

HISTORIC ENGLAND
PRACTICAL BUILDING CONSERVATION

EARTH, BRICK & TERRACOTTA



Historic England

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Historic England
1 Waterhouse Square
138–142 Holborn
London EC1N 2ST

Published by
Ashgate Publishing Limited Ashgate Publishing Company
Wey Court East Suite 420
Union Road 101 Cherry Street
Farnham Burlington
Surrey GU9 7PT VT 05401-4405
England USA

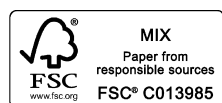
www.ashgate.com

British Library Cataloguing in Publication Data

A catalogue record for this book is available from the British Library

Library of Congress Control Number: 2009925645

ISBN-13: 9780754645535



Printed in the United Kingdom by Henry Ling Limited,
at the Dorset Press, Dorchester, DT1 1HD

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The volume editors would like to take this opportunity to thank them for their help and support with this book, as well as for the information and images they have so generously provided.

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ABOUT THIS BOOK

This volume of the *Practical Building Conservation* series deals with the practicalities of conserving the rich and diverse heritage of buildings in England made from materials based on clay in one of three forms: earth, brick and terracotta.

Earth is certainly one of the oldest of all building materials and it has a long history of use in England. Although over time its use declined, its properties are again being recognised. The section on **Earth** brings together the latest understanding of construction methods, deterioration and conservation techniques. It includes an excursus looking at the conservation of wall paintings on earthen supports.

Fired brick was introduced to England by the Romans, but production disappeared at the end of their occupation. When re-established in the Middle Ages its popularity grew and it is now arguably the most ubiquitous of all English building materials. Although there is an extensive literature available on brick construction and conservation, it is widespread; the section on **Brick** attempts to bring this information together in one easily referenced source.

Terracotta is the most recent of the three materials covered. Although early forms were used in England to decorate fashionable buildings in the Tudor and Elizabethan periods, as a construction material it is a product of the Industrial Revolution and flourished in the late Victorian and Edwardian periods. Great claims were made for the material – and its glazed form faience – but its popularity waned over the course of the 20th century. Nevertheless, faience and terracotta remain an important material for cladding façades. Although construction methods are similar in principle, there is great variation in detail, which can be challenging for repair. Conservation approaches to treatment and repair are in their infancy in England, but – as the section on **Terracotta** demonstrates – have enormous potential to extend the lifespan of these buildings, which are so important to townscapes throughout the country.

The book concludes with a detailed **Special Topic** looking at the conservation of ceramic wall tiles, floor tiles and mosaics (roof tiles are covered in the *Roofing* volume of this series).

Unsurprisingly, the volume is large, and for ease of use it has been divided into two parts. **Part A** contains the **General Introduction** to the volume (covering the aspects of conservation common to all clay-based materials), and the section on the conservation of earthen materials. **Part B** covers the conservation of fired-clay materials: brick, terracotta and faience, and tiles. Each section follows a similar format, beginning with an introductory chapter on the material and its history of manufacture and use in England. Subsequent chapters cover deterioration, assessment, and treatment and repair. Each section concludes with a short summary of the special care and maintenance needs of the material.

Part A and **Part B** both include a complete table of contents. A full index, covering both volumes, is to be found at the end of **Part B**, along with an **Appendix**, a **Glossary**, and a **Bibliography**.

The contents of this volume reflect current best practice, drawing on extensive knowledge and expertise, both within Historic England and amongst leading practitioners. Areas of conservation practice that are not well developed or understood – such as the consolidation of earthen walls by grouting, conservation of earthen plasters, or the repair of terracotta units – are considered in as much detail as possible. The aim is to increase awareness of such topics, thus prompting further trials and research and promoting better conservation practice.

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MATERIALS

All raw materials used for earthen construction, bricks and terracotta that are commonly known as ‘clays’ contain clay minerals. This group of mineral substances differs from all others because of the way they interact with water. They possess unique properties that make them an essential ingredient in all soils used for earthen construction, bricks and terracotta.

WHAT IS CLAY?

In broad terms, clays are part of naturally occurring, fine-grained soils (with an average particle size less than 0.002 mm). When damp, they are plastic and cohesive: they deform when an external force is applied, and retain the deformed shape when the force is removed. When dried or fired, they become hard and brittle.

Clays are created by chemical decomposition of certain bedrock minerals due to the actions of weathering and hydrothermal and biological processes, and physical disintegration. Although physical breakdown is necessary, it does not create clay minerals. Some clay deposits remain close to the bedrock from which they formed (primary or residual deposits). Others have been carried considerable distances by water, wind or glacial action (secondary or transported deposits). In the course of transportation, soil particles may become segregated according to size, and be deposited in separate layers or beds, as gravel (larger than 2 mm); sand (2 mm–0.063 mm); silt (0.063–0.002 mm) or clay (<0.002 mm).

Of the common rock-forming minerals, few (other than quartz) are durable enough to withstand being broken down to particle sizes smaller than silt without becoming chemically altered in the process. Therefore, while some clay-sized particles may be of quartz, most will be clay minerals.

