carry out an assessment of a particular type is established and agreed with interested parties.
2. The required data output from the assessment is identified.
3. An assessment process, including methods and techniques, is selected and is appropriate for the output required.
4. Information is sought which is relevant to the assessment.
5. The site is investigated and the assessment's requirements and/or constraints are appraised and recorded.
6. Relevant permissions are obtained and confirmed as accurate.
7. Account is taken of health and safety hazards and adequate provisions made.
8. Relevant insurances are checked (for e.g. archaeological contractors) as sufficient for the intended work.
9. All personnel assisting in the assessment are adequately briefed with particular regard to method, use of equipment and safety.

THE ASSESSMENT AND ITS OUTPUT

Best Practice Indicators (All/some will apply)

1. The assessment is accurate, thorough and complete (for the intended purpose) thereby reducing risk and uncertainty in related activities.
2. The assessment is carried out in accordance with best professional practice.
3. Correct equipment and instruments are used correctly, calibrated where necessary and properly maintained.
4. The assessment process does not damage or harm in any way the fabric of the buildings, structures or their surroundings.
5. Due account is taken of relevant environmental factors.

6. All work complies with the Trust's Health & Safety requirements.
7. The assessment takes account of adjacent buildings, structures or elements which may be in the ownership of others and of historic importance.
8. Actual or potential causes of failure or decay are identified and clearly described.
9. The assessment includes an analysis of materials and descriptions and results of tests where necessary.
10. Where observed data is inconsistent with other information, further investigations are made to clarify the inconsistencies.
11. Where accurate inspection and measurement have not been possible the reason for this is clearly explained and communicated to interested parties.
12. Expert advice is sought in cases of difficulty.
13. The assessment documents (drawings, notes, reports etc) are accurate, complete and legible to non-specialist readers.
14. The assessment drawings include, where appropriate, 'full size' details of important features of the building or structure.
15. An interpretation of data, fault diagnosis and advice, based on the assessment data, is provided for interested parties.
16. One copy of the assessment documents is deposited in an 'approved archive', such as the Waterways Archive or the relevant county historic environment record (HER).

2. Archaeology

2.1 Archaeological recording

Archaeology is a specialist area of the Trust's heritage work and usually requires expert consultants.

The following may require archaeological recording:

- works to listed buildings or scheduled monuments
- works to a site registered on a Historic Environment Record (HER)
- works requiring planning permission
- conservation management plans
- emergency works involving ground breaking

The level of investigation will depend on the status of the site and the nature and extent of any intended work.

Archaeological investigations usually involve one or more of the following:

- desk-based assessment
- evaluation involving trial trenches
- watching brief
- salvage recording
- excavation

Of these by far the most common at the Trust is archaeological desk-based assessment.

2.2 Archaeological desk-based assessment

An archaeological desk-based assessment will usually be required in response to one or more of the following:

- development proposals for a site
- listed building or scheduled monument consent
- an environmental impact assessment
- preparation of a management plan

An archaeological desk-based assessment is intended to assess the known and potential archaeology of a site. It results in a written document containing either copies of or information about the following:

- documentary sources
- maps and plans
- photographs

All or some of these will be collated to identify the character, extent and potential archaeological resource of a site. The assessment may also make recommendations for further archaeological works, including the following:

- a strategy to record, conserve and manage the archaeology of a site
- further investigation; evaluation or watching brief
- further research

Desk-based assessments may be requested by local planning authorities or government agencies or by the Trust's own managers. In all cases it is important not to proceed before a written brief has been agreed with the relevant county archaeologist.

PREPARATION

Performance Criteria

1. The need to carry out archaeological recording is established and agreed with interested parties.
2. A recording process, including methods and techniques, is selected and is appropriate for the output required.
3. Information is sought which is relevant to the recording.
4. Relevant permissions are obtained and confirmed as accurate.
5. Account is taken of health and safety hazards and adequate provisions made.
6. An environmental appraisal is raised and correctly validated with any conditions met before work commences
7. Relevant insurances are checked (for e.g. archaeological contractors) as sufficient for the intended work.
8. All personnel assisting in the recording are adequately briefed with particular regard to method, use of equipment and safety.

THE ASSESSMENT AND ITS OUTPUT

Best Practice Indicators (All/some will apply)

1. The recording is accurate, thorough and complete (for the intended purpose) thereby reducing risk and uncertainty in related activities.

9. The recording is carried out in accordance with best professional practice.
10. Correct equipment and instruments are used correctly, calibrated where necessary and properly maintained.
11. The recording process does not damage or harm in any way the fabric of the historic buildings, structures or their surroundings.
12. The recording takes account of adjacent buildings, structures or elements which may be in the ownership of others and of historic importance.
13. All work complies with the Trust's Health & Safety requirements.
14. The method of work complies with actions in the environmental appraisal.
15. Where observed data is inconsistent with other information, further investigations are made to clarify the inconsistencies.
16. Where accurate inspection and measurement have not been possible the reason for this is clearly explained and communicated to interested parties.
17. The recording documents (drawings, notes, reports etc) are accurate, complete and legible to non-specialist readers.
18. An interpretation of the recording is provided for interested parties.
19. One copy of the recording documents is deposited in an 'approved archive', such as the Waterways Archive or the relevant county historic environment record (HER).

3. Project Planning & Specification

3.1 Background

A key element in the development of a successful heritage project is ensuring that the project is based upon a detailed knowledge and understanding of an historic site or structure and its issues. Before embarking on a programme of works it is essential to establish the extent and cause of any underlying defects to be rectified, and then use this information to guide the development of the project and project team.

It is also important that projects are developed allowing sufficient lead time for necessary heritage consents to be obtained. This can take up to 15 weeks for certain sites. Heritage advice should therefore be sought at an early stage.

3.2 Conservation repair philosophy

Prior to the development of the project specification, it is important that the Trust's over-arching conservation philosophy is adopted to guide the development and scope of the works.

The Trust advocates a philosophy of honest minimum intervention when considering repairs to its structures. Generally repairs carried out should be the minimum required to maintain the integrity of the structure and completed in a way that makes no attempt to disguise or artificially age the work. It may be appropriate to datemark major repairs so that these are apparent to future generations.

3.3 Project planning

The process of project planning will obviously not be identical for all heritage projects; and should be undertaken in accordance with the Trust's standards. The following heritage processes should be followed.

- Appointment of project team taking into account the location and scope of the project. This team should include a heritage adviser.
- Sufficient information is made available to allow accurate identification of defects and remedial works following survey. Additional specialised survey work is commissioned if required.
- Identification of project objectives and required outcomes.
- General works methods and scope are evaluated and agreed within the project team, including assessment of heritage suitability.
- Statutory requirements are identified, with delivery method agreed.
- Identification of proposed project timetable (in addition to this there should be associated assessment of implications of seasonal working on materials such as lime mortars).

3.4 Project Specification

Once project planning is complete, preparation of the detailed specification can be undertaken. Once again this should take into account the heritage implications of the proposed works.

- The specification names the type of contract to be used and identifies any special conditions or clauses to be taken into account.
- The specification defines preliminaries i.e. full details of the requirements for the execution of the works with particular reference to site management and operations.
- Due reference must be made to information held in survey drawings and associated assessments.
- Chosen methods are evaluated and agreed by the project team as being suitable for the asset.
- All works are covered by detailed specification and method statements which take into account the heritage implications of the project in a clear, concise and understandable format including, where appropriate, cross references to associated documents.
- The specification provides full and accurate details of material specifications and requirements for the project including, where appropriate, sources of heritage materials.
- The specification is complete, well-structured and presented in a form facilitating its use by interested parties.
- The specification accurately identifies the levels and standards of workmanship expected within the project.
- Works information packages should include details of required heritage skills to undertake the project, along with criteria (such as references or CV's) to allow assessment of potential contractors' capabilities and abilities to deliver works.

3.5 Drawings

In addition to the works specification, drawings and other graphic information form a key part of any conservation project. They should:

- Take full account of survey works completed.
- Have a clear purpose and be relevant to the project.
- Be cross-referenced to the relevant specification or method statement.

- Be of sufficient scale and detail as relevant to their element of the project (i.e. drawings of a detail element of the works should be of a larger scale than simple site arrangement plans). Equally where applicable, isometric drawings should be considered to illustrate detail.
- Distinguish clearly any differences between existing and new fabric.
- Show temporary or protective works where applicable.
- Be cross-referenced to an up-to-date drawing register to allow changes in drawings to be recorded throughout the project.
- On completion a set of ‘as built/as repaired’ drawings should be completed and stored within project files and approved archives for future reference.

PREPARATION

Performance Criteria

1. All personnel involved in the project are adequately briefed with regards to any heritage designations and requirements.
2. The philosophy, scope and outcomes of the project are agreed by all interested parties.
3. The project team has all required skills.
4. All methods and specifications proposed are established and agreed with interested parties.
5. A recording process, including methods and techniques, is selected and is appropriate for the output required.
6. Information is sought which is relevant to development of the project specification.
7. Relevant consents are obtained and confirmed as accurate.
8. Account is taken of health and safety hazards and adequate provisions made.
9. Relevant insurances are checked (e.g. for contractors) as sufficient for the intended work.

OUTPUT

Best Practice Indicators (All/some will apply)

1. The specification is accurate, thorough and complete (for the intended purpose) thereby reducing risk and uncertainty.
2. The works are carried out in accordance with best practice.
3. All consents and conditions are adhered to.
4. Correct equipment and instruments are used correctly, calibrated where necessary and properly maintained.
5. The works do not cause detriment to, or damage in any way the fabric of any historic buildings, structures or their surroundings.
6. Due account is taken of relevant environmental factors.
7. All work complies with the Trust’s Health & Safety requirements

8. The works take account of adjacent buildings, structures or elements which may be in the ownership of others and also of historic importance.
9. Where further works are required they are carefully considered and specified in order to ensure that they complement the project and protect the structure.
10. Where alterations or material changes are specified the reasons for these and their extent is clearly explained and communicated to interested parties.
11. The recording documents (drawings, notes, reports etc.) are accurate, complete and legible to non-specialist readers.
12. One copy of the specification documents and 'as built' plans are deposited in an 'approved archive' on completion, e.g. Waterways Archive or relevant county Historic Environment Record (HER).

4. Stonework Repairs

4.1 Stone Types

Stones can be classified into three groups:

- Igneous – consisting of silicates formed when molten magma has cooled, either within the earth's crust or as a result of volcanic activity. The group includes rocks such as basalt and granite.

Granite setts

- Sedimentary - formed from sandy or muddy deposits which were laid down in layers and subjected to enormous pressure, evolving into a wide range of good building stones. A simple classification of these is as follows:
  - Rudaceous (rubbly) – breccia, conglomerate
  - Aranaceous (sandy) – sandstone, gritstone, quartzite, flagstone
  - Argillaceous (clayey) – clay, shale
  - Calcareous (carbonates) – limestone, tufa, travertine

Slate roof

- Metamorphic rocks - usually formed by the re-crystallisation of older rocks by intense heat, great pressure and chemical action. Some examples are calcium carbonate turning into marble and old clay rocks into slate. Metamorphic rocks have a characteristic texture caused by the 'foliation' or parallel arrangement of the materials. Slate is particularly easy to split along the foliation, making it an ideal material for roofing. This metamorphic foliation is not to be confused with the bedding layers of sedimentary stones.

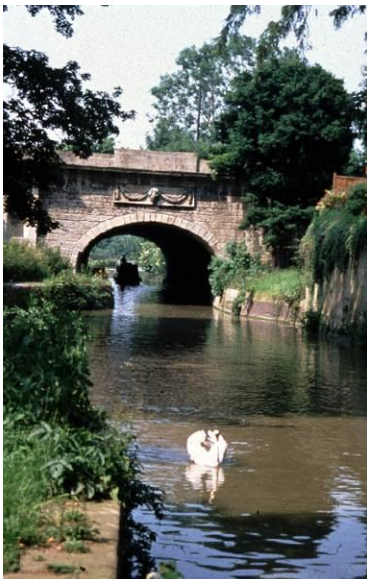
4.2 Properties of stone

Appearance:

Colour varies from white (e.g. chalk) to pale grey (e.g. Portland stone), to cream (e.g. Bath stone,) to reddish brown (sandstone) and to dark grey (e.g. granite). Texture of surface has a considerable effect on the scale and tone of the masonry. Surface contamination and weathering can create dramatic differences between old and new stone.

Performance:
The properties that most affect the performance and durability of stone are compressive strength, porosity, water absorption, frost resistance, sulphate content, acid resistance and abrasive resistance.

Compressive strength:
This is resistance to being crushed. Structural failures in stonework are very rarely due to the stones being crushed because most building stones are strong in compression. Failures are more likely to be the result of settlement, thermal or moisture movements or deterioration caused by frost attack, rusting iron or salt contamination. There are occasions however, when the compressive strength of new stones must match that of old ones and in the case of a large structure, where stresses are high, a certain minimum strength may be prescribed.



The Trust has many fine stone structures

The strength of new stones must match that of old ones

<u>Comparative compressive strengths</u>

Suppliers of new stone can provide compressive strengths when required. Some examples compared to other materials are given below.

Material	Compressive strength (N/mm^2)	Density (kg/m^3)
Stokeground Bath – base bed	22.5	2,126
Stokeground Bath – top bed	13.8	1,988
Portland Roach	52	2,100
Portland Whitbed	36	2,200
Welsh Blue Pennant	158	2,630-2,850
Clipsham limestone	32	1,826
Woodkirk Yorkstone	54	2,400
Concrete (typical)	40	2,240
Bricks (typical commons)	20	1,800
Bricks (engineering class A)	70	2,800

Compressive strength should not be confused with hardness which is the stone's resistance to abrasion or scratching. Samples may be tested using the point of a sharp blade and given a number between 1 (talc) and 10 (diamond) on Moh's scale of hardness. This may be relevant when flooring materials are to be selected for conservation work.

Natural bed

Sedimentary rocks such as sandstones and limestones are made in layers, planes or laminations, commonly referred to as beds. In plain masonry the stones should be placed with the layers flat (natural bed) i.e. at right angles to the pressure. The voussoirs of an arch should have the beds at right angles to the thrust line of the arch. Cornices and string courses should have the beds vertical and at right angles to the wall (edge bedding). Above all, having the beds vertical and parallel to the face of the wall (face bedding) must be avoided. This will result in delamination and spalling of the stone.

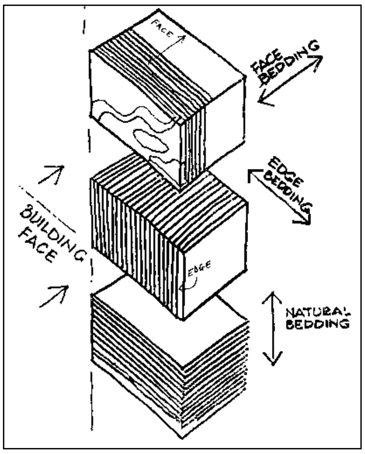


Diagram of bedding planes

4.3 Masonry type

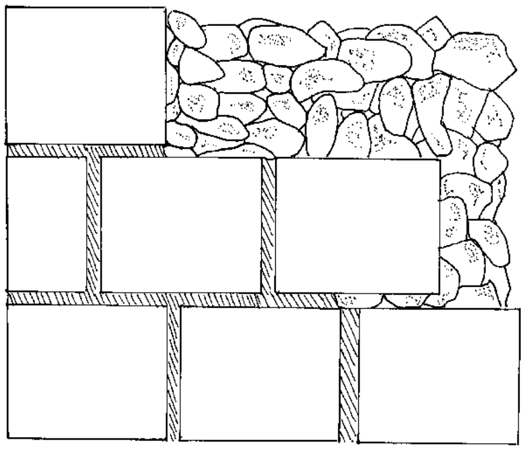
After quarrying, stone can be prepared for use as masonry in a number of ways:

- Quarry dressing
- Machine dressing – sawing, planing, moulding
- Hand dressing – hammered, punched, boasted, picked etc.

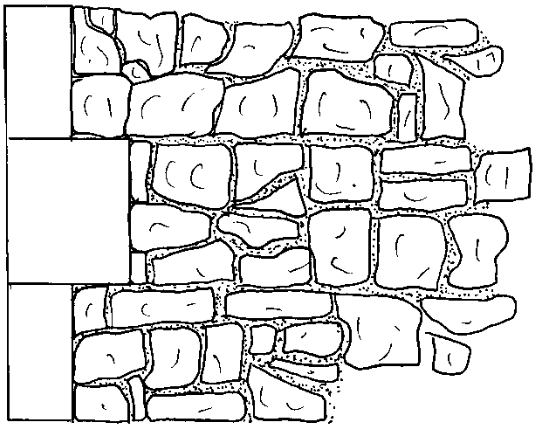
The type of masonry produced depends partly on the properties of different stones and also on where it is to be used. For example Portland and Bath stone can be dressed to a very fine ashlar surface for facing prestigious buildings but a quarry dressed rubbly stone would be more suitable for a rural cottage or boundary wall. Some typical methods of construction are:

- Ashlar – solid or with brick/rubble backing
- Rubble - random coursed
  - uncoursed
  - brought to courses
  - squared
  - snecked

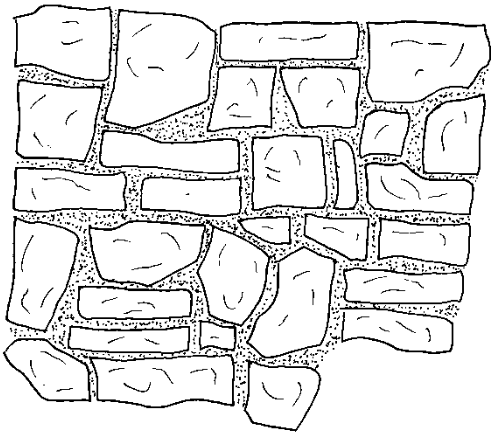
See diagrams overleaf:



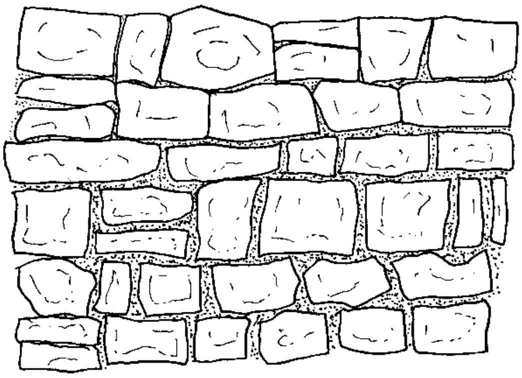
Ashlar – solid or with brick/rubble backing



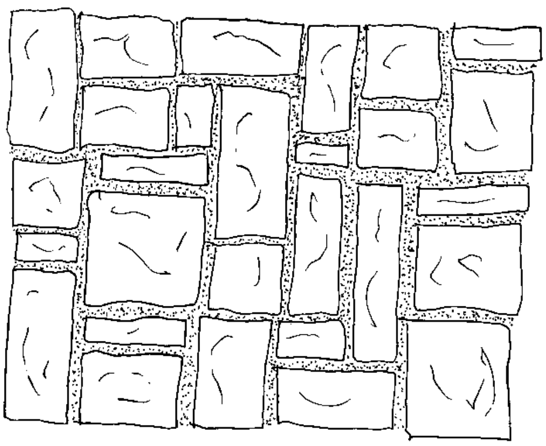
Ashlar quoin with Rubble - random coursed



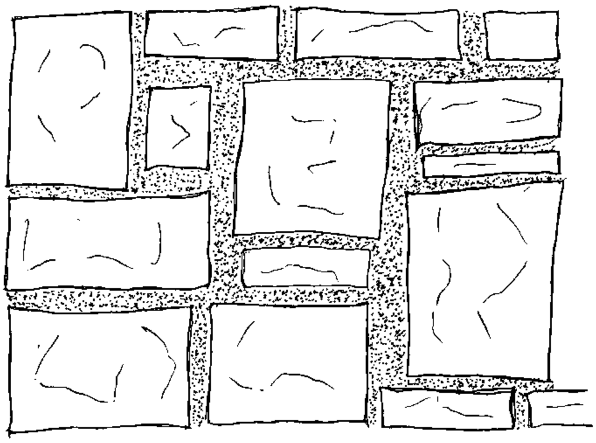
Rubble – uncoursed



Rubble – random coursed partly squared



Rubble – uncoursed squared



Rubble – squared with snecked coursing

4.4 Causes of deterioration

The rate at which stonemasonry will decay depends on a number of factors, including the type and quality of stone, the mortar, building design and structural defects. Deterioration may be due to several factors combining in effect.

<u>Type of stone</u>

The properties of different stones play a major part in their susceptibility to decay:

- Pore size and distribution of pores, and the degree of resistance afforded to salt crystallisation and frost attack.
- The vulnerability of limestones, marbles and calcareous sandstones to attack by acids, particularly sulphuric acid from acid rain or polluted air. Sulphuric acid combines with calcium carbonate to form gypsum which forms a skin on the stone surface and prevents evaporation, leading to spalling. Lichens also produce small quantities of acid which etch the surfaces of limestones and marbles.
- The solubility of limestone in water which leads to some surface erosion

Calcium sulphate blister caused by pollution

- The tendency for sandstone to suffer from ‘contour scaling’. It is often confused with lamination due to face bedding; however this can occur when stones are correctly bedded. Repeated wetting and drying of old sandstone, coupled with air pollution leads to the formation of a tough skin of iron oxides, gypsum, carbonates and silicas. This breaks away when thermal movement of the skin is different from that in the background material.

<u>Type of mortar</u>

- The density of the mortar used for bedding or pointing - dense mortars, particularly those made with ordinary Portland cement, prevent the masonry from breathing through the joints. They also lack flexibility and therefore restrain the natural movement (thermal and moisture) of the stones. This can lead to spalling of individual or even groups of stones.
- The condition of the joint face - the quality of the mortar and the shape of the joint are crucial to the durability of the masonry as a whole.

Good pointing employing a lime mortar

<u>Building design</u>

Poor design and construction can contribute significantly to the deterioration of masonry:

- Selection of the wrong or poor quality stone originally. The stone type may have been correct but a poor sample used. In repair work the aim must be to use the best quality of stone appropriate to the job.
- The need for stone to ‘season’. Stone fresh out of the ground is often referred to as ‘green’ and contains quarry sap which is ground water. Such stone should be protected in the winter and allowed to dry out before use or it will be prone to frost damage after installation.
- Incorrect bedding of sedimentary stones particularly limestones and sandstones where ‘face bedding’ leads to lamination

Stones fixed in wrong bedding plane

- Juxtaposition of some stones. When sandstone is positioned below a limestone detail, e.g. a string course, the washings of calcite, gypsum and other salts from the limestone will collect in the coarse pores of sandstone, leading to a substantial reduction in its durability.
- Poor structural design and architectural detailing, e.g. ineffective copings, cornices or cills. Poor design of alterations or conversions.
- Faulty workmanship in construction or repair.
- The use, in the past, of iron cramps to tie masonry together. Persistent moisture penetration causes the iron to rust, expand and crack stones apart with spalling. Corrosion of iron cramps in old masonry has caused much damage in the past. Replacements and all new components should be of stainless steel or phosphor bronze. Galvanised steel is less durable and not recommended.


Damage caused by iron cramp

<u>Structural defects</u>

- Bulging of one or both sides of a masonry wall due to the loss of integrity of the core. The latter, often of loose, weak materials, may be washed out by excessive water penetration e.g. due to a leaking gutter or lack of pointing.
- Leaning due to a loss of lateral restraint arising from the careless removal of buttresses, buttressing walls, tie beams or floors in a building. This involves a risk of collapse.
- Differential settlement of foundations, e.g. due to a disturbance of an otherwise stable condition by adjacent excavations or changes in ground water level. Subsequent cracking, even if not structurally significant, may well allow excessive rainwater penetration.
- Crushing (rare) or buckling (common) of masonry due to overloading or loss of bearing. Building conversions and extensions, or change of use, may lead to this situation.
- Timber decay - particularly in old embedded ties, plates or noggins which have rotted when water has penetrated masonry. This often gives rise to eccentric loading on weak masonry which will then buckle or bulge.


Disintegrating core work

<u>Other factors</u>

- Lack of maintenance – particularly failure to remove vegetation such as saplings and ivy, or to repair defective roofing, flashings and gutters.
- Inappropriate use of paints and water repellents which prevent masonry from being able to breathe
- Incorrect method of cleaning – this can cause permanent damage to historic masonry and only approved systems should be used. Never use mechanical abrasive methods such as grit-blasting.

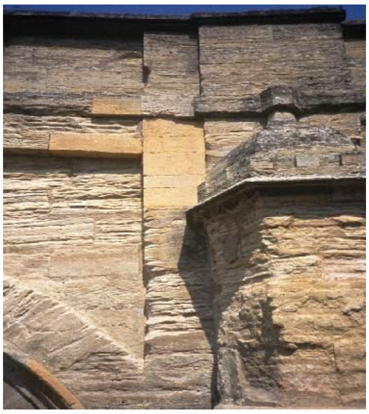

Disruption caused by vegetation

4.5 Method of repair

Careful survey will have identified individual or groups of stones in need of repair. The principle of minimum intervention usually means that only stonework in current need of repair is dealt with. Wholesale replacement for the sake of appearance is rarely feasible or necessary. Once work has started it is of course possible that other areas of stonework are damaged or found defective and are therefore in need of repair. Where the deterioration has been caused by a clearly identified source, e.g. a leaking or blocked rain water pipe or excessive rising damp, these matters will require attention at the same time. Remedying such defects will retard the rate of stone decay.

Sandstone voussoirs

Repairs to stonework can be carried out in a number of ways, sometimes in combination. These include the following:



Replacement with new stone

<u>Replacing with new stone</u>

Cutting out stones is usually done with a hammer and chisel, normally to a depth 75 to 100mm (never less than 50mm) but it is sometimes easier to take out a whole stone rather than face it with a 100mm skin. New stones should be laid on their natural bedding plane (the quarry will mark this if it is not clear) except with elements such as cornices and voussoirs of an arch where they will be laid as edge bedding. Stones should be deeper (from front to back) if they are required to be set into core work to improve stability.

Replacement stones should, wherever possible, be cut similarly to existing ones. Machine sawn stones are not a good match for old stones cut with a chisel. The outer face should lie on the original plane not flush with adjacent weathered stonework.

New stones need careful handling. The cavities and the replacement stones are dampened and placed on a mortar bed with lead or slate packing as necessary. The top and side joints are pointed up to the surface and any voids behind the new stone are grouted after the mortar has set.

<u>Piecing in</u>

A similar method to that described above, but used when an original stone is only partly decayed or damaged, usually on the outer face, an edge or a corner. In this case small stones, usually rectangular, are used to ‘plug’ the holes left when the damaged part has been removed from the whole stone. This is only feasible when the host stone is in sound condition. The joints between the old and new stone are kept as fine as possible and certainly thinner than those between whole stones. Conservation principles maintain that the repair should remain noticeable but not obtrusive.

Preparation for piecing-in

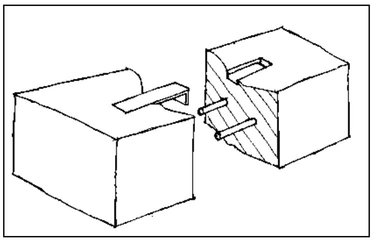
Completed work

Plastic or mortar repairs

The common misuse of this technique, especially with the use of hard grey cement-rich mortars, results in damaging and unsightly repairs. This is skilled work to be undertaken only if stone replacement is impracticable. Matching the original stone can be very difficult.
The correct choice of mortar colour, texture and constituents is essential to success. Sample mortars must be prepared and tested beforehand.

Pinning or stitching

This covers techniques used to stabilise or reinforce masonry in situ where stone replacement is inappropriate. The preservation of fragile historic fabric often requires the highly skilled and delicate use of metal parts such as stainless steel or bronze and resins (polyester or epoxy) for this kind of specialist work.



Pinning and cramping

Water repellent treatments

On sound masonry surfaces water repellent liquids, usually based on silicones or waxes, are sometimes used to reduce water ingress and rain penetration. But their use is controversial because they restrict evaporation and encourage rainwater to penetrate any cracks that may be present in the masonry. Moreover some appear to discolour the masonry over time, require frequent re-application and none of them can be used on decaying masonry where soluble salts are present.

Such treatments should be avoided and should not be considered a substitute for proper repair and maintenance as they are likely to lead to long term damage of historic stonemasonry.

Consolidants

These liquids are sometimes applied to the surface of masonry in order to strengthen it. Based on chemicals such as silicates, silanes and acrylics, they must penetrate deep enough to prevent an impervious skin forming which in turn would tend to move differently from the material behind and encourage frost and salt attack.

As with water repellents (see above) these treatments should be avoided as there is a risk that evaporation is impeded which exacerbates the situation.

Both consolidant and water repellent treatments contain chemicals, which are undesirable near water-courses and are likely to lead to long term damage of historic stonemasonry.