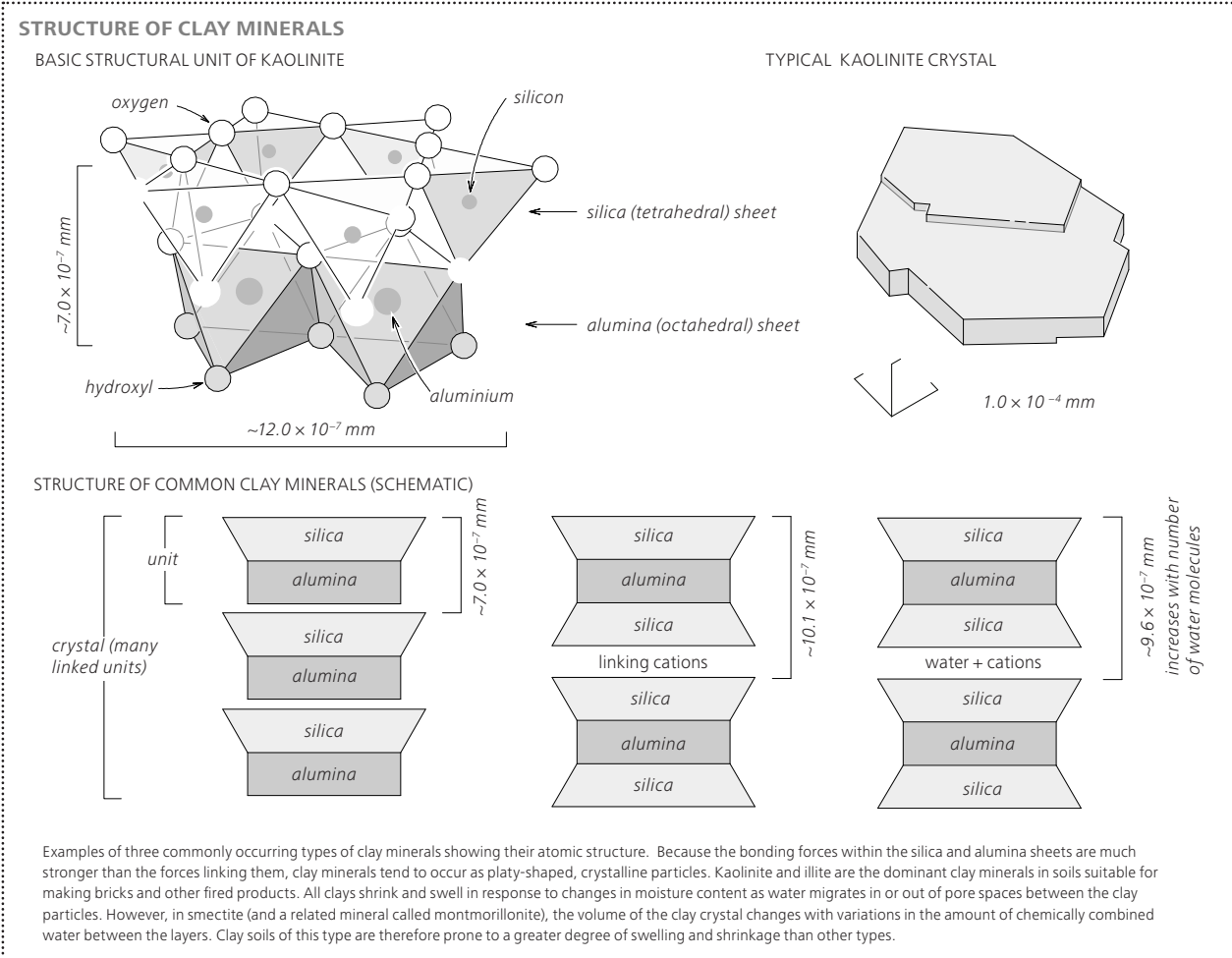
WHAT ARE CLAY MINERALS?

Clay minerals are inorganic crystalline substances with an atomic structure consisting of sheets of silica and alumina (or sometimes magnesia), arranged in parallel layers. The stacking arrangement of these layers, and the ions and water molecules that link them, define the various types of clay minerals, and influence their respective properties and behaviour.

Clay-rich soils normally contain one or more clay minerals combined with varying amounts of other materials from the original bedrock, including accessory minerals such as particles of quartz, mica, undecomposed feldspar, metal compounds and carbonaceous materials. Clay soils owe their distinctive characteristics of plasticity, cohesion, swelling and shrinking to the interaction of clay minerals with water. In addition, the presence of accessory minerals greatly influences the properties and behaviour of the clay material in both fired and unfired states.

HOW DO CLAY AND WATER INTERACT?

The plasticity, cohesion and volume-change behaviour peculiar to clay minerals are attributable to the interaction of clay particles with water molecules and associated ions. This influences the behaviour of the particles in relation to one another. These interactions are complex, and only a simplified description is given here (see **Further Reading** for sources of more detailed information).



Because of their sheet-like shape and very small size, clay crystals have an extremely large surface area in proportion to their volume. As a result, their behaviour is governed largely by surface effects. Electrostatic charges on the surfaces of the crystalline particles attract water molecules, that form a film of bound (adsorbed) water that surrounds the particle. The film of adsorbed water attracts more water molecules along with ions dissolved in the water that form a diffuse layer around each particle. Beyond this layer, free water can inhabit the pores between the particles. The structure of water is altered by the ions dissolved in it, so the thickness of the layers that build up around the particles depends on the types of ions in solution associated with it.

The layer of water and dissolved ions that surround each particle is shared with neighbouring particles. This not only allows them to move in relation to one another, but also binds them together and gives rise to the plastic and cohesive properties of clays. Clay-rich soils remain plastic and deformable over a wide range of moisture contents. The upper and lower limits of this behaviour are defined as the liquid limit and plastic limit respectively. At moisture contents above the liquid limit, clay particles are suspended in free water and the mixture will flow. But when the moisture content falls below the plastic limit, the particles bond together and the material becomes brittle.

Protecting & Decorating Earthen Surfaces

EXTERIOR WALLS

Prior to the 19th century, the exterior walls of many earthen buildings were left exposed, and would have gradually weathered. This is particularly true in the case of agricultural buildings, or sheltered east- or north-facing walls. Where an overhanging thatched roof provided protection, many exposed walls have survived in remarkably good condition. Walls facing south or west, which were more exposed to driving rain, were more likely to be painted with a chalk or mud slurry, or with limewash (sometimes incorporating tallow for greater weather resistance). Slurries had to be re-applied annually, by which time some, if not most, of the previous year's application would have weathered away, although multiple coats can still be found on the sheltered parts of some buildings, such as under the eaves. Limewash was also applied annually, but was more durable, so multiple coats built up over the years to form a coating that could be several millimetres thick. On timber-framed buildings with wattle-and-daub infill, the limewash often extended across the framing timbers as well as the daub.