PREPARATION

Performance Criteria

1. The preliminary survey is carried out thoroughly and in sufficient detail, including identification of the type of stone, to enable specifications and method statements to be prepared and approved.
2. The work is adequately planned, organised and supervised with particular regard to the health and safety of operatives and the public.
3. An environmental appraisal is raised and correctly validated with any conditions met before work commences.
4. The method of repair is carefully selected after a thorough analysis of the causes of deterioration and is the minimum necessary.
5. The specification (which must be prepared by a suitably qualified specifier, e.g. an engineer or architect) takes into account the pattern of construction and joint thickness of the existing work.
6. Stones used for the replacement of damaged or missing masonry are the best possible match in type, appearance and performance characteristics.
7. Selection of replacement stone takes into account the following:
    - The availability of locally quarried stone suitable to match the existing masonry.
    - Stone salvaged from elsewhere or reclaimed from other parts of the structure is used only if it is in good condition.
8. The materials used in the mortar are selected with regard to the type and appearance of the existing mortar and the condition of the stonework.
9. Metal components (dowels, cramps and anchors) are of stainless steel or non-ferrous metal.
10. All contractors and operatives involved are competent and experienced in conservation work of the required standard.

METHOD

Best Practice Indicators

1. Repair work and materials comply with the drawings and specification unless authorised by the project manager and/or heritage adviser.
2. All materials are handled with care to avoid damage and properly stacked or stored under cover until required for use.
3. No drilling of historic stonework such as copings is permitted.
4. Temporary works including safety fencing are non-invasive and reversible, leaving no trace of their presence.
5. The mortar is properly mixed using the method set out in the specification, with additives only included after consent from the project manager and/or heritage adviser.
6. Water is clean and fresh from an identified source - canal or river water should not be used.
7. Stones are placed in the correct position with regard to their bedding plane.

8. No work is carried out when a descending air temperature in the shade falls below 5°C, neither is it resumed until an ascending air temperature in the shade reaches 4°C.
9. Finished repairs are protected from rain and prevented from drying out too rapidly for at least 24 hours. In frosty weather they are suitably protected for a period of up to seven days and longer if necessary in severe conditions.
10. The repair is effectively carried out. It is visually and structurally acceptable and maintains the historical integrity of the asset.
11. All work complies with the Trust's Health & Safety requirements.
12. The method of work complies with actions in the environmental appraisal.

5. Brickwork Repairs

5.1 Historic brickwork

Britain's canals, especially in the lowland parts of the country, relied heavily upon brick as their principal building material. A very large number of historic brick buildings and structures survive and their effective repair and conservation is an important part of the Trust's work.

Bricks used in the early years of canal building were often relatively soft with an uneven consistency in their core. Consequently they were prone to frost damage where they remained damp for extended periods, such as occurs in lock chambers and bridge arches. Bricks used later in the 19th century, particularly after the arrival of the railways, tended to be fired to a higher temperature and had a much better survival rate. Many of the hard blue 'engineering' bricks used for repairs to waterway structures were inserted when canals came under railway ownership.

Good quality traditional brickwork

5.2 Brick sizes and shapes

Most bricks are produced nowadays to a nominal work size of 215 x 102.5 x 65mm on which there are manufacturing tolerances. In the past there was a much wider variation of the size of bricks, particularly on the depth. Prior to metrication in the late 1960s, bricks were generally deeper in size, varying from 67mm ($2^5/_8$ inch) to 75mm (3 inch). Matching these older sizes for repair work is critical to maintaining the correct thickness of mortar bedding.

The Trust has many fine brick built structures

Apart from rectangular bricks there are 'standard special shapes' made for some types of brick. It can be difficult to match these for replacement work; however some brick makers will manufacture special shapes to order.

In extreme cases it is possible to cut a rectangular brick with a carborundum disc to produce a required shape. The bricks suitable for cutting should be frogless and unperforated and of uniform colour through the body of the brick where cutting is going to expose the inside.

5.3 Appearance

Most bricks used in heritage repairs are ‘facing bricks’ having been selected for colour and/or shape and surface texture. Colours vary depending on the type of clay (particularly oxides that may be present) and the method of firing or position in the kiln when the bricks were made.

The surface texture of the brick affects the appearance of a wall. Hand-made bricks are usually sand-faced and the face may be irregular. Bricks used on the waterways have traditionally been handmade and in some cases would have been slop moulded. Slop moulding involves using water instead of sand to release the clay from the mould, giving a ‘water struck’ appearance as opposed to a ‘sandy’ appearance.

When a brick is fired at a high temperature the clay starts to melt and vitrify. This gave rise to the use of vitrified headers in earlier times. It is difficult to match vitrified bricks nowadays though they are less likely to deteriorate because of the reduced absorption through the partial vitrification of the brick.

Modern engineering bricks tend to be uniform in colour, usually blue or red. They are regular in shape and precise in dimension. This enables them to be laid with a thinner joint of about 6mm rather than the 10mm which is often necessary for one of the more irregular facing bricks.

5.4 Performance characteristics of bricks and brickwork

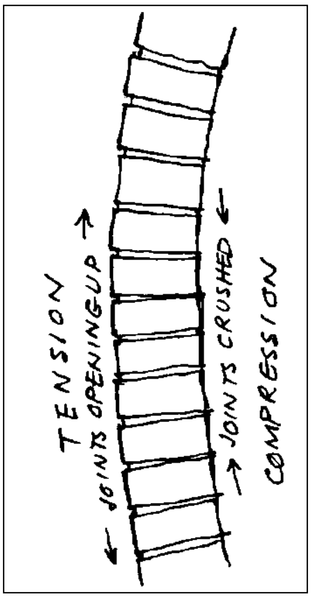
The properties that most affect the performance and durability of bricks are compressive strength, water absorption, frost resistance and movement tolerance.

Compressive strength

This is resistance to being crushed although structural failures in brickwork are very rarely due to the bricks being crushed. Typical compressive strengths of commonly used bricks are given below:

Engineering class A	not less than $70N/mm^2$	
Engineering class B	not less than 49	“
LBC Flettons	14-25	“
Handmade clay	7-60	“
Sand limes (calcium silicate)	7-50	“
Concrete	10-40	“
Limestone	23-49	“

Present day manufacturers will provide compressive strength values for the bricks they make. In most types of bricks there is a considerable range of strengths as can be seen from the figures above. This is important, if only for the reason that when using them the associated mortar must never be stronger than the bricks themselves.



Buckling brickwork

Water absorption, porosity and durability

Brickwork absorbs moisture because it is porous. As with stone, porosity is difficult to measure but water absorption is not. Neither porosity nor water absorption are a true measure of durability because many bricks are quite porous but reasonably frost resistant because (as with stone) their pore structure (i.e. size and distribution of pores) allows some freezing to take place without damaging the solid matter in the brick.

Present day brick-makers are obliged to provide details of the water absorption of their various products. In practice clay bricks will vary from about 3% to 30% (of dry weight) with engineering bricks at the lower end. In exposed locations where frost attack or salt contamination is likely, it is common practice to specify bricks with lower water absorption.

Frost resistance

Brickwork is subject to many freeze-thaw cycles in winter. It is the structure, size and distribution of the pores in the material which determines its ability to withstand the effects of the freeze-thaw cycle, i.e. allowing ice to form in the pores without breaking the fabric apart. Although it is often assumed that the stronger the brick the more frost resistant it will be, this is not necessarily the case and it is better to select frost resistant bricks by observing their performance over several years or, in the case of new ones, classification under BS 3921.

Moisture and thermal movement

Clay bricks expand as they absorb water (very small amounts in dense bricks) and shrink when they dry out. They also experience thermal movement, which can be a problem in long walls. As a general rule, the use of flexible mortars incorporating lime and flexible connections (e.g. wall ties) will prevent these small movements from causing damage to the brickwork. Old brick walls are rarely affected by thermal or moisture movements, even when large, because they are sufficiently flexible. However, inappropriate alterations and extensions can introduce elements of rigidity which are liable to restrain these natural movements and result in failures.

5.5. Second-hand and reclaimed bricks

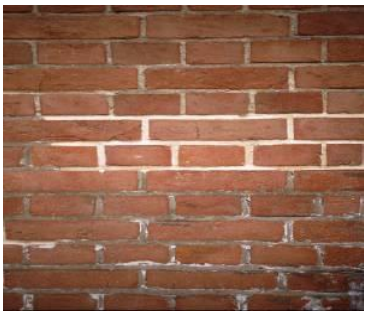
These should be inspected very carefully. Previous use may give rise to contamination with soluble salts or damage caused by the removal of dense mortars or paint. Historically some bricks were never meant to be used externally as they were under-fired so care must be exercised when inspecting second hand bricks to ensure they are fit for external situations.

In some cases it is possible to re-use damaged bricks by turning them, but only if the back face is a genuine face with suitable texture and colour.

Sound bricks can be salvaged and re-used

5.6 Mortar appearance and strength

Mortar colour and texture has a considerable effect on brickwork as a whole. The type and proportions of lime and sand in the mix as well as the use of any additives such as pozzolans will all affect the appearance. It is essential that sample panels are prepared when a mortar is to be matched. It may also be necessary to undertake a mortar analysis in order to identify the ingredients of an historic mortar. The strength of mortar must be no higher than that of the bricks and it must not impede evaporation; permeability is crucial.



Lime based mortar (white) and cement based mortar (grey) in the same wall

5.7 Defects in Brickwork

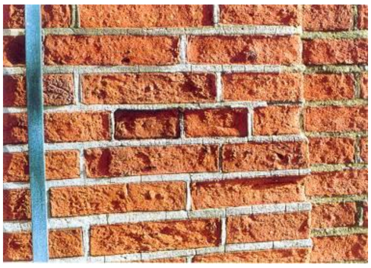
Brick decay

This can be due to a number of factors sometimes in combination:

Lime wash out and salt efflorescence on the underside of an arch

- Persistent dampness - this can lead to a loss of compressive strength, a lowering of frost resistance and a greater risk of salt contamination as dissolved salts follow the moisture through the brickwork. It can also be unsightly and encourage organic growth.
- Frost damage - ice forming within the pores of bricks expands and creates stresses in the fabric which may then break.
- Soluble salts - sulphates of sodium, calcium, magnesium or potassium may be dormant in a wall and will attract moisture. Salts can be present in bricks, mortar, the adjacent soil or the washings from limestone copings and string courses. When a wall is subject to wetting and drying, any salts present will crystallise either on the outer surface, known as efflorescence, or inside the wall, which is crypto-florescence. Efflorescence can be brushed off but severe crypto-florescence can worsen progressively and, like ice crystals, cause damage to the fabric. The failure of individual bricks, often seen as spalling, may be due to salt crystallisation or frost attack, or both, and is exacerbated by the use of an impervious cement-rich mortar for bedding or pointing.
- Organic growths such as algae and moss block the pores in brickwork, preventing evaporation and so increasing the possibility of salt or frost attack.

Mortar faults

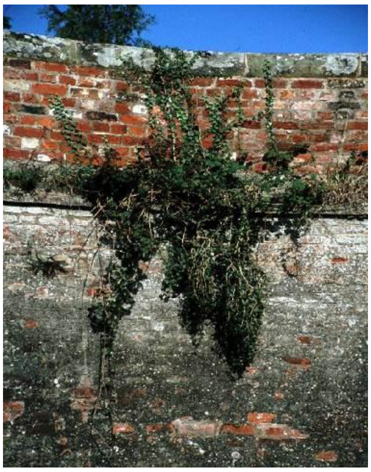


Spalled brickwork due to use of hard cement mortar

- Density – the mortar used for bedding or pointing must have a low enough density to allow slight movements and evaporation. Strong brittle mortars, such as those employing Portland cement rather than lime, lead to spalling of softer bricks. Brickwork generally has a relatively high proportion of its mass allocated to the joints, usually 15 -19% at the face, so these have a vital part to play in the performance of the wall.
- Joint face – the shape and quality of the pointing are critical to the condition of the brickwork. Voids left behind the mortar or repointing that is too thinly applied will encourage water ingress with potential for leaching out, frost damage or vegetation growth.

<u>Structural defects</u>

- Thermal and moisture movements - if brickwork is constrained by dense, inflexible mortar then the bricks are crushed by being 'pinched' between rigid elements.
- Brick arches - arches and vaults will tolerate considerable movement before failure because the bricks are held in place but any severe movement in an abutment, as a result of settlement or damage, can cause unsightly and potentially serious cracks to appear. The flatter the arch or vault, the more risk of collapse. The thickness of the arch, between the 'intrados' and the 'extrados', and the quality of construction will affect its durability.
- Bulging of one or both sides of a masonry wall due to the loss of integrity of the core. The latter, often of loose weak materials, may be washed out by excessive water penetration, e.g. due to a lack of pointing.
- Leaning due to a loss of lateral restraint arising from the careless removal of buttresses, buttressing walls, tie beams or floors in a building. This involves a risk of collapse.
- Differential settlement of foundations due, for example, to a disturbance of an otherwise stable condition by adjacent excavations or changes in ground water level. Subsequent cracking, even if not structurally significant, may well allow excessive rainwater penetration.
- Crushing or buckling of masonry due to overloading or loss of bearing. Building conversions and extensions, or change of use may lead to this situation.
- Timber decay - particularly of embedded ties, plates or noggins which have rotted when water has penetrated masonry through a lack of maintenance. This often gives rise to eccentric loading on weak masonry which will then buckle or bulge.
- Vegetation growth – saplings growing in the mortar joints can exert tremendous jacking forces which will displace and crack brickwork.



Organic growth can cause problems

5.8 Methods of repair

Careful surveying will identify individual bricks or patches of brickwork in need of repair. The principle of minimum intervention means that only brickwork in current need is repaired and wholesale replacement for the sake of appearance should avoided. It can be difficult to match new work with old, often resulting in a patchwork effect. Particular attention should be given to matching the bond pattern and joint thickness.

Where the deterioration has been caused by a clearly identified source, e.g. a leaking pipe, rising damp, rotten timbers, these matters will require attention at the same time. Remedying such defects will reduce the rate of deterioration.

A patchwork of poorly matched bricks, mortars and 'plastic repairs'

Repairs to brickwork may be carried out in a number of ways and in some cases are very similar to those for stonework. Common techniques include the following:

Replacing whole bricks

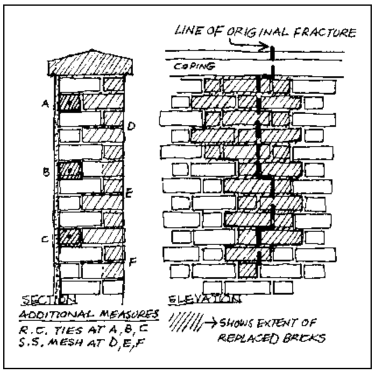
Cutting out, usually of whole bricks, is done with a hammer and chisel taking great care not to damage adjacent sound bricks. Disc cutters should never be used. The surrounding joints are removed first, particularly if they are in loose cement-rich mortar, with quirks and long necked raking out chisels with parallel faces. Wedge shaped jointing chisels should not be used as they can damage the brick edges or arises.

Replacing brickwork on a historic heel grip platform.

The cavities and bricks are dampened as necessary to reduce suction, but with engineering bricks the suction is so low that dampening may be unnecessary. Replacement bricks are placed on a mortar bed, occasionally with lead or slate packing if necessary. The side and top joints are then packed solid with mortar and pointed up.
Where the replacements form a patch of several bricks, temporary supports or wedges may be needed to prevent the masonry from collapsing.