Most forms of earthen walling (except rammed earth) took a long time to dry out, so it was an advantage of slurries and limewash that they could be applied before the wall was fully dry, without any adverse effect. If render was applied, it was essential that the wall was fairly dry and had finished shrinking. Otherwise, there was a risk that the render would crack.

In East Anglia, many clay lump buildings, especially farm and ancillary buildings, were protected with a coat of coal tar. This was a by-product of coal-gas production. It was applied hot, directly to the clay lump wall, or over an earthen render. Sometimes sand was mixed in with it, or applied as a blinding layer whilst the tar was still wet, which provided a key for a coat of limewash. As the oil in the tar evaporated, it shrank, forming a crazed finish. Some authorities believe that this allowed any water trapped by the tar (drawn up into the fabric due to capillary action or entering via a defect at the wall head) to evaporate out via the cracks, but there has been no detailed investigation of the moisture transport properties of tar coatings.

Prior to the 19th century, only the most exposed walls or high-status buildings would have been rendered, usually with an earth render, perhaps with a lime skim coat. From the beginning of the 19th century, it became more common to render earthen buildings, not only for greater protection, but also in an attempt to hide the nature of the construction, as earthen buildings were increasingly being viewed as inferior. For greater durability, renders based on lime and sand began to be used in preference to earth. These early lime renders were usually thin – often a single coat about 6 mm thick that followed the contours of the building – and were finished with several coats of limewash. Where cob, witchert and rammed earth were used for polite buildings, two- or three-coat renders were often applied, which enabled the plasterer to create flatter surfaces and sharper arrises appropriate to the architecture. The new patent ‘cements’ were also used during the 19th century. In the mid-20th century, lime gave way to Portland cement, which has been applied to many earthen buildings since then. Also, acrylic and alkyd-resin masonry paints have been widely applied for decoration, both to historic lime renders as well as to more recent cement render. The lime revival of the late 20th century has resulted in more use of lime-based renders, but often these are based on natural hydraulic lime. ➔MORTARS

INTERIOR WALLS

The interior of most agricultural buildings were generally unplastered, but were sometimes painted with limewash. Most early earthen dwellings would have been finished inside with a single coat of earthen plaster, painted with limewash, whiting or distemper. Lime skim coats applied over a base coat of earthen plaster are known from the 16th century. In some areas, this type of two-coat work was still being applied to new buildings until the mid-19th century. Limewash, soft distemper or, later, oil-bound distemper were used for decoration. Decorative plaster ceilings were usually painted with whiting. During the 16th and 17th centuries, earthen plaster or wattle-and-daub panels were also decorated with wall paintings, applied either directly to the earthen substrate, onto a ‘ground’ of limewash or a lime-plaster skim coat. A number of these survive, especially in Devon (see the excursus [Wall Paintings on Earthen Supports](#) at the end of this section). ➔MORTARS

In the second half of the 20th century, some earth and lime-based plasters were replaced with cement and gypsum, often in conjunction with damp proofing treatments. Acrylic and vinyl emulsion paints became the most widely used interior paints. Since the late 20th century, there has been a renewed interest in earthen coatings and paints with low embodied energy, and proprietary clay plasters and paints are now available.

Facing page: Limewash applied directly to cob was a common finish for many buildings, particularly humble dwellings.

ASSESSING SURFACE CONDITION

As well as assessing the structural condition of an earthen building, it is also important to examine the surface condition of the fabric for signs of past or ongoing erosion, or for evidence of damp.

EXPOSED WALLS

On an exposed earthen wall, large aggregate standing proud of the surface is indicative of water erosion. It may also be possible to see rivulets of fine material that has been transported by rainwater from higher up the wall and re-deposited lower down. Accelerated water erosion tends to occur at the junction between lifts of mass earthen material, within vertical cracks and just above the plinth, as these are all places where rainwater may be concentrated.

Thin lenses of material cracking and separating from the surface or accumulating at the foot of a wall are indicative of frost damage. This is unusual in a well-maintained with adequate plinth and eaves overhang, but can occur in a less well-protected building or one suffering from maintenance defects that result in the earthen fabric becoming saturated.

Damage to earthen walls caused by the crystallisation of soluble salts is most likely to occur at low-level, particularly immediately above the plinth, resulting in erosion of the earthen fabric at this point. The surface of the remaining material may be crumbly or powdery, and easily dislodged when scratched with a finger.



The exposed pebbles standing proud of the surface suggest erosion caused by water dripping from the roof and blowing back against this wall. Such surface erosion is often rapid initially, but once the fines have been removed the larger aggregates often prove to be more resistant to weathering and the rate of erosion may slow down considerably.

Abrasion or impact damage is most likely to be found at the corners of buildings, around doorways or, on earthen floors, in the areas of maximum foot traffic. Whether such deterioration is ongoing depends on the use of the building. Holes formed by masonry bees are also easily identified, and insect movements at an active site are easy to spot. As well as dark damp patches, any staining or areas of algal growth should be noted, as these can indicate high levels of moisture within the wall. Such areas can often be related to a defect in the building or its rainwater disposal system, splashback at the base of the wall, or poor surface water drainage. The condition of such areas should be further investigated by probing with a sharp tool or penetrometer. If the tool penetrates easily, the material is very weak and could be at risk of collapse. A small sample should be removed in order to assess the integrity of any fibrous reinforcement, the proportion of clay and the moisture content of the material. This will enable an experienced surveyor to determine whether urgent intervention is required.

PAINTED OR RENDERED WALLS

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The surface condition of any render and paint finishes should be noted, with particular attention paid to cracks, staining that could indicate high levels of dampness, crumbling or powdering areas, hollow patches, blistering of paint finishes, or areas of missing render. **MORTARS**

Voids behind render or plaster can be located by gently tapping the surface with a light hammer, and listening for a hollow sound. In the case of cement renders, this invariably indicates detachment from the substrate. Cement render applied over a mesh will almost always sound hollow.

Top: As well as noting the condition of plaster and render, the location of any damage can give a clue to possible causes. High-level damage is often caused by a defective roof or, as here, missing or poorly maintained rainwater goods.

Bottom: Limewash is particularly effective at indicating those parts of a wall that receive the greatest amount of water, whether through splashback or poor surface water drainage, exposure to rain-bearing wind, runoff from the roof or defective rainwater disposal systems.



NEW SUBSOIL

Earth for construction was traditionally often dug at the building site. Digging new material for repair on site is probably not an option, unless a very small amount is required, or the plot is large enough that remodelling part of it would be acceptable. Subsoil may be available from another site nearby, perhaps where new buildings are being constructed or excavation is taking place to build a road.

Farmers are sometimes able to supply suitable material, and are often knowledgeable about soil types. However, as mentioned above, soil properties can vary over a short distance or at different depths in the same spot, so testing will be required to confirm that materials are suitable for use. If there is some deficiency, it may be possible to modify the subsoil to improve its properties. Subsoil must be free of organic material such as roots and humus.



For repairs to cob walls at Bowhill, near Exeter, subsoil was obtained from a nearby excavation for a reservoir.

If the locally available material does not meet the required clay content and particle size distribution, then subsoil may need to be sourced from further afield. The soil survey maps, produced by the National Soil Resources Institute, and the accompanying bulletins, provide detailed descriptions of soil types down to a depth of about 1 m to 1.5 m, for the whole of England and Wales. These provide a useful guide to the general physical characteristics of soils in an area, and indicate where suitable material might potentially be sourced. The properties of the subsoil can then be confirmed by trial excavations and testing of samples.

Quarries or clay pits may produce overburden that is suitable for construction. Crushed chalk can also be obtained from quarries that produce chalk (usually referred to as lime) for agricultural use. This is crushed and screened to various sizes, and can usually be supplied in one-ton dumpy bags.

Some specialist suppliers sell small quantities of material for earthen construction. Regional earth building groups, or possibly local authority conservation officers, can advise on possible sources.

CHARACTERISING EARTH FOR REPAIR

An experienced practitioner can learn a lot about subsoil by merely kneading a sample and noting if it feels gritty or smooth, or by compressing a damp handful into a ball, and noting whether it holds together or crumbles. A number of other simple tests, shown in the following table, yield useful information about the properties of the original earthen fabric and proposed repair material. They also indicate whether a potential new source of material is worthy of further investigation. Subsoil properties can vary significantly over short distances, so when evaluating material from a particular source, several samples should be tested to ensure that they are representative. The subsoil should be gently crushed to break down lumps, and sieved through a 5-mm mesh to remove stones before testing.

These tests are generally of low accuracy, and results also vary significantly depending on the moisture content of the sample. At best they enable a qualitative comparison between the original fabric and potential new material or between numerous samples of subsoil. When comparing original fabric and possible sources of subsoil for repair, it should be noted that weathered historic material may contain less clay than the original subsoil from which it was made.

By carrying out all these tests on a sample of material, it is possible to gain an impression of the nature of the material, its similarity to historic fabric and its potential for repair. However, it is not possible to identify soil characteristics in detail by means of visual or tactile examination alone. More accurate laboratory testing, particularly an assessment of the particle size distribution of the material, is needed to determine whether earth from a particular source (either salvaged from a building or freshly dug) is suitable for conservation work.

SIMPLE TESTS FOR CHARACTERISING EARTH

DESCRIPTION

PROCEDURE

INFORMATION OBTAINED

THE RUB TEST



Rub a small amount of the soil between the fingers

If the soil feels gritty, it contains mostly sand, and little clay or silt

If it feels smooth but can be easily rubbed off the hands when dry, this indicates a silty soil

If it feels smooth, but adheres to the skin when dry and can only be removed by washing, this indicates a clay-rich soil

THE SHINE TEST



1. Roll a handful of damp soil into a ball
2. Cut the ball in half with a clean, damp knife

A shiny cut surface indicates a clay soil

A dull surface indicates a soil with low clay content

THE DILATANCY TEST



1. Mix a sample of soil to a soft putty consistency and roll into a small ball. Place in the palm of one hand.
2. Tap the side of the hand against the heel of the other hand to jar the sample until a glossy film of water forms on the surface
3. Squeeze the sample with the fingers of the other hand




If the sample stays glossy, there is a high clay content

If the sample slowly loses its gloss and becomes matt over a couple of minutes, there is a medium clay content

If the sample turns matt almost instantly, clay content is low

Note: These tests apply only to clay-based soils, not to crushed chalk for use in rammed chalk repair

SIMPLE TESTS FOR CHARACTERISING EARTH

DESCRIPTION	PROCEDURE	INFORMATION OBTAINED
<p>THE SAUSAGE TEST</p> 	<ol style="list-style-type: none"> 1. Roll a sample of damp soil into a long sausage shape, about 12 mm in diameter 2. Place the sausage on a table or workbench, and slowly slide one end of it off the edge until it breaks 	<p>The length of the broken-off piece indicates clay content: the longer the piece, the higher the clay content</p>
<p>THE RIBBON TEST</p> 	<ol style="list-style-type: none"> 1. Wet the soil until it can be moulded into a sausage shape about 12 mm in diameter and up to 300 mm long 2. Hold the sample in one hand and feed it slowly across the palm of the other, whilst compressing it by the thumb into a ribbon 3–5 mm thick 3. Measure the length obtained before the ribbon breaks <p>For greater control, the ribbon can be fed over a section of kitchen worktop with a rounded edge</p>	<p>The longer the ribbon, the higher the clay content it is difficult to form a ribbon at all in very low clay soils, whereas a very clay-rich soil might form a long ribbon about 250 mm long</p>
<p>THE DRY CRUSHING TEST</p> 	<ol style="list-style-type: none"> 1. Make a small ball (approximately 12 mm in diameter) of damp subsoil and leave to dry 2. Observe how easy it is to crush the ball with the fingers 	<p>If the ball crumbles and falls apart with little effort, it has low clay content</p> <p>If the lump is crumbled with difficulty, it has medium clay content and could be suitable for construction</p> <p>If the lump is almost impossible to crumble, there is a high clay content and the material is likely to suffer from excessive shrinkage when used for building</p>

Note: These tests apply only to clay-based soils, not to crushed chalk for use in rammed chalk repair

REPAIRING RODENT DAMAGE

Where rodent damage is very extensive, the wall may be seriously weakened. Occasionally, this can lead to collapse. Usually, however, if the wall is dry, rat runs can be dealt with by means of incremental repair. First, the extent of the tunnels and chambers must be established by means of drilling between the entry holes at 300–350-mm intervals with a 300-mm long masonry drill bit.