Brick slips

This technique is sometimes used where the deterioration of a brick is superficial and cutting out an otherwise sound whole brick is deemed unnecessary. Only the front part of a brick is removed, to a depth of say 45mm, so that a brick slip approximately 35mm thick can be inserted. Slips are cut from a sound original brick or are purpose made. They are bedded in mortar and anchored to the background with small stainless steel wire ties.



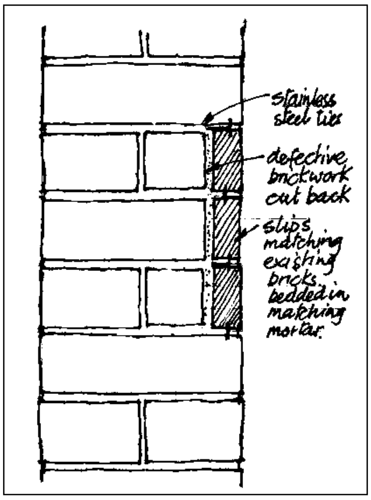
Part re-building brickwork

'Plastic' or mortar repair

The common misuse of this technique, especially with the use of hard grey cement-rich mortars, results in damaging and unsightly repairs. Matching the adjacent brickwork with a lime based mortar is difficult and requires considerable skill. The correct choice of mortar colour, texture and constituents is essential to success. Replacement of bricks is the preferred option.

Rebuilding

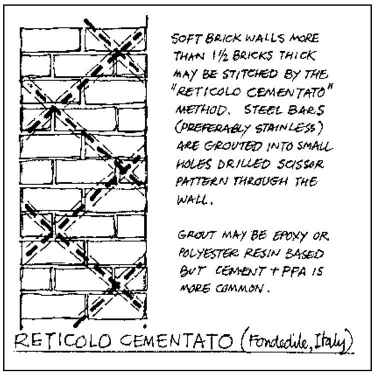
Where structural damage such as excessive cracking, bulging or settlement has occurred, it may be necessary to demolish a section of a wall and rebuild it. Depending on the size and shape of the rebuild, and the probability of further movement, the new work may be reinforced using proprietary stainless steel brick reinforcement (perforated metal strips laid in bed joints) and/or slender reinforced concrete ties. It is important to extend the repair well beyond the immediate vicinity of the defect and to use a flexible mortar. This will help to disperse stresses as the new work 'settles in' with the old.



Brick slip repairs

<u>Stitching</u>

Repairs carried out in-situ, i.e. without disturbing the fabric, are sometimes preferable, particularly with valuable historic masonry. Techniques whereby fragile brickwork is stabilised by boring holes in a pattern and inserting reinforcing bars or pins are referred to as 'stitching'. The process is known as Reticolo cementato. The pins, usually stainless steel, are set in a resin grout (epoxy or polyester). This is very specialised work and requires the services of a qualified contractor.



Reticolo cementato

PREPARATION

Performance Criteria

1. The preliminary survey is carried out thoroughly and in sufficient detail to enable specifications and method statements to be prepared and approved.
2. The work is adequately planned, organised and supervised with particular regard to the health and safety of operatives and the public.
3. An environmental appraisal is raised and correctly validated with any conditions met before work commences.
4. The method of repair is carefully selected after a thorough analysis of the causes of deterioration and is the minimum necessary.
5. The specification (which must be prepared by a suitably qualified specifier, e.g. an engineer or architect) takes into account the bond and joint thickness of the existing work.
6. All replacements for damaged or missing bricks are the best possible match in size, appearance and performance characteristics with the originals.
7. Selection of replacements takes into account the following:
    - The availability of suitable locally made bricks
    - Second-hand bricks or those reclaimed from other parts of the structure and cut bricks are of sufficient quality for re-use in the new location
8. The materials used in the mortar are selected with regard to the type and appearance of the existing mortar and the condition of the brickwork.
9. All contractors and operatives involved are competent and experienced in conservation work of the required standard.

METHOD

Best Practice Indicators

1. Repair work and materials comply with the drawings and specification unless authorised by the project manager and/or heritage adviser.
2. All materials are handled with care to avoid damage and properly stacked or stored under cover until required for use.
3. No drilling of historic brickwork such as copings is permitted.

4. Temporary works including safety fencing are non-invasive and reversible, leaving no trace of their presence.
5. The mortar is properly mixed using the method set out in the specification, with additives only included after consent from the project manager and/or heritage adviser.
6. Water is clean and fresh from an identified source - canal or river water should not be used.
7. No work is carried out when a descending air temperature in the shade falls below 5°C, neither is it resumed until an ascending air temperature in the shade reaches 4°C.
8. Finished repairs are protected from rain and prevented from drying out too rapidly for at least 24 hours. In frosty weather they are suitably protected for a period of up to seven days and longer if necessary in severe conditions.
9. The repair is effectively carried out. It is visually and structurally acceptable and maintains the historical integrity of the asset.
10. All work complies with the Trust’s Health & Safety requirements.
11. The method of work complies with actions in the environmental appraisal.

6. Lime Mortars

6.1 Introduction

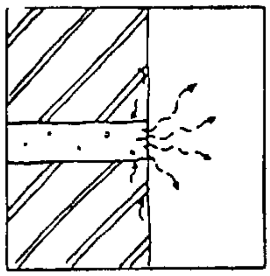
Lime mortars were used as the traditional binder for brick and masonry construction from pre-Roman times until the 20th century. The manufacture of ordinary Portland cement (OPC) was not developed until after 1850 and has only replaced lime for general building work in the last 100 years. Although OPC is frequently visible on repairs to historic canal fabric, it should be remembered that the original construction was undertaken entirely with lime. The correct material for repair work to heritage structures is a lime based mortar. The use of cement based mortar can cause lasting damage to historic fabric and should be avoided.

Traditional lime mortar

6.2 Types of Lime

All limes are produced from quarried limestone that has been burnt in a kiln to produce quicklime. A controlled amount of water is then added to this highly reactive substance in a process known as slaking. The resulting slaked lime hardens, or sets, on contact with carbon dioxide in the atmosphere. This is called carbonation.

Mortars containing lime are fundamentally different to those using OPC and have characteristics essential for preserving historic structures. Unlike OPC they are permeable and flexible, allowing structures to breathe and to withstand a degree of thermal and structural movement. Modern cement mortars set very hard in a



A permeable joint lets masonry breathe

relatively short time; lime mortars are slower to set but continue to harden for a much longer period.

Slaked limes come in three categories:

Hydraulic limes

These are made from limestone containing clay impurities. Silicates present in the clay react with water to produce what is called a hydraulic set. Lime mortars made from this type of limestone will set through contact with additional water as well as through carbonation, producing a stronger binder. Hydraulic limes must be stored in dry form, sealed from the air and are sometimes called 'bagged limes'. Mortars and concretes made with hydraulic lime will set under water, which is essential for waterway construction and this is the type of lime generally used on the Trust's heritage assets.

Bagged hydraulic lime

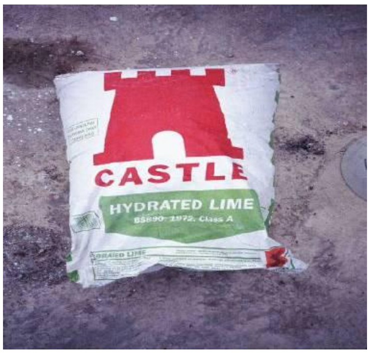
Hydraulic limes are available with different clay contents and degrees of 'hydraulicity'. Strengths are divided into eminently hydraulic (identified as NHL5), moderately hydraulic (NHL 3.5) and feebly hydraulic (NHL2).

Non-hydraulic limes

Also known as 'pure' limes and the type often used in mortars for general conservation building work. Quarried from limestone without impurities, they set only through carbonation and will not set under water. Consequently non-hydraulic lime is always stored in wet form, unlike hydraulic lime, and can safely be kept for very long periods. Non-hydraulic limes are available either as lime putty or pre-mixed with sand, when it is known as 'coarse mix'.

Hydrated lime

Hydrated lime is a type of non-hydraulic lime produced by controlled slaking with steam or a minimum of water which is then dried and stored in sealed bags. The material is widely available from building merchants and is generally used for adding flexibility to cement mortars. It is much less reactive than good lime putty and specifications for conservation work should not include mortars made with hydrated lime.



Bagged hydrated lime

6.3 Setting agents

The following can be used to accelerate the setting time and strength of lime mortars:

Pozzolans

These are substances that react in the same way as the presence of clay in the limestone. Their addition increases the hydraulicity of lime mortars and they have been used historically since Roman times. Some examples are:

- Brick dust
- Coal ash
- Pulverised fire ash (PFA)
- Metastar – commercial product containing kaolin

Prompt

Another method of increasing the hydraulicity is to use Prompt, a lime fired from limestone with high clay content. This is also called 'natural lime cement', but should not be confused with modern cements such as OPC. Natural lime cements have been used historically, e.g. 'Roman cement' in the 1780s, and can give a very rapid set. Prompt is entirely compatible with other limes but its presence in the mortar mix will reduce the properties of permeability and flexibility. For conservation work, the proportion should not exceed 12% of the lime binder.

6.4 Selection of mortar mix

Weaker permeable mortars should be used for historic work. These enable masonry and brickwork exposed to rain to dry out through the pointing, reducing the risk of them being damaged by freezing in cold weather. Lime pointing acts a sacrificial element in the historic fabric and eventual re-pointing in the long term should be anticipated. On the other hand, using hard mortars such as OPC for pointing helps to keep the softer stone and brickwork saturated, thereby increasing their vulnerability to frost damage.

In order to match a new mortar with an existing one it may be necessary to take a sample for mortar analysis. For general building work, lime mortars should contain well graded sand with a range of particle sizes. Too high a proportion of fines reduces vapour permeability of the mortar and increases shrinkage, setting time and sensitivity to adverse weather conditions.

Selection of an appropriate mix should take the following factors into account:

- Colour of the lime (varies from cream to white), aggregate and any other ingredients, e.g. crushed limestone, brick dust, coal ash.
- Texture – shape and size of the aggregate and impurities.
- Condition of the existing masonry, brickwork or render.

Performance characteristics of strength, permeability and durability – a mortar with different characteristics to the original may be required if there have been changes in the immediate environment. The mortar should not be stronger than the masonry or brickwork.

6.5 Mortar Mix Summary

Mortar Ingredient	Typical Uses
NHL5 (eminently hydraulic lime)	For exposed and constantly wet areas of masonry, e.g. lock chambers, bridge abutments, waterway walls.
NHL3.5 (moderately hydraulic lime)	For less exposed areas, e.g. bridge faces and parapets, towpath walls, buildings.
NHL2 (feebly hydraulic lime)	For dry sheltered areas with friable brickwork/masonry and building interiors.
Pozzolanic additive	For addition to hydraulic limes to improve setting times but only where specified. Examples are Metastar, brick dust, coal ash.
Prompt	For addition to hydraulic limes to improve setting times but only where specified. Also called 'natural cement', Prompt is a lime product and should not to be confused with OPC.

Well graded sharp sand	Essential for a well- structured lime mortar. Selection varies depending on specification.
Soft sand	Essential to ensure workability. Selection varies depending on specification.

6.6 Mixing lime mortars

The harmful effects of handling wet mortars due to their alkalinity and the dangers of handling unslaked lime should be carefully noted. Suitable protective clothing must be worn, particularly for overhead work.

It is best practice to prepare sample mixes, several if necessary, with different constituents and allow them to cure before selecting a suitable match with the original mortar. Trial/ mock-up panels of masonry or brickwork pointing may be required.

Lime products need careful handling

In cold weather it is important to avoid any risk of freezing to the mortar until the process of setting or curing is complete. Using the incorrect constituents or poor quality mixing and handling will delay the curing period and increase susceptibility to frost damage over time. The risk of damage is reduced by the following:

- Undertaking the job between May and September where possible and providing additional protection in winter months, e.g. tenting and heaters.
- Choosing a mix with an appropriate type of lime for good strength gain in the prevailing conditions.
- Using a well graded aggregate.
- Correct storage, batching and mixing of materials.
- Using only sufficient water to achieve workability.
- High class standard of workmanship with regard to laying and pointing techniques.
- Protecting the work to ensure adequate curing in the prevailing conditions.

Sharp sand

<u>Preparation of the mix</u>

Lime mortars require more mixing and preparation than modern cement mortars. These points should be observed:

- The constituents for the mix are accurately gauged by volume. This is critical as lime mortars contain a higher proportion of binder than normally required for OPC mixes.
- Mortar mixing ceases when the temperature of the materials, or where the location they are to be used, falls below 5 degrees C; nor does it commence until the temperature rises above 4 degrees C.
- Mortars containing hydraulic lime are thoroughly mixed just before use with only enough water to achieve workability.
- The mix is allowed to stand for a minimum of 20 minutes before use.
- Workability of mortars once mixed is regenerated by vigorous stirring or ‘knocking up’, not by

A sample panel for lime mortar in brick repairs continually re-wetting them.

- Mortars containing Prompt should be mixed in smaller quantities, never re-wetted and when they have started to set, excess mortar is discarded.

Bulking of sand

Aggregates must be accurately batched by volume when dry. If the sand to be used in the mix is wet it occupies more volume than the same amount of dry sand and allowance should be made for the bulking up. This can be calculated by comparing the increased volume dry sand occupies in a standard container after it has been wetted. The percentage increase in volume is equal to how much additional sand should be included in gauging for the mortar mix.

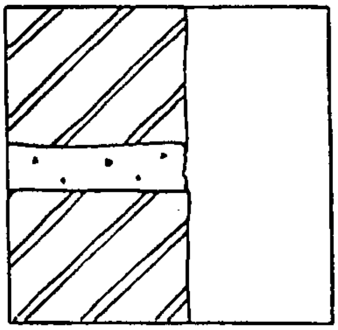
For example, if damp sand occupies 25% more volume after soaking then the gauged sand for the mix must also be increased by 25%, so a 2:1 damp sand and lime mix is actually gauged at 2:5:1.

6.7 Repointing

Examining the masonry

Repointing on historic masonry is preceded by a detailed visual analysis of the masonry to determine:

- The nature and properties of the masonry units - weak porous bricks, hard extruded bricks, limestone, sandstone, granite.
- The characteristics and constituents of the existing mortar – type of mortar, its texture and relationship to the masonry units.
- The mode of construction of the wall - bonding, width of joints and joint profile, including any inappropriate re-pointing with dense mortar and modern finishes.



Flush joints are traditional

Re-pointing of joints in masonry is carried out only when joints have weathered out to the extent that:

- The stones or bricks are vulnerable to damage.
- Excessive penetration of rain or other water increases the risk of frost attack or salt contamination.
- There is a risk of structural failure or movement.