The wall should be divided into sections about 500-mm wide. In one section at a time, the cavities are exposed by carefully removing material from one face of the wall. All loose debris and dust is removed, before thoroughly wetting the repair site. Oak posts, firmly wedged into position, may be used as either temporary or permanent props.

The choice of material to fill the cavities will depend on their location and the nature of the original material. The cavities are often found at the foot of the wall, where compressive stresses are highest, and access to the repair site may be difficult. A lime-stabilised earth-straw mix can be rammed into the cavity, allowing the repair to harden off before proceeding to the next section. For larger cavities, the best option might be to use earth blocks laid in bonded courses. In such a case, the top course must be secured by hammering slate or tile wedges into the top joint, and then backfilling with an earth or natural hydraulic lime and sharp sand mortar. Various other options have been used in the past, such as natural hydraulic lime concrete or grout based on natural hydraulic lime, pulverised fuel ash [PFA] and bentonite. Such materials are unlikely to be as compatible as earth-based materials and risk weakening adjacent fabric due to the comparatively large amount of water they contain. However, clay-based grout or weak lime-PFA-bentonite grout may be useful for filling small inaccessible voids that connect larger tunnels or chambers.

Health & Safety

DEALING WITH RAT RUNS

There are a number of diseases that can be transmitted in animal urine, of which the most common is leptospirosis. This is a bacterial disease transmitted to humans through contact with the urine of infected animals, normally via contaminated soil or water. Symptoms vary from headaches and flu-like symptoms to jaundice and organ failure, which can be fatal. The more severe forms of the infection are commonly known as Weil's disease. Although it can be very serious, in 2011 there were only 29 reported cases contracted in England and Wales, none of which proved fatal.

Leptospirosis is mostly associated with rats' urine (but can be spread by the urine of other wild and domestic animals) and so poses a risk to workers dealing with the debris associated with rat runs in earthen fabric. Infection is caused by bacteria entering the bloodstream, so can be contracted through cuts, damaged skin, or contact with eyes, mouth or nose. There is no evidence that it can be contracted simply through contact with undamaged skin, although it is always wise to take precautions.

Prevention includes covering all scratches and cuts with waterproof plasters, and wearing appropriate protective clothing (particularly gloves, and eye protection and a face mask if splashing is likely). Always wash hands after working with potentially infected material, especially after contact with water, even if gloves were worn.

SECURING DELAMINATED DAUB

Daub may lose adhesion with its wattle support (see **Deterioration & Damage**). Small areas of delaminated daub may be stable and not a cause for concern, but larger detached areas are at risk of collapse. Provided the material is otherwise sound, it may be possible to secure delaminated daub either by tying back to the wattles, staves or even the plaster on the opposite side of the panel, or by grouting to reinstate the bond between the detached layer and the backing.

Tying

There are a number of different ways of tying, and the choice of technique depends on the nature and condition of the wattle support, and whether there is access to both sides of the panel. Because of the low tensile strength of daub, a large bearing for the tie is required. Otherwise, there is a risk that ongoing movement may cause the tie to simply pull through the daub.

Grouting

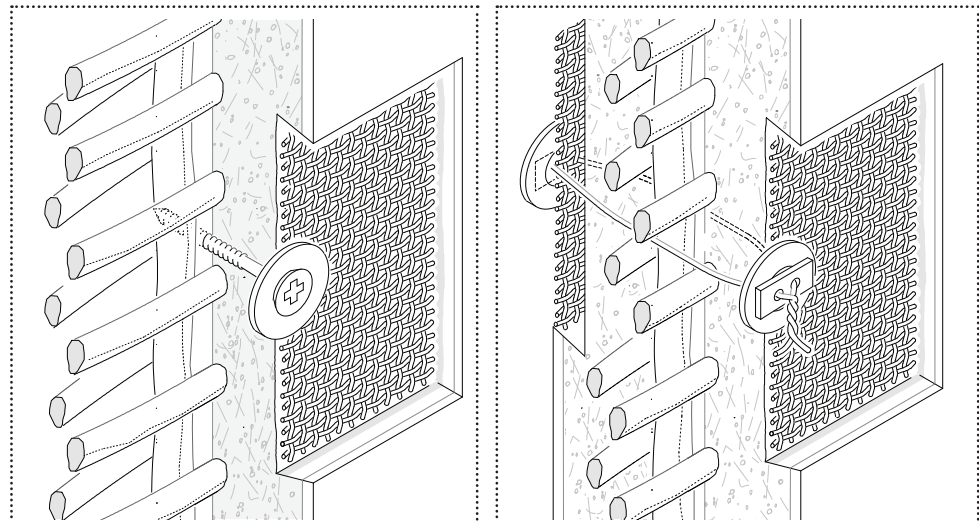
Where tying is not practicable, it may be possible to reinstate the bond between the detached daub and the remaining intact material by introducing a grout into the void between them. This carries certain risks, and should only be undertaken by a skilled conservator following a risk assessment. **MORTARS**

The risks and techniques are similar to those for grouting earthen plasters and renders. In some cases, it may be possible to introduce grout via the top or edge of the panel, or at the edge of a damaged area, without needing to drill holes into the face of the daub.

Tying wattle and daub

Left: Where there substantial staves that can be located, it may be possible to secure delaminated daub by inserting a screw, supported with a stainless-steel mesh 'washer', through the daub and into the staves. The surface is then repaired using a matching daub mix.

Right: If the staves are thinner or are hard to locate, a fine drill bit can be used to make a parallel pair of holes through which wire ties can be passed from one side of the daub to the other. The wire is prevented from pulling through the daub by a metal mesh 'washer'.