Loose mortar, open joints – a wall in need of repointing

NB: Some weathering of joints must be expected and is usually insufficient reason for repointing. On no account should a whole wall be repointed when some parts do not require it.

Joint design

The joint shape or profile is chosen after full consideration of the existing or original profile and what is desirable for conservation and durability of the masonry or brickwork.

Modern joint profiles such as struck (angled), bucket handle or raised (strap) pointing are not appropriate for historic work. Most historic masonry joints were finished flush as the masonry was built, but on some buildings decorative joint profiles were used. Repointing rubble stonework or old walls, where the arrises of the units have decayed should not be flush-faced (the cause of much damage when done in cement-rich mortar in the past). The mortar joint should be slightly recessed to enable it to match the original mortar profile adjacent to the new work.

Joint preparation

1. Joints are cleaned out to a minimum depth of 25mm and never to a depth less than their width.
2. Great care is taken to avoid damaging the arrises of the stones or bricks, particularly where dense repointing has been done in the past.
3. Cutting out is performed with quirks and long-necked jointing chisels with parallel faces, **not** wedge shaped chisels which damage the arrises.
4. Cutting out using angle grinders is **not** permitted.
5. Cutting out should leave a clean square face at the back of the joint to provide optimum contact with the new mortar.
6. Joints are brushed and flushed out with water to remove dust and loose material.
7. Spillage from the preparation process is prevented from falling into the canal or river.

Cutting out

Wetting

Prior to repointing, sufficient water should be applied to the masonry to ensure that water is not drawn out of the new mortar too quickly. This may require the walls to be soaked the night before to ensure a good reservoir of water is in the fabric and then moistened up on the morning of the work. Clearly the need for this depends on the type and condition of the masonry and the prevailing weather.

Filling the Joints

1. The materials in the mortar are carefully selected and accurately batched to provide joints which are consistent in colour and texture.
2. Joints which have dried out since cleaning are re-wetted.
3. Joints are thoroughly filled with mortar, placed and packed using appropriate sized pointing keys without encroaching over the arrises or faces of the stone/brickwork.
4. Deep cavities are repointed in two stages. Dry mortar is packed in the back of the joint before the standard repointing mortar is used to complete the process.
5. After achieving an initial set, new mortar is beaten with a churn brush, to expose the aggregate, compact the surface and remove excess mortar from the joint face.
6. New mortar is protected against the harmful effects of the weather and protected from too rapid drying out – see below.
7. In underwater work, the canal or lock is not refilled until the mortar has cured sufficiently to prevent damage. Underwater joints are finished flush.
8. Mortar in ‘above water’ situations is not placed in areas of chipped, broken or damaged brick/stonework. It is kept to the joints.

Purpose made repointing keys

High quality, flush jointed repointing

Protection

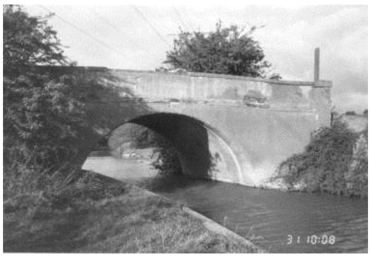
Particular attention is given to the curing of mortar pointing. In the summer it should be kept damp (by intermittent mist spraying) for at least seven days and protected against direct sunlight for at least fourteen days. In the winter, depending on exposure, it will need protection from frost and excessive rainfall.
In the summer hessian or a similar material should be used to protect the work against heat and drying winds; this material should also be kept damp. In the winter insulation sheets and polythene should be employed to protect the work, although it should be taken off during clement weather to assist with curing. Tenting and portable heaters may be necessary in order to keep the temperature around the area of repair at an acceptable level.

Protecting with wet hessian

6.8 Renders

Historic rendering on the waterways is generally associated with buildings rather than operational canal structures such as bridges and locks. The exception is the underside of bridge arches where lime rendering may be specified as a form of protection for decaying stone or brickwork. Lime rendering is normally undertaken by specialist contractors and is not covered by this repair standard.

Rendering with sprayed dense cement coatings in order to 'repair' badly weathered brickwork, e.g. the Gunite process should never be used on historic structures. It causes further damage as the cement prevents thermal movement and breathing in the historic fabric, resulting in cracking and de-lamination of the remaining brick faces.



A cement rendered bridge

PREPARATION

Performance Criteria

1. The preliminary survey is carried out thoroughly and where repointing work is proposed the need is clearly established. Sufficient detail is obtained to enable specifications and method statements to be prepared and approved.
2. The work is adequately planned, organised and supervised with particular regard to the health and safety of operatives and the public.
3. An environmental appraisal is raised and correctly validated with any conditions met before work commences.
4. The method of repair using lime mortar is carefully selected after a thorough analysis of the causes of deterioration and is the minimum necessary.
5. The nature of existing mortars, either lime or cement based, are properly assessed before a new mortar is specified, including where necessary the use of historic mortar analysis.

6. The specification (which must be prepared by a suitably qualified specifier, e.g. an engineer or architect) for the mortar mix identifies the correct type of lime, aggregates and any additives to give a good match with existing lime mortars and ensure durability of the fabric.
7. The specification for the re-pointing takes account of the joint thickness and the profile of existing pointing.
8. All contractors and operatives involved are competent and experienced in the use of lime mortar to the required standard.

METHOD

Best Practice Indicators

1. Repair work and materials comply with the specification unless authorised by the project manager and/or heritage adviser.
2. Lime, aggregates and other materials are handled with care to avoid damage and properly stored under cover and protected from frost until required for use.
3. Temporary works including safety fencing are non-invasive and reversible leaving no trace of their presence.
4. The mortar is properly mixed using the method set out in the specification unless authorised by the project manager and/or heritage adviser. The addition of Prompt is only as separately specified.
5. Water is clean and fresh from an identified source - canal or river water should not be used.
6. No work is carried out when a descending air temperature in the shade falls below 5°C, neither is it resumed until an ascending air temperature in the shade reaches 4°C.
7. The masonry or brickwork joints are correctly filled with mortar, tamped and finished to the appropriate specified profile without smears left on the face of the fabric.
8. All mortar work is protected from rain and prevented from drying out too rapidly for at least 24 hours. In frosty weather it is suitably protected for a period of up to seven days and longer if necessary in severe conditions.
9. All work complies with the Trust's Health & Safety requirements.
10. The method of work complies with actions in the environmental appraisal.

7. Carpentry Repairs

7.1 Timber species

The traditional timbers used for construction on the canals are:

- English oak – a hardwood and the main species used in large construction especially for lock gates.
- Elm – a hardwood that survives well when immersed in water so ideal for paddles and lock floor planking.
- Douglas fir – a softwood imported from North America suitable for fencing and construction,

Oak is used in traditional lock

sometimes used for balance beams.

gate construction

- Pine (joinery redwood) - another softwood imported from Scandinavia/Russia widely used in buildings.

Good quality building timber requires rigorous selection from slow grown trees with a high proportion of heartwood, free of the outer sapwood layer and other defects. In the canals' heyday this was easier to achieve than now and since World War II quality has suffered as a result of more limited choice. Consequently much of the timber available today has a greater proportion of sapwood and is a poor match for that used by the canal builders. However at a premium it is still possible to obtain high quality oak, pine and fir and this should be the objective for all heritage work.

An original canal company towpath gate, Shropshire.

In the 20th century tropical hardwoods such as Greenheart, Jarrah, Ekki and Opepe also came into use for lock gates and wharves, as they were perceived to be more resistant to decay and in some cases cheaper than home grown oak. However this did not reflect the true cost of extraction. For heritage work the use of imported tropical woods in canal structures should be avoided, except where the required specification cannot be achieved with traditional timbers e.g. in large marine piers.

7.2 Seasoning timber

The moisture content of timber affects its durability. With the exception of certain woods such as elm, the greater the moisture content the greater the risk of decay. Seasoning not only causes timber to shrink; it can also cause distortion such as warping or twisting. To overcome this, traditionally timber was and still is seasoned by stacking on spacers under cover and allowed to air-dry. This gives a range of moisture content from 17-23% which is acceptable for an exposed structure such as a lift bridge.

Timber is hygroscopic; it absorbs or releases moisture in the air until it reaches a balance with the humidity of the surrounding atmosphere. In order to avoid excessive shrinkage, internal carpentry and joinery work, particularly in a heated location, is best done using kiln-dried timber where the moisture content drops to about 15 per cent or less.

7.3 Sourcing timber

- Wherever possible new timber for repairs should match the original species. Due to the lack of availability of new elm, oak is generally an acceptable substitute.
- All new timber must be from a source approved by the Forest Stewardship Council (FSC) and have the correct 'chain of custody' documentation.
- Reclaimed or salvaged timber can be vulnerable to infestation or rots and may be contaminated e.g. with tar or lead based paints. It should only be used in exceptional cases with the consent of the project team leader.

Traditional carpentry is still found in operational structures.

- Timber was traditionally supplied in standard imperial sizes and these should be replicated for repair work.

- Timber selection must take into account the strength required either in compression (struts), tension (ties), bending (beams), or shear (joints) - tensile strength along the grain may be two or three times the compressive strength and as much as thirty times that across the grain.
- Timber strength is affected by species, density, direction of grain and presence of knots - structural timber should be stress graded to meet the characteristics of the repair.
- Unless the timber is to be used ‘green’ e.g. for lock gates, it should be properly seasoned either by air drying to 20% moisture content or by kiln drying to a stated level.

7.4 Defects

The following are common timber defects found in heritage structures:

Shakes

Shakes appear naturally as green timber seasons and shrinks causing it to split along the grain. It is generally harmless but for the sake of appearance or to prevent water penetration, shakes can be filled with a proprietary filler. Where it is considered that shakes have weakened a timber it may be necessary to strengthen it, e.g. by plating or strapping.

Dry Rot

A serious type of fungal attack usually affecting softwoods. Dry rot flourishes in unventilated places with high relative humidity where the moisture content of the timber is greater than 20%. It can spread very quickly to dry timber by transmitting moisture along mycelium threads, even through plaster and masonry, eventually resulting in complete decay of timberwork. Treatment requires the application of preservatives, replacement of damaged timber and most importantly the lowering of humidity through adequate ventilation.

Wet rot

A much more common fungus than dry rot but less serious because it is more localised. Nevertheless it can still lead to timber decay and failure. In their early stages wet and dry rot can look very similar. The most common victims of wet rot are:

- Timber in buildings not protected by a damp proof course e.g. ground floor skirtings or cellar joists.
- Leaking roofs.
- Timber in direct contact with the ground e.g. fencing posts.
- Where a painted finish has failed and allowed moisture to penetrate e.g. window frames, doors, gates and fencing.

Wet rot can be arrested by removing the moisture source. Normal prevention is to use pressure treated timber or protect against contact with moisture.

Insect attack (woodworm)

There are two types of timber destroying beetle likely to be seen on waterway structures, the common furniture beetle (Anobium punctatum) and death watch beetle (Xestobium rufovillosum). Furniture beetle generally targets sapwood in both hard and softwoods whereas death watch beetle prefers hardwoods, especially oak softened by decay. Affected softwoods can be treated with preservative but controlling death watch beetle in oak requires specialist help. Lowering the relative humidity in buildings and moisture content of timber is a significant factor in controlling attacks. Protection for new timber is by pressure treatment before use.

Broken joints

Traditional timber joints, properly executed, are inherently strong. Failures may result from excessive loading, structural movement or impact damage causing the whole or a part of the joint to break. The heritage approach to repair work is to rebuild the joint on a ‘like for like’ basis with matching new timber. Where additional support is required due to material weaknesses or excessive loading, this should be carefully designed to complement the original joint in an honest but sympathetic manner. In this way, both the structural and the historic integrity of the structure are maintained.

Fire damage

Timber burns readily but where an adequate section is used it can retain its strength in fire for longer than unprotected steel. Timber in fire forms a charcoal coat which slows the rate of combustion so the cross-sectional area of an element is therefore important. Where historic buildings have large "slow burning" beams, the burnt sections with enough 'residual section' left in them after a fire may be retained if they are 'de-charred', although the visual effect may be less than satisfactory.

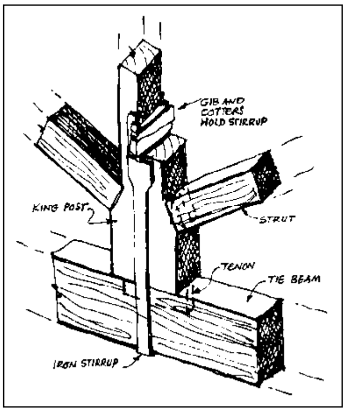
7.5 Repair techniques

Much of the waterways' historic timberwork is composite with both wood and metal components e.g. lock gates and roof trusses. When ironwork needs to be replaced, galvanised or stainless steel should be used unless there is a special case on heritage grounds for replicating the original material. Steel fixings should not be used in oak as the tannin present will react with the steel and stain the timber surface.

Repair of historic timberwork can adopt a number of different techniques:

Traditional joints

There are a wide variety of traditional carpentry joints but on the waterways the most obvious examples are pegged mortice and tenon joints. The mortice and tenon was used widely for framing gates, doors, windows and in building construction e.g. king post roof trusses in many waterways buildings. The scarf joint is another example often found, particularly in roofs, where beams or joists are spliced and jointed together in their length in order to extend them. Scarf joints can sometimes have complex designs in order to accommodate particular stresses. Repair work will involve disassembly and replication of the joint using new matching timber.



Typical king post truss

Scarf repairs

Scarf joints are also an excellent method of repairing damaged timbers that have to remain in situ and require a combination of repair and replacement. New timber is scarf jointed to the old in a traditional manner. The scarf design will vary according to the stresses it needs to resist, either compression, tension, bending or twisting.

A traditional scarf joint repair to a corner post

Splicing and Plating

A more functional approach to repair involves the strengthening or replacement of damaged timber by bolting new timber lengths spliced side by side with the old. Plating refers to the addition of timber or metal plates bolted on each side of a damaged member to provide the required strength. Slack mortice and tenons can similarly be strengthened by bolting T or L shaped plates on each side. Important to bear in mind that the appearance of repairs like these can be less harmonious than traditional jointing.

Resin repairs

Epoxy resin may be used in conjunction with carbon fibre rods to reinforce scarf or butt joint repairs with a minimum of disturbance to timbers e.g. for repairing rotten timber ends. However this method must not be used in exterior or structurally critical locations. Resin filler can also be used to repair and consolidate decayed areas of timber for visual improvements especially where they are going to be painted.

7.6 Treating and painting timber

Preservative treatments

Unpainted historic timber should not be treated with anything other than a colourless preservative and this will only be effective on sapwood and the less durable softwoods. Where new softwoods are introduced these should be pressure treated before delivery and all cut surfaces immersed or brushed with two flood coats of appropriate preservative on site. Ensure that the activity fully complies with the Trust's environmental standards.