INTRODUCTION

There is a long-established tradition for decorating interior spaces with paintings in England. Wall paintings are found in many different kinds of buildings, including the most modest. The type of decoration can vary widely as well: from plain limewash, painted lines, simple blocks of colour or patterned stencilling, to large figurative cycles. Historically they are of great interest, because they give an unparalleled insight into how the building was used, and the interests, aspirations and status of the users.

The more modest examples of painted decoration may have been regarded as temporary, and therefore subject to being renewed or changed according to taste. This makes surviving examples all the more significant.

The potential for a historic building to contain wall paintings must be considered during any building intervention. Surviving paint is important and, if discovered, will need to be recorded and assessed. Recording and any eventual conservation are specialist tasks carried out by a wall-painting conservator.

This excursus looks at the conservation of decorative painting on walls where the primary support (the wall itself) is made of earth – cob, mud, wattle and daub – or the secondary support (the plaster) includes a layer of earthen plaster. More information on the general conservation of wall paintings can be found in the *Mortars, Renders & Plasters* volume in this series. **MORTARS**

Cullacott farmhouse, Cornwall, a 15th-century manor house, contained extensive areas of wall painting. It was later re-used as a farm building and fell into disrepair. Three schemes exist at Cullacott, the first one being the earliest known painting on cob in England, and a rare example of decorative painting applied directly on to the earthen support without any preparatory layer.

Facing page: These paintings in Surrey are an example of 16th-century 'grotesque' work. Wall paintings are often found during building works. They can run across plaster, stone and timber alike, so care should be taken during refurbishment.



EARTH, BRICK & TERRACOTTA

EARTH: EXCURSUS: WALL PAINTINGS ON EARTHEN SUPPORTS

Hand-moulding bricks

Although the methods and tools used for hand-moulding tend to vary from one brickyard to another, and there have been regional differences, the basic sequence of operations is as shown here.

1. A 'clot' or 'warp' of clay is extracted from the pile on the moulder's bench. Sometimes a metal scoop or 'cuckold' would be used for this, if the brickmaking soil was very gritty. The clot is then moulded, ready for throwing into the sanded mould box.

2, 3. The clot is cast firmly into the mould box. The surplus clay protruding from the top of the box is then removed with a wooden 'strike', or in some cases a wire 'harp'. The mould box used here is divided to produce four bricks and has a fixed base.

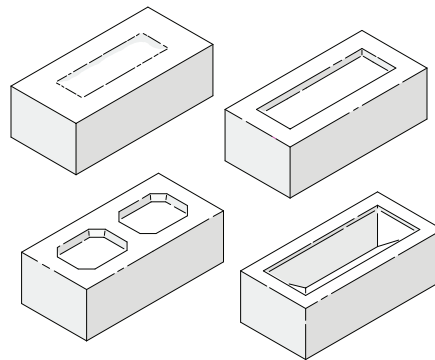
4. A palette board is placed on top of the mould box which is then flipped over.

5. The mould box is lifted clear, leaving the newly-moulded bricks on the palette board.





FROGGED BRICKS



Brick moulds

Top: A metal mould box and stock. The stock is fixed to the moulding table and the bolts on either side support the mould box and can be adjusted to vary the height of the brick. The 'lack' or 'kick' screwed to the stock forms the frog in the brick.

Middle: Frogs have been formed in a variety of shapes. Earlier types, dating from the late 17th and 18th centuries, tend to be relatively small and shallow, as shown in the top left example. Some machine-made bricks have frogs on both sides.

Bottom: A selection of mould boxes used to produce specially shaped and decorated bricks.



Traditionally, mould boxes were made from beech. Sometimes a brass or iron frame was fitted to the top of the box to reduce wear, caused by striking off the excess clay during moulding. The interior of the box might also be lined with thin brass or an iron sheet. Sometimes the edges of the stock were also shod with iron. From the late 17th century, the stock frequently incorporated a block, 'kick' or 'lack', which produced a 'frog' in the brick; in the 19th century, brick manufacturers often imprinted the frog with their name or a trademark. The purpose of the frog has been the subject of much debate. There are many possible explanations. One is that the 'kick' helped to spread the clot of soft clay into the corners of the mould. Another is that the frog enabled green bricks to dry more quickly and reduced the risk of shrinkage cracking. It has also been suggested that the frog helped ensure thorough firing, reduced the weight of bricks and made it easier to lay them with narrow joints.

The use of worn or repaired mould box or stock leaves marks on the brick that can sometimes be seen in historic brickwork (see *Assessment*). From the late 19th century, moulds were also made of iron or steel. In some instances, larger divided moulds were used to produce up to four bricks at once. These moulds were placed directly on the moulding table, and could be used either with or without a stock. Hand-operated presses were also available to consolidate hand-moulded bricks, making them more uniform and consistent.

Joints in brickwork

1. A rare survival of double-struck or 'bird's beak' profile joints, probably dating from between 1515–20, Hampton Court Palace, Surrey.

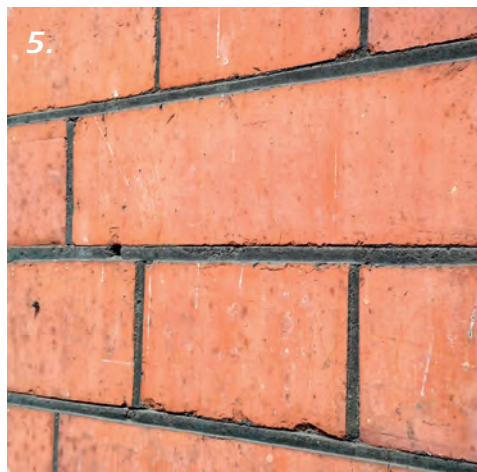
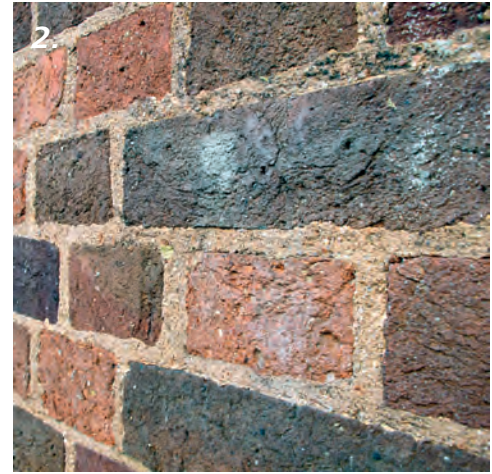
2. Flush joint. This type of joint finish was not commonly used for high quality facework until modern times.