Paint treatments

For exterior work, bear in mind that paint treatment can eventually encourage rotting of timber if it is not regularly maintained. Tar based coatings are now not acceptable unless there is a special heritage case for matching the original covering. Where colouring is required for the natural wood then an appropriate woodstain should be used. Traditionally, painted timber was primed, undercoated and glossed by brush and repairwork should adhere to this process, ensuring the new paint is fully compatible with the background material.

Paint looks shipshape, but it can lead to rotting timber

PREPARATION

Performance Criteria

1. The preliminary survey is carried out thoroughly and in sufficient detail to enable specifications (by a qualified specifier) and method statements to be prepared and approved.
2. The work is adequately planned, organised and supervised with particular regard to the health and safety of operatives and the public.
3. An environmental appraisal is raised and correctly validated with any conditions met before work commences.
4. The method of repair is carefully selected after a thorough analysis of the causes of deterioration and is the minimum necessary.
5. Replacement of structural timbers is carried out using the following guidelines:
6. Retain as much sound existing timber as possible.
7. Only replace what is necessary for structural integrity.
8. Cut away and splice in new members, using the same pieces/scantlings as the original.
9. Do not re-use timbers salvaged from other buildings.
10. Resin repairs, the use of fillers and adhesives are used with great care and skill and only with the consent of the project team leader.
11. All timber used to have the FSC 'chain of custody' documentation.

12. All contractors and operatives involved are competent and experienced in conservation work of the required standard.

METHOD

Best Practice Indicators

1. Repair work and materials comply with the drawings and specification unless authorised by the project manager and/or heritage adviser.
2. All materials are handled with care to avoid damage and properly stacked or stored under cover until required for use.
3. The type of timber used for the repair matches the original wherever possible or is an acceptable substitute.
4. The materials used are suitable for the purpose of the repair and free from defects.
5. Traditional techniques are used particularly with respect to the method of jointing.
6. Nails, bolts, screws, connectors and the like are of appropriate quality and non-ferrous or galvanised steel where there is a risk of corrosion.
7. The chosen method of repair is effectively carried out and the surface finish of new timber is a good match with the existing timber. The repair is visually and structurally acceptable and maintains the historical integrity of the asset.
8. All work complies with the Trust's Health & Safety requirements.
9. The method of work complies with actions in the environmental appraisal.

8. Metalwork Repairs

8.1 Introduction

Metals of various types were fundamental to the construction of the canals and in many cases the original materials remain in use today. Traditional metalwork is a distinctive element in waterway historic fabric. Examples range from simple fixings and fittings, to decorative features, machinery and structures of major substance. It is important to understand the different metals that were used, their significance and how to conserve them.

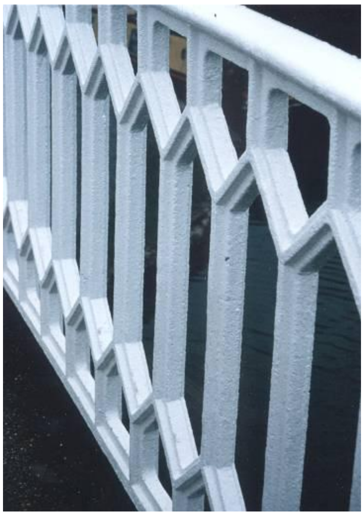
Wrought iron

- An almost pure fibrous iron material with less than 0.1% carbon but retaining slag impurities which gives it a laminar appearance.
- Highly ductile, malleable and flexible, can be worked hot or cold and easily welded.
- Works well in tension but has relatively poor fire resistance.
- Widely used since the inception of the Canal Age.
- Many small items were handmade in blacksmiths' forges and there is much variation in section and quality of early wrought iron. The best has good resistance to corrosion.
- Commercial production of wrought iron ceased in 1973, however it can still be recycled and supplies of the genuine material are available for repair work.

Wrought iron

Cast iron

- Crystalline iron alloy containing 2-5% carbon known as ‘grey cast iron’ in early form.
- Brittle nature, weak in tension but strong in compression, with relatively good resistance to fire and corrosion.
- First used as structural cast iron in the 1779 Iron Bridge by Abraham Darby III where he employed multiple fabrication of a limited number of iron elements which were then bolted together. In the following 100 years cast iron was widely used for canal structures.
- Production of cast iron required timber patterns which if they still exist can be reused for casting replacement elements.
- Defects include casting flaws such as ‘blow holes’ and embrittlement where historic elements are liable to snap when being handled or repaired.



Cast iron

Steel

- Covers a wide range of iron alloys of which mild steel with 0.2% carbon is the most common traditional type found on canals.
- Steel is strong in compression and tension.
- Mild steel is ductile, suitable for rolling into sections, strip and sheet and easily welded. It is very susceptible to corrosion so protective paint coatings are essential.

- Sometimes difficult to distinguish steel from wrought iron but important to note that modern ‘wrought iron work’ is generally in mild steel.
- Mild steel was first manufactured by the Bessemer process after 1856 and by 1880 was being produced in large quantities.
- Stainless steel containing chromium and nickel is hard, smooth and resistant to corrosion.

Steel swing bridge

Lead

- Used for centuries in sheet form as a roof covering for prestigious historic buildings and widely employed to form gutters, flashings and for general plumbing.
- Also used as a method for securing ironwork into masonry - especially on the canals for mounting railings and bedding wrought iron or steel anchor plates into quoin stones.
- An essential ingredient in historic paints.
- Very malleable with a low melting point, easily soldered, and can be worked into complex shapes. It has excellent corrosion resistance except where in contact with organic acids present in mosses, lichens and timbers.
- Lead has high thermal movement and is liable to rippling or buckling – correct detailing and workmanship is important.
- Ancient lead was cast but milled lead became common in the early 19th century and continues in

Lead flashings on a roof

use today.
- Lead is toxic especially in the form of soluble compounds such as historic paints – its use and repair should only be undertaken within H&S guidelines.

Traditional lead pouring on lock gate anchor frame

8.2 Alternatives

- Where corrosion of iron or steel elements is a risk, replacement in stainless steel or bronze may be acceptable depending on where it is used and the historic importance of the parent structure.
- Combinations of some metals must be avoided, e.g. lead and aluminium or steel and cast/wrought iron which can lead to galvanic corrosion.
- Generally no acceptable substitute for lead on heritage structures apart from internal plumbing – for repairs ironwork can still be 'leaded' into masonry provided there is an appropriate risk assessment.
- Copper is a traditional alternative to lead for roof coverings of historic buildings.

8.3 Cleaning and preparation

This may require chipping, scraping, disc sanding, needle gunning and grinding surfaces to remove all fins, burrs, sharp edges, weld spatter, loose rust and loose scale. Where cleaning is carried out on a standing waterway structure, the system must be approved for heritage use and meet the Trust's environmental and safety standards.

Crevices should be cleaned out. Degrease thoroughly using emulsion cleaners followed by thorough rinsing with clean water, ensuring that all waste products are contained and correctly disposed. Primer is applied when surfaces are dry and on the same day as cleaning. A suitable general purpose primer would be one coat of zinc phosphate modified alkyd applied with a full brush to all surfaces.

8.4 Repair methods

The method of repair should ensure that the result is visually acceptable and is usually a choice or combination of:

- Strengthening or reinforcing by adding plates or stiffening members as necessary.
- Dismantling and re-erecting – this is specialist work to be undertaken with great care which enables original components to be used for re-casting and new fixings to be inserted. All parts must be marked or numbered.

The following traditional techniques may be used for carrying out historic repairs:

<u>Welding</u>

Quality depends on type of material to be welded (wrought iron and mild steel suitable, cast iron highly specialised and expensive, stainless steel with care). Using the correct technique requires skill and training is needed. Consumables used in welding must match parent metal. For structural joints full strength butt welds are recommended with all laminations attached. Fillet welds to wrought iron are satisfactory provided they incorporate a sound edge.

Welding can play a part in repair techniques

Stitching

Effective in dealing with cracks in cast iron plates or in the replacement of sections by inserting and stitching in new pieces, e.g. by the Metalock process.

Plating and strapping

Where cold stitching proves impractical, compatible metal plates can be fabricated to fit over a defect and maintain the structural integrity of the structure. Plates and straps are introduced to stabilise and the repair should be hidden from view where possible. This method is generally reversible and minimises the impact on the host metal.

An early strap repair to a cracked cast iron handrail

Bolting

Bolts should be carefully selected to match existing wrought iron or steel in order to avoid galvanic corrosion. Advice from a structural engineer should be sought in complex cases. High strength friction grip bolts are not advised except for 20th century steelwork.

Riveting

Usually employed to match new elements into existing wrought iron or steelwork. It is unsatisfactory for cast iron. Advice from a structural engineer should be sought in complex cases.

Re-casting

Cast iron replacements can be manufactured where original elements are missing or damaged, either by using the original patterns or making new ones from the existing structure. Replacements should be discreetly date stamped to distinguish them from the originals.

Cast paddle stand with 1984 date stamp

Adhesive bonding

An established alternative technique to welding and riveting. Manufacture and supply of adhesives is highly specialised – seek advice. Best carried out in controlled workshop conditions although in-situ repairs are possible with care. Joint preparation (cleaning, degreasing etc.) is essential.

Filling

Metal fillers based on steel particles in an epoxy resin binder may be used on cast or wrought iron to make good areas of corrosion and defects, provided the members themselves are structurally sound. An acceptable alternative to welding which may be difficult to achieve in-situ. Proper preparation of the host metal is essential.

PREPARATION

Performance Criteria

1. A survey and analysis of the structure is completed in sufficient and accurate detail so that drawings, specifications (by a suitably qualified specifier) and a method statement can be prepared.
2. The work is adequately planned, organised and supervised with particular regard to the health and safety of operatives and the public.
3. An environmental appraisal is raised and correctly validated with any conditions met before work commences.
4. Historic metal is to be retained and repaired in situ whenever possible, with replacement only when there are significant defects or missing elements.
5. Metal used for repairs is to be of an identical type to the host metal except where there is clear justification on heritage grounds for suitable alternatives, e.g. substituting stainless steel masonry cramps for the traditional iron which is prone to rusting.
6. The metal used, whether wrought or cast iron, steel, lead or other non-ferrous metal, has properties suitable for its intended use and has the required strength characteristics.
7. Reclaimed or salvaged metal to be used only when it is considered suitable for its purpose and is free from significant defects such as excessive wear and tear, casting flaws, fractures, distortion, embrittlement or corrosion.
8. Contractors and operatives are employed who are qualified and experienced in work of the required standard

METHOD

Best Practice Indicators

1. Metal and other materials comply with the specification or their suitability for the work.
2. All materials are handled with care during transit and on site and properly stacked or stored under cover where appropriate until required for use.
3. Temporary works including safety fencing are non-invasive and reversible leaving no trace of their presence.
4. Where appropriate, metal sections are cleaned, prepared and primed before despatch from the works.
5. The materials used in the repairs are suitable and adequate for the purpose of the repair.
6. Every opportunity has been taken to use traditional techniques.
7. The repair is effectively carried out. It is visually and structurally acceptable and maintains the historical integrity of the asset.
8. All work complies with the Trust's Health & Safety requirements.
9. The method of work complies with actions in the environmental appraisal.

9. Concrete Repairs

Mass concrete structures using hydraulic lime as a binder date back to Roman times but the modern form of concrete made with Ordinary Portland Cement (OPC) did not develop until after 1850. The Kiln Warehouse on the River Trent in Newark is an example of a mid-late 19th century mass concrete building. One of the earliest known uses of concrete for canal work was channel lining for the Thames & Severn Canal in 1900. Subsequently the material has been used widely in place of the traditional brick or stone. Purpose made copings, some of which have historic note, are common on canals such as the Shropshire Union.

1930s concrete structures are now part of the nation's heritage

The inclusion of iron or steel bars to create reinforced concrete allowed the creation of more complex structures and this became the basis for much of modern construction. Notable early examples of the use of reinforced concrete are a 1915 footbridge over the River Trent, the 1930s Grand Union bridges and lock balance beams on the Bridgwater & Taunton Canal.

Historic concrete covers a broad range of 20th century construction, not all of which has heritage value. However one category with increasing significance includes concrete defence structures, especially those dating from World War II. There are many examples along the southern canals such as anti-tank bollards and pillboxes, a number of which have now been listed.

*Reinforced concrete footbridge, River Trent, 1915. Listed grade II**

Reinforced concrete was also introduced for boat construction on the inland navigations, the first example being two prototype narrowboats built for the BCN in 1918. A large number of concrete barges were built for use on estuarial waterways during World War II.

9.1 Defects in concrete

Concrete can suffer from a number of defects, the majority relating to corrosion of the iron or steel reinforcing bars if they are present. Normally the bars are protected by the highly alkaline state of the concrete encasing them. However if the alkalinity is reduced or the metal exposed to the atmosphere then it is liable to rust. In this process the metal expands and exerts great pressure on the surrounding concrete resulting in cracks or spalling, where layers of concrete flake and break away.
The following are common defects in concrete:

- Frost damage, especially where water can penetrate into cracks – results in concrete cracking and spalling.
- Sulphate attack – loss of strength due to presence of sulphate salts in the concrete or adjacent materials.
- Carbonation – penetration of the concrete by carbon dioxide and water from the atmosphere leading to corrosion of reinforcing bars and subsequent spalling.
- Chloride attack – corrosion of reinforcing bars due to the presence of chlorides in the concrete or the use of de-icing salts (especially on road surfaces).

Carbonation of concrete leading to spalling and exposure of corroding reinforcement

- Low cement content – results in excessive weathering and corrosion of reinforcing bars.
- Inadequate cover to reinforcement - results in corrosion of reinforcing bars (a common problem on early 20th century concrete).

9.2 Surveying

Surveying reinforced concrete structures requires some knowledge of typical defects. The survey may be 2 phase:

Phase 1

- Desk study - obtaining records of construction and previous repairs
- Visual inspection and measurement
- Hammer test for locating defective material

Phase 2

- Detailed inspection (full access with scaffold) including cover test for reinforcement
- Laboratory tests on dust and chip samples
- Engineer's report including structural test results

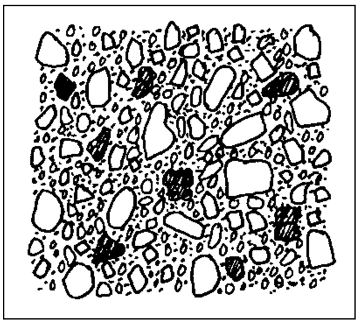
Laboratory tests may include:

- Sulphate content
- Chloride content
- Cement content
- Depth of carbonation
- Density
- Water absorption
- Compression testing of concrete cores
- Examination for stress corrosion

9.3 Materials for repair

Aggregates

Well-graded aggregates should be used. Coarse aggregates are used in larger repairs but the size will be governed by the shape of the repair and reinforcement. Rounded aggregates up to 10mm are not uncommon. Smaller repairs will require the use of a mortar rather than concrete, made with well-graded pit sand. Water to cement ratios must be low to minimise shrinkage. Overhead work may require the use of lightweight aggregates from an approved source.



Well-graded aggregate.

Polymers and resins

Agents included in mortars for strengthening concrete repairs are generally of two types:

- Polymers such as Styrene Butadiene (SBR) or Polyvinyl Acetate (PVA) which are added to cementitious systems. These are added in latex form to a mortar and have the advantage that they improve the bond between old and new material, strengthen the mortar and contribute to the alkalinity of the mortar surrounding the reinforcement.
- Reactive thermosetting resins such as epoxy, polyester or acrylic resins which are added to aggregates alone. Resin based mortars require careful preparation and

application, being particularly useful for small repairs where the cover to reinforcement is less than 12mm. The resultant material is very dense and adheres strongly to adjacent surfaces.

Concrete or mortar mix

Concrete or mortar mixes using natural aggregates range from 2.5 to 4 parts aggregate to 1 part OPC depending on the type and size of repair. Strengths vary from 30 to 50N/mm^2 at 28 days. Rapid Hardening Portland Cement (RHPC) may be used where early strength gain is required. Polymers and resins should be used strictly in accordance with the manufacturers or specialist advice.

9.4 Repair methods

It should be noted that in repairs to historic concrete there may be a conflict between conservation principles and current technology. The use of polymers, for example, is considered good engineering practice but may not suit the requirement for historic integrity. This is a matter to be resolved with heritage specialists.

Larger scale repairs often involving reconstruction are similar to new work and outside the scope of this document. For small to medium sized repairs 3 methods are in common use:

- crack repairs
- spalled concrete repairs
- sprayed concrete

Resin based repairs may be used to improve protection of reinforcement but in some cases cover can only be increased by surface coatings or rendering. In severe cases, sprayed concrete as an external skin may be necessary.

Crack repairs

The cause of cracking must be investigated to determine whether remedial action should extend beyond the scope of a concrete repair. Some cracking from shrinkage may be inevitable. Cracks at right angles to reinforcing steel are considered less harmful than those along its length and unsightly cracking may require little more than surface coating. Crack sizes should be measured and 6mm is an acceptable maximum width for repair. The overriding decision is whether a crack is allowing the ingress of water.

'Dead' cracks with no movement may require one of the following:-

- Neat cement and water grout brushed into cracks
- Chase out to 5mm or 10mm width and point with cement and sand mortar
- Low-viscosity polymer grout without pressure
- Polymer injection by gravity or mechanical pumps – requires injection points to be selected and the cracks between them to be surface sealed
- Resin injection (e.g. epoxy) where structural strength is required

'Live' cracks which are stable but have some movement will require the use of a proprietary sealant with sufficient flexibility to cope with this variation. The ideal cross section for the sealant may be achieved by cutting a chase and forming a movement joint.

Repairs to spalled concrete

The cause of spalling must be investigated to determine whether remedial action should extend beyond the scope of a concrete repair. Common causes are carbonation and chloride attack.

A typical repair sequence for spalled concrete:

1. Test, expose and remove defective concrete to a sound alkaline base after testing with a chemical indicator (e.g. phenolphthalein).
2. Expose reinforcement beyond corroded parts. Blast clean and protect immediately with two coats of polymer modified cementitious slurry, the second coat blinded with sharp sand.

3. Apply a bonding bridge of cement, sand and polymer slurry to the whole exposed area.
4. While slurry is still wet, apply the first layer of repair mortar not exceeding 25mm deep.
5. Build up further layers as each one is strong enough to support the next. Finish with a surface texture to match the existing.
6. Allow to cure with protection.
7. Complete refurbishment by coating with highly alkaline cementitious render if required.

Where resin-based materials are used, it is essential to thoroughly clean surfaces to be totally dust free. Resins are supplied in two or three part packs for mixing just prior to repair. Proper mixing is essential and the manufacturer's instructions must be followed. Resins are exothermic, generating heat which increases the rate of stiffening. The material must be well compacted since its main purpose is to render the repair impermeable.

<u>Sprayed concrete</u>

Application of this technique should not be used on historic brick or stone structures as it prevents them being able to breathe. In the 20th century a sprayed concrete product known as Gunite was sometimes applied to canal bridges with drastic effects.

A 'gunited' bridge. Such drastic action has little to do with conservation

This is a specialist activity in which a thin layer of high quality fine concrete is sprayed on to the surface to which it will bond strongly, restoring protective cover to reinforcement, making good spalled concrete and 'improving' appearance. The technique enables a low rate of application in thin layers to be used for awkward shapes and a high rate of application for larger areas.

When sprayed concrete is applied to undamaged concrete to achieve an overall uniformity of finish, the host surface should be roughened to remove any deposits and cement laitance (surface residue) so that a good key with the new material will be achieved.

PREPARATION

Performance Criteria

1. A survey and tests on the structure are completed in sufficient and accurate detail so that specifications (by a suitably qualified specifier) and method statements can be prepared.
2. The work is adequately planned, organised and supervised with particular regard to the health and safety of operatives and the public.
3. An environmental appraisal is raised and correctly validated with any conditions met before work commences.
4. The method of repair is carefully selected after a thorough analysis of the causes of deterioration and is the minimum necessary.
5. The cement used in repairs is either Ordinary Portland Cement or where appropriate, Rapid Hardening Portland Cement. If the original concrete was built with Sulphate-resisting Portland Cement or deterioration has occurred due to sulphate attack this can be specified.
6. The aggregates used in repairs are from natural sources for concrete.

7. Where necessary, repair materials containing polymers or reactive thermosetting resins are used as part of an approved repair system.
8. Where additional or replacement reinforcement steel is required it is compatible and suitable for the purposes of the repair.
9. Contractors or specialists are employed who are competent and experienced in work of the required standard.

METHOD

Best Practice Indicators

1. The materials used in the repair comply with the specification unless authorised by the project manager and/or heritage adviser.
2. All materials are handled with care to avoid damage and properly stacked or stored under cover until required for use.
3. No drilling of historic concrete such as copings is permitted.
4. Temporary works including safety fencing are non-invasive and reversible, leaving no trace of their presence.
5. Defective material is identified and broken out completely and all surfaces to be joined with new material are suitably prepared.
6. The new concrete is properly mixed using the method set out in the specification.
7. Water is clean and fresh from an identified source - canal or river water should not be used.
8. No work is carried out when a descending air temperature in the shade falls below 4°C, or resumed until an ascending temperature in the shade reaches 3°C.
9. Finished repairs are protected from rain and are prevented from drying out too rapidly for at least 24 hours. In frosty weather they are protected for a period of three to seven days depending on circumstances.
10. The chosen method of repair is effectively carried out. It is visually and structurally acceptable and maintains the historical integrity of the asset.
11. All work complies with the Trust's Health & Safety requirements.
12. The method of work complies with actions in the environmental appraisal.
13. Accurate records are kept showing the use of all materials and the position and extent of the repairs.

10. Painting Historic Fabric

10.1 Introduction

Where historic fabric has been traditionally painted this forms a significant element in the heritage value of the asset. However where structures were not originally coated they should retain the same appearance unless there is a justifiable heritage reason for the alteration. In some cases painting at a later stage contributes to a structure's distinctiveness, e.g. bridge arches painted white as a warning to boats.

Paint is traditional for some waterway buildings

Historic fabric should only be painted for the following reasons:

- Replacing paintwork which is defective due to wear and tear, fire damage, flood damage or incorrect paint used on a previous occasion.
- Re-coating paintwork for maintenance purposes.
- Applying new paint on repairs and re-constructions to match existing paintwork.
- Reinstating paintwork where the original coating has been removed, e.g. historic timber that has been stripped in an earlier 'restoration'.

10.2 Considerations for removing old paint

The need for removing the paint or coating should be clearly established on conservation grounds. In some cases there may be serious environmental health constraints such as in the removal of lead paint, which should only be undertaken where there is no alternative. Typically the reasons for removing paint are to:

- Reveal historic coatings underneath
- Remove defective paintwork
- Reduce the overall paint thickness, e.g. where important architectural detail has been obscured by multiple layers of paint

Original paintwork should not be removed merely to satisfy a desire for unpainted surfaces. The over-riding consideration in removing paint from historic surfaces is that the fabric underneath must not be damaged.

Where it is important to establish the type and colour of historic paintwork which is known or suspected to lie beneath several subsequent layers, this can be achieved by historic paint analysis. Conservation officers may require this in conjunction with a listed building application to repaint a structure.

All works to remove paint must comply with the Approved Process: Heritage Works for *Cleaning Historic Fabric*. In addition selection of the specific method for removal should also take into account:

Defective paintwork leads to wet rot in timber

- The type of paint to be removed
- The thickness and condition of the paint
- The nature of the substrate and its condition
- Climatic conditions for exteriors – important where repainting needs to follow directly after removal

10.3 Methods of removal

The following are the most frequently used methods of paint removal for maintenance and repair of structures.

Water washing

Suitable for emulsions, lime wash, whiting and soft distemper – removal works best with warm water and scrubbing. Mild liquid detergents are preferable to alkaline soaps. Where the substrate is plaster, the water should be kept to a minimum or it may cause blistering.

Steam stripping

Useful when water washing is too weak to be effective – water thinned paints can be sponged off. Super-heated steam cleaners, e.g. the DOFF type, are particularly effective. Care is needed as steam can damage fragile surfaces such as old plaster.

Chemical paint removers

- Solvent (non-caustic) – usually methylene chloride. Good for removing oil-based paints, less effective for others and several applications may be necessary so may be rather slow. Care is needed as solvents can be toxic or flammable. Application and removal strictly in accordance with manufacturers' instructions.
- Alkaline (caustic), e.g. caustic soda. Effective, but can damage any porous surfaces including plaster, brick and stone, and also metal, plywood and putty. Good for removing oil-based paints but thorough washing needed afterwards to remove alkaline deposits.
- Poultices – for stubborn, grooved or textured surfaces. Poultices consist of attapulgite or sepiolite clay, or whiting and sawdust, mixed with a non-caustic stripper. They are covered with cling film to prevent rapid drying.

Old paint systems must be removed with care

Abrasive methods

Mechanical abrasive methods have the potential to permanently damage surfaces and only appropriate systems should be used. No abrasive method is suitable for removing paint from lead.

- Hand held scrapers and abrasive blocks, wire brushes, cloths or papers - laborious but often effective.
- Mechanical sanders – suitable for timber surfaces, e.g. floors. Care is needed to avoid damaging the substrate.
- Blast cleaning – specialist operation with a wide range of applications but careful selection of the correct system is vital. These employ a range of aggregates from talc and soda to very coarse materials. Systems designed to combine 'soft' aggregates with a swirling torc action, e.g. the JOS type and SodaBlast, are suitable for historic brick and stone.
- Other mechanical abrasion that involves chipping, wire brushing and grinding is only suitable for iron and steel

Removing masonry paint by sympathetic blast cleaning before repainting

Hot air strippers
Good for oil paints and varnishes especially on timber, but not for water-based paints, metal or plaster backgrounds. Usually with a variable temperature. Care is needed near glass to avoid cracking it, especially thin historic panes.

Burning off with blow torch
Effective for oil paints but requires skilled use to avoid scorching and carries a high risk of fire. Not suitable for removing paint from lead.

10.4 Preparation of surfaces for painting

The choice of method will depend on:

- the nature of the base material and its condition
- the prevailing environmental conditions
- the type of coating system which is to follow

Previously painted surfaces

Sound surfaces should have loose paint scraped off to a hard edge and be sanded or washed, e.g. with sugar soap, to remove grease and dirt. All holes and cracks should be made good with a suitable stopper and the surface lightly abraded to provide a key for the new coating.

19th century brickwork painted with inappropriate modern masonry paint

Unsound surfaces which are flaking, peeling, blistering or cracking should be stripped back to bare surface and then treated as a new surface. Mould growth must be removed with an approved fungicidal wash that is allowed to dry thoroughly afterwards. Dry brushing mould merely spreads the spores.

Plaster
Plaster should be dry (allow up to 1 month drying time per 25mm thickness of new plaster). Efflorescence should be brushed off and loose powdery plaster treated with a stabilising solution or an alkali-resistant primer, applied thinly to prevent it going glossy.

Steel and iron
Wherever possible, preparation should be in a protected and dry environment. Dirt, welding flux, mill scale, rust and grease can be removed by degreasing on site with organic solvents or white spirit. Paint removal is normally either by grit blasting or chipping/wire brushing and should be followed with a blasting or tolerant primer. Once the surface is prepared it must be primed within 4 hours and before any condensation can form.

Bare wood
Timber must be dry with moisture content below 25%. Dirt, grease and tar should be removed with organic solvents/white spirit and moss, algae and lichen with a biocide solution and scraper. Rub down sound surfaces using brass or steel (for coarse work) wire brushes and abrasive cloths and papers. Avoid excessive wear of the surface. Cut out and repair rotten wood, fill holes with an approved stopper and apply knotting (shellac) before painting any knots likely to stain

Repaired towpath 'clapper' gate before repainting

Stone, brick and rendering
Ensure surfaces are dry. Remove efflorescence and loose powdery or flaking material by brushing off. Mould growth, moss, and lichen should be removed by brushing and scraping followed by an approved fungicidal and/or biocide wash. This must be thoroughly rinsed off afterwards and dried.

10.5 Selection of paint and other coatings

Criteria for selection

There are numerous types of paint or coating and many variations within each type. For conservation work paint selection should take into account the following:

- Identification of historic paint surfaces - it may be necessary to remove subsequent paint layers in order to achieve this.
- Where required, the need to match an old paint for colour, texture, thickness and performance, including a patch painting trial.
- The impact of a 'modern' paint system on the historic fabric, especially with regard to reversibility.
- Correct selection of a paint system for patch repairing old lead paint. Lead was widely used as an ingredient in paint up until the 1960s; however use of lead paints is not permissible now except under licence for Grade I and II* listed buildings. Alkyd gloss systems have achieved considerable success as a replacement for lead paint.

Types of paint

Brief details of some common paints and coatings are given in the table below. These are general points and it is advisable to consult manufacturers in specific applications.