3. Well-preserved late 18th-century 'jointed', 'penny-round' or 'ruled' joint. Note the irregularity in true width of the joints, typical of Georgian and early Victorian brickwork. This type of joint was intended to give brickwork a more precise and regular appearance when viewed from a distance, and was very widely used.

4. Detail of 'jointed' joint. The tool used to form the false joint is numbered 19 in Moxon's 1703 illustration and would have been guided with a pointing rule (numbered 18). The mortar is finely textured and binder-rich.

5. 19th-century 'struck' joint. Again the intention is to give the joints a fine, precise appearance, even though bricks were becoming increasingly regular and could be laid with narrower joints than before.

6. In gauged brickwork the joint almost disappears. In this Edwardian example the bed and perpendicular joints are about 1-mm thick.



Tuck Pointing

In tuck pointing, irregularities in the shapes and sizes of bricks are disguised through the skilful use of coloured mortars and the neat lining out of joints. It was originally used during the 18th century to create the illusion of high-quality rubbed and gauged brickwork, and became a popular treatment for the principal façades of speculative terraced housing that was then proliferating in London. Although tuck pointing was not cheap, it was not as expensive as gauged brickwork.

By the 19th century, tuck pointing was described as a 'sham' or a 'deceit' as it was often utilised to improve the appearance of poor-quality brickwork. Nevertheless, many fine town houses were tuck pointed.

THE PROCESS

First, the bed and perpendicular joints are pointed with a mortar coloured to match the surrounding bricks ('stopping'). The stopping mortar is usually made with sands with a small particle size, which creates a smooth appearance, and a natural hydraulic lime binder. Ground earth pigments, such as red and yellow ochres, are added to obtain the desired colours. Often, a translucent colour wash (not limewash) is applied before tuck pointing to regularise the varying tones of bricks. The stopping mortar is finished flush with the faces of the bricks, masking uneven joint widths and damaged arrises.



Restored tuck pointing on the façade of an early 18th-century town house in Westminster, London.

Once the mortar has suitably stiffened, or become 'leather' hard, narrow grooves ('housings') are scored into the middle of the joints with a purpose-made tool. An appropriately positioned 'pointing-rule', or 'feather-edge' is used to ensure the housings are straight and level for the bed joints and plumb for the perpendents.

Next, a lime and silver sand mortar ('fine stuff'), mixed to a putty-like consistency is placed ('tucked') in the housings in the bed joints with a narrow pointing key or 'jointer'. Once the fine stuff has stiffened sufficiently the joints are trimmed precisely with a 'Frenchman', a knife with a small bend at the tip of the blade. Using the 'pointing-rule' to guide the blade, surplus mortar is cut away to leave a regular, narrow ribbon. The perpendicular joints are then treated in a similar fashion.

POLLUTION

Airborne pollution not only soils brickwork: it changes the physical and chemical characteristics of surfaces. The interactions between pollutants and materials can be complex, and are governed by numerous factors. These include their chemical compositions; the location, orientation, exposure and physical properties of the wall; and the prevailing environmental conditions. Airborne pollutants may be taken in by the surfaces of brickwork as wet or dry aerosols – minute particles in liquid or solid form – or dissolved in water. Rainwater tends to be mildly acidic because of the combination of atmospheric carbon dioxide and sulphur dioxide with water vapour. Although acidic rain does not chemically affect bricks, it will react with lime mortar, dissolving the calcium carbonate binder and producing soluble salts, including calcium sulphate (gypsum). Calcium, carbonate and sulphate ions are transported in solution within the pores of both bricks and mortar, and calcite and gypsum are deposited at or near the surface as water evaporates. Over time, the accumulation of salts and the deposition of atmospheric pollutants within the pores form a thin outer layer or skin with different moisture and thermal movement characteristics to the substrate. This induces stresses between the skin and the substrate, which can eventually lead to superficial detachment and blistering.



Accumulated salts and soiling can form a skin on the surface of bricks which may blister and become detached due to differential moisture and thermal movements, and salts.



Building defects, such as inadequate or faulty water-shedding features or defective rainwater goods, can lead to sections of walling becoming very wet. In this condition, they are highly susceptible to damage by frost action.

When the temperature of liquid water falls below 4°C, its volume increases by about 9%. In freezing conditions, ice formation within the pores of bricks and mortar occurs initially at the exposed surfaces, then progresses inwards as heat is lost from the wall. Liquid water ahead of the ice expands as it cools and exerts hydraulic pressure on the pore walls. Where the pore structure prevents water from escaping ahead of the advancing pressure front, the resulting internal stresses can cause damage when the tensile strength of the materials is exceeded.

Brickwork exposed to freezing on two sides, such as parapets and free-standing walls, is particularly vulnerable. Damage can occur relatively quickly where bricks are highly porous, weak or underfired. In other cases, more gradual deterioration is caused by repeated cycles of freezing and thawing. Typical symptoms include granulation, spalling and the detachment of lens-shaped fragments.



Frost damage

Top: A large area of frost-damaged brickwork attributable to defective rainwater goods.

Bottom: Frost damage to a brick parapet. Water leaking through open joints in the coping has saturated the brickwork beneath.

BUTTRESSES, PIERS & POSTS

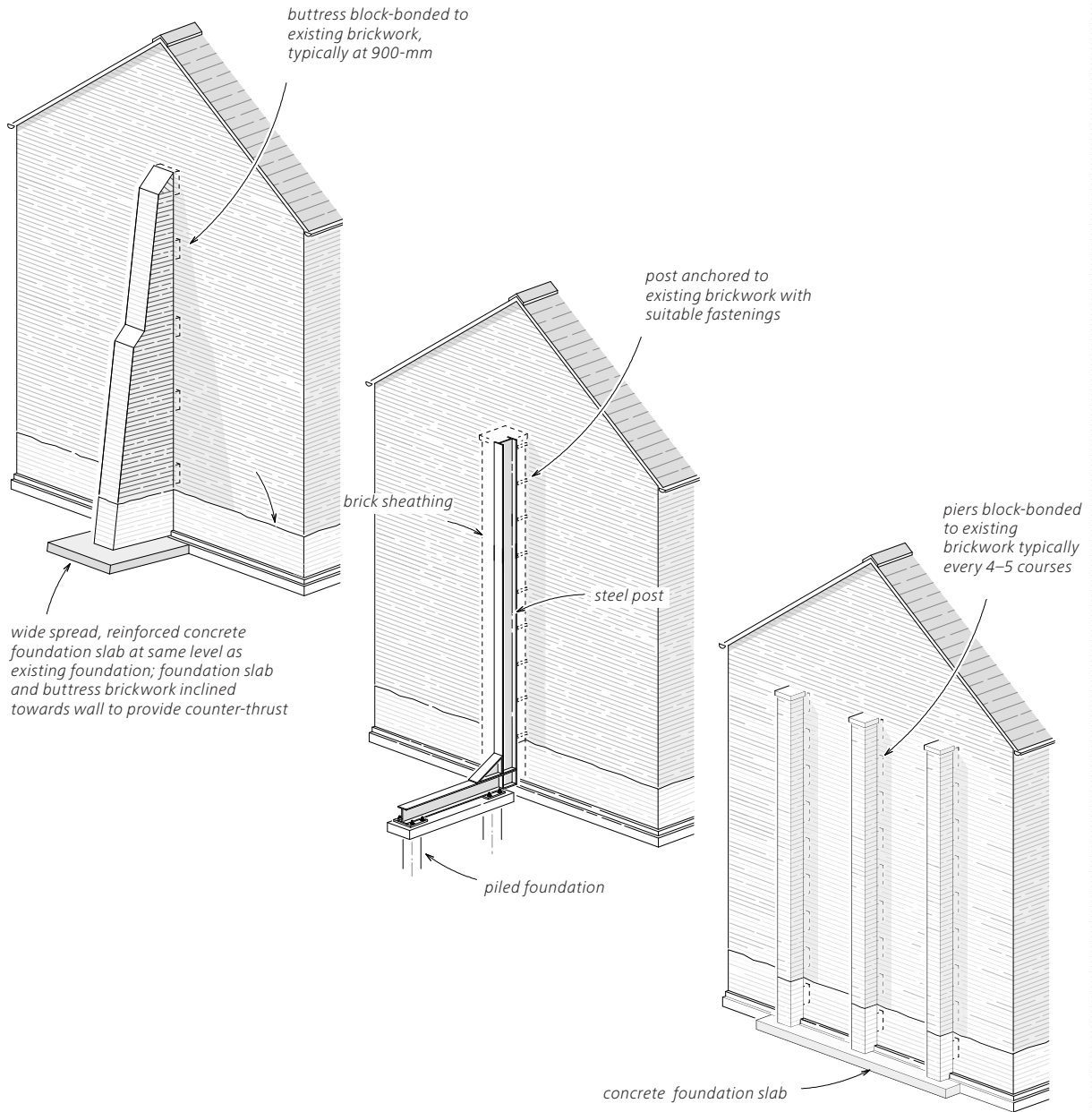
The construction of external brick buttresses or piers is a traditional method of stabilising inadequately restrained walls. Although buttresses remain a satisfactory solution in practical terms, their use today tends to be limited by their visual impact. It is important that the foundations of a buttress are designed to minimise settlement and prevent the new structure from settling away from the existing wall, pulling it further out of plumb. Adequate tying of the buttress to the existing wall is most important. Traditionally, buttresses were block-bonded every 4–5 brick courses or tooth-bonded every alternate course. In some instances a small number of brick piers may suffice in place of a single, large raking buttress.

Alternatively, L-shaped reinforced concrete or steel posts may be erected to restrain a wall that leans either towards or away from the posts. The posts are tied to the wall, and the horizontal legs secured to adequate foundations. Often, piling is used where there is a potential for uplift. The method of tying the posts to the wall depends on whether they are resisting compressive or tensile forces, and can be designed to allow for differential movement between the post and the wall if necessary. Posts of this kind can be provided either inside or outside the building, and may be clad in brickwork. The normal standards of corrosion protection of structural steelwork and reinforcement, based on a 50-year service life, are inadequate for conservation interventions, and should be enhanced.



Heavy 19th-century brick buttresses intended to provide a counter-thrust to a flank wall. If buttress foundations are not well designed or constructed, settlement can occur which can pull the wall further out of plumb, rather than restrain it.

TYPICAL BUTTRESSES, POSTS & PIERS



JOINT FILLING

When the replacement mortar is applied, the inside surfaces of the joints should be damp but not wet. A range of pointing irons of differing blade widths that will fit within the variety of joints to be filled will be needed. So-called ‘pointing trowels’ and jointing tools that are wider than the joints to be filled should not be used, as they may smear mortar on the face of the bricks, and do not allow it to be firmly compacted into the back of the prepared joint.

Ensuring that the replacement mortar is of the correct consistency is important for successful pointing and clean working. It should not be too wet. A well-prepared lime mortar will be workable and cohesive, and have a consistency similar to soft clay. Mortar of the right consistency can be readily picked up on the blade of the pointing iron, and placed firmly and accurately into the back of the joint. With care it is possible to fill even narrow joints without getting mortar on the surface of the bricks. However, when pointing very narrow joints, the surface of bricks can be protected with plastic-faced adhesive tape. This is applied over the joint to be filled, and a slit is cut with a scalpel or craft knife, following the joint. The mortar is then applied through the slit with a pointing iron of the appropriate width. The preparation of lime mortars is described in detail in the *Mortars, Renders & Plasters* volume of this series. [MORTARS](#)

Where possible, pointing should proceed from the upper