Common paint name	**Reversible**	**Film form**	**Thinner/solvent**	**Properties**	**Use**
Acrylic gloss	No	Copolymer PVA or acrylic resins	Water or warm water	Washable, alkali-resistant, non-toxic, low odour`	Interior ceilings, walls and wood, not bare metal
Alkyd gloss	No	Oil-modified alkyd resins	White spirit	Washable, good all round gloss with good weather resistance	Most interior and exterior, surfaces but particularly wood
Bituminous paint	Yes	Bitumens of different sorts blended	Solvent naphtha, white spirit or paraffin	Impermeable, black (aluminium added for reflective version) weather-resistant	Metal, wood, roofs, tanks, gutters etc.
Cement paint	No	White Portland cement + additives	Water	Alkali-resistant, low cost, rough texture	Masonry, pebbledash, farm buildings etc.
Chlorinated rubber	Yes	Chlorinated rubber	Hydrocarbons, Esters, Ketones (see manufacturer guidance)	Flexible, waterproof, quick drying, good chemical resistant.	Most materials but particularly metal. Road marking.
Distemper (water paint)	Yes	Casein, oil or size + whiting	Water	Permeable, wipeable, (except 'soft' distemper) - weathers naturally	Walls or ceilings generally, both interior (not 'soft') and exterior
Emulsion	No	PVA polymerised with resins	Water	Permeable, washable, many variations, readily available	Walls and ceilings generally, not metal
Epoxy (2-pack)	No	Epoxy resins	Xylol and butanol (see manufacturer guidance)	Tough, impermeable, resistant to acids, alkalis, solvents and water	General use – very good for metal

Common paint name	Reversible	Film form	Thinner/solvent	Properties	Use
Lime wash	Yes	Lime putty + linseed oil	Water	Historic use, can be pigmented - sympathetic, recoatable.	Interior and exterior walls, ceilings and wood, not metal
Masonry paint	No	Acrylic or vinyl copolymer resins + minerals	Water	Alkali-resistant, tough, flexible, good filler, non-toxic	External brick, stone, rendered wall.
Micaceous iron oxide	No	Linseed oil and phenolic resins	White spirit	High build, tough, weather and corrosion resistant	Iron and steel structures
Oil-based	No	Oil and resin combinations (traditionally with lead).	White spirit	Washable, weather resistant, dries out with age leading to surface cracking	Interior and exterior surfaces if not alkaline. Lead for Grade I and II* only.
Polyurethane (2-pack)	No	Polyurethane resins	See manufacturer guidance	Chemical, water, abrasion and heat resistant. Good adhesion.	Tough surfaces generally, eg floors.
Varnish (acrylic)	No	PVA copolymer or acrylic polymers	Warm water	Washable clear sealer (sometimes mixed with emulsion for sealing walls)	General use but mainly interior joinery
Varnish (oleo-resin)	No	Oil modified alkyd or phenolic resins	White spirit	Hard wearing and weather resistant clear finish (gloss flat or egg-shell)	'Long oil' (marine varnish) for external wood. 'Short oil' for interior use only.
Wood stain (spirit or oil)	No	N/A – material is absorbed into the surface	Spirit - methylated spirit Oil – white spirit	Coloured and transparent – enhances natural shades of wood	Wood generally interior and exterior

10.6 Application of Paints and Finishes

<u>Plasters</u>

Non-permeable coatings such as vinyl and cement based paints prevent historic fabric breathing and are not suitable for lime plasters. Permeable alternatives are:

- Lime wash – historically both internal and external walls were coated in lime wash applied in several thin coats, as many as six on new surfaces. Each coat is so thin that it looks and feels like water but becomes opaque as it dries. The first coat should be put on to a lightly damp wall. Coloured pigments can be added.
- 'Trade matt' or 'contract' emulsion paints - these are semi-permeable and suitable for internal surfaces.
- Whiting (chalk and alum) and clay paints - interiors only.
- Distemper - available in three basic forms; for interiors, non-wipeable soft and wipeable standard distemper; for either interiors or exteriors, oil bound distemper.

Lime washed flood arch of restored aqueduct

Steel and iron

Use an ‘inhibiting’ primer immediately after thorough preparation. Examples are zinc phosphate, zinc chromate or zinc dust. Note that common red oxide primer is not inhibiting to rust. To prevent corrosion use an elastic paint system with an overall thickness of at least 125 microns (may require four or five coats) such as:

- Micaceous iron oxide – for high degrees of exposure
- Chlorinated rubber – for high degrees of exposure
- Alkyd resin-based undercoat + gloss (or semi-gloss)
- Heavy-duty bitumen, coal tar or coal tar epoxy paints
- Lead-based oil paints - Grade I and II* listed buildings only

Timber

The traditional lead primer has been replaced by alkyd or acrylic primers, to be followed by one or two undercoats and a finishing coat, rubbed down between coats with wet abrasive paper. Other finishes include:

- Polyurethane and acrylic glosses
- Varnishes
- Stains - opaque and coloured for high quality work

Note that modern clear and translucent systems have little relevance to historic finishes.

Stone or brick

Where historic stone and brick surfaces are painted this has often been added at a later stage in a frequently unsuccessful attempt to cure a damp problem. Modern masonry paints prevent walls breathing and are generally not suitable for historic fabric; any proposal to repaint must incorporate appropriate preparation of the surface. Suitable coatings for brick and stone are:

- Mineral or silicate, but not cementitious, masonry paint.
- Lime wash (see for plasters above) with the addition of linseed oil – not suitable for dense brick and stone.
- Oil bound distemper is considered a good ‘natural’ alternative.

Lime rendered bridgekeepers cottage before repainting

External renders

Lime-based renders should be treated in the same way as porous stone and brick. For cementitious renders, mineral and silicate masonry paints or oil bound distemper are viable alternatives to conventional masonry paints.

Cottage after repainting with a mineral paint

PREPARATION

Performance Criteria

1. The justification for painting and the method of doing so, including removing old paint layers, is firmly established before the work starts.
2. Painting of designated assets has been authorised by the statutory authorities.
3. A thorough inspection of the building or structure is completed so that appropriate methods and materials can be accurately specified (by a suitably qualified specifier) for the work. Any environmental conditions which may affect the work to be done are also taken into account.
4. Where necessary, tests are carried out to determine the presence of old lead paint and the correct protective measures incorporated into the method statement.
5. Where a new coating is to match an existing one, it is the best possible match in colour, texture, thickness and performance, confirmed if necessary by trial patch painting.
6. The work is adequately planned, organised and supervised with particular regard to the health and safety of operatives and the public.
7. An environmental appraisal is raised and correctly validated with any conditions met before work commences.
8. Contractors and tradesmen are employed who are competent and experienced in work of the required standard.

METHOD

Best Practice Indicators

1. The method of preparation and painting fully complies with the specification for the project.
2. Temporary works including scaffolding and safety fencing are non-invasive and reversible, leaving no trace of their presence.
3. Environmental protection measures are rigorously implemented to cover prevention of contamination to land or water and containment of all residue and washings during the preparation of surfaces.
4. The method of surface preparation including any paint removal is effective but avoids damage to the substrate.
5. Adequate protection is provided against the presence of moisture and excessively high or low ambient temperatures during the work. Where necessary, finished work is protected from adverse conditions until it has cured.
6. The method of painting is effectively carried out and the historical integrity of the asset is maintained.
7. All work complies with the Trust's Health & Safety requirements.
8. The method of work complies with actions in the environmental appraisal.
9. Accurate records are held of the painting process and associated preparation.

11. Cleaning Historic Fabric

11.1 Context

Cleaning historic fabric should be undertaken with care as many of the traditional materials used for construction are particularly vulnerable to damage from inappropriate methods of removal. Cleaning may be required for a number of reasons.

Graffiti removal

Graffiti is unsightly, potentially damaging to historic structures and can be offensive. Unresolved graffiti attacks tend to attract further damage, with the presence of a “tag” encouraging others to overwrite it. Often there is a combination of media, e.g. felt tip with aerosol paint, which may require a two-pronged approach. Felt tip can be notoriously difficult to remove from some surfaces.

Certain issues have particular relevance for heritage structures:

- Significant historic settings can become blighted by the presence of graffiti, especially when it is accompanied by littering and other anti-social behaviour. A prompt response to graffiti damage generates a sense of care and helps to discourage further attacks.
- Rapid treatment of graffiti is also desirable because paints, glues and inks dry-out over time and can become increasingly difficult to remove as they bond to the background material. Historic brick and stonework is particularly vulnerable and the correct method of removal is essential in order to minimise the extent of damage.

Graffiti – an ever present problem on waterway structures

- For offensive graffiti includes all those examples which are racially offensive, sexually offensive, homophobic, defamatory or depict a sexual or violent act, the Trust’s contractors are tasked to take reasonable steps to remove offensive graffiti within 1 day of being instructed. If the wrong method is used this could risk damaging the asset.
- Graffiti on historic structures should not be painted over unless the wall was previously painted. In exceptional circumstances involving offensive graffiti, temporary cover painting may be considered but the process should be an approved reversible one.

General paint removal

Removing paint or tar based products from historic structures may be required either to:

- Remove inappropriate treatments damaging the substrate
- Return the structure to its original appearance
- Provide a sound surface for repainting
-

Results of applying plastic-based paint to historic brickwork

In typical cases masonry originally unpainted or treated with lime wash has subsequently been over-painted with an acrylic or cementitious paint. This prevents the historic stone or brickwork from breathing, resulting in lamination due to frost and salt damage and peeling of the paint layer. Any proposal to return a structure to an original unpainted appearance should always consider that the painted appearance may contribute to its existing heritage value. Proposed alterations to designated structures must also be discussed with statutory

authorities first.

A good example of sympathetic cleaning

Removal of dirt and other deposits

Deposits to be removed usually consist of airborne dirt bound together and to the masonry surface with calcium sulphate (gypsum, typically on limestone) or silica (typically on sandstone or clay bricks). Other deposits may be:

- cement splashes
- calcium carbonate deposits
- efflorescent salts
- bird fouling
- heavy and light oils
- organic growth
- metallic stains, e.g. copper sulphate

11.2 Cleaning Trials

A trial is an essential prerequisite of any cleaning activity. It must be properly specified, recorded and supervised. A proposal to clean must take into account the impact of the appearance after the cleaning process. The patina of age contributes to the value of the historic asset and is particularly important on vulnerable surfaces like ashlar limestone. Some local authorities (e.g. the City of Bath) have specific guidance on the cleaning of historic assets. A trial will assist in the decision ‘to clean or not to clean’, enable comparisons to be made and full specifications to be drawn up.

In addition, there are environmental constraints with the use of all cleaning systems, especially in proximity to water, which should be carefully considered. All data relating to the method adopted for cleaning must be carefully recorded.

11.3 Removal techniques

There are a variety of methods used to remove paint and other substances. Generally cleaning systems must only be used by trained operatives. Where paint removal is part of a maintenance or repair process, refer also to the Approved Process: Heritage Works, *Painting Historic Fabric.*

It should be noted that only systems specifically approved on both heritage and environmental grounds may be used for cleaning surfaces. Always refer to the current datasheet for approved methods and take account of constraints for different locations before selecting the appropriate system.

Techniques for cleaning can be split into mechanical and chemical systems.

Mechanical system selection

Mechanical systems attempt to abrade or chip the media from the surface; these include wet or dry air-abrasion systems such as wire-brushing, grit-blasting and high pressure hosing either cold or with steam.

Abrasive systems can damage the underlying surface, particularly when used on brickwork or masonry and must always be approved before use on heritage structures. High pressure hosing is frequently used but in some cases can cause permanent damage to pointing and friable surfaces. It can also force water into previously dry areas leading to salt migration and subsequent efflorescence. While aggressive grit-blasting methods may be appropriate for cleaning ironwork they are never suitable for timber, historic brick or stone.

The Six Packs Pub before

cleaning

However systems using ‘soft’ aggregates with a high degree of control (e.g. JOS type or SodaBlast) can be ideal for cleaning vulnerable fabric.

Selection should also take into account:

- Compliance with the Trust’s Health & Safety regulations – only 110V electricity supply is permitted.
- Disturbance to the public – mechanical systems tend to be very noisy in use.

After cleaning with a mildly abrasive system

Containment of residue – Dust or run-off is potentially hazardous and adequate controls must be employed to enclose and remove all deposits, particularly where there is a high risk these can enter water courses, such as in cleaning bridges.

<u>Chemical system selection</u>

Chemical preparations are based on dissolving the paint media or other deposits; these solvents can range from water to potentially hazardous chemical ‘cocktails’. Careful selection is important as some chemicals will mark permanently and can drive the ink from the graffiti further into the pores.

Selection should also take into account:

- Containment of both chemicals and residue - the potential for contamination of adjacent ground and water courses from either is a critical factor. Certain products are not permitted for use near water at all.

- Reaction time - chemical systems often require solvents to be left on the surface for a period of time and repeat applications may be necessary.

Graffiti on Bath stone, Grade II listed asset*

After removal by chemical cleaning

Acid cleaners for removing cement or lime stains - these should be used very cautiously and only with the approval of a heritage adviser.

11.4 Graffiti prevention

Rapid response and removal of graffiti is recognised as the first line of defence in discouraging attacks. Additional options are:

- In areas of persistent graffiti attacks discuss with the Environmental Operations team (or Heritage & Environment team in Scotland) about the opportunities for planting robust species to discourage access.

- Anti-graffiti coatings can be effective on modern structures but are generally not suitable for historic fabric.

- Improved lighting, CCTV and physical barriers such as fencing - before adding any of these always consider their potential impact on the historic setting.

- Other preventative measures – community policing (photographs of repeated graffiti can assist the police in bringing a prosecution), neighbourhood watch schemes, membership of the Alliance to Reduce Crime against Heritage (ARCH), developing local community ‘ownership’.

PREPARATION

Performance Criteria

1. For graffiti attacks, the details and images are recorded including the type of media used, the exact location, the nature of the surface affected and if known, the time and manner of the attack.
2. For general removal of paint and other deposits, the need for cleaning has been clearly established including both visual impact and any defects to the structure arising from the coated surfaces.
3. Ownership of the property whether the Trust, local authority or a third party, and responsibility for cleaning has been confirmed.
4. Cleaning of designated assets has been authorised by the statutory authorities.
5. The current database on approved cleaning methods has been consulted and an appropriate selection made for the location of the site and the type of cleaning required.
6. The work is adequately planned, organised and supervised with particular regard to the health and safety of operatives and the public.
7. An environmental appraisal is raised and correctly validated with any conditions met before work commences.
8. Where there is no precedent for using a cleaning method at a particular location, the project includes a small scale trial with assessment of results before the method is fully adopted.
9. Contractors and tradesmen are employed who are competent and experienced in conservation work of the required standard.

METHOD

Best Practice Indicators

1. The cleaning method fully complies with the specification for the project, unless authorised by the project manager, heritage adviser and Environmental Operations team.
2. Environmental protection measures are rigorously implemented to cover prevention of contamination to land or water and containment of all residue and washings.
3. Temporary works including scaffolding and safety fencing are non-invasive and reversible, leaving no trace of their presence.
4. Where specified, a small scale trial is undertaken and results approved before full cleaning commences.
5. The chosen method of cleaning is effectively carried out without damage to the structure and the historical integrity of the asset is maintained.
6. Graffiti removal work avoids a change in appearance to the surface of the asset.
7. All work complies with the Trust’s Health & Safety requirements.
8. The method of work complies with actions in the environmental appraisal.
9. Accurate records are held of the cleaning process and associated activities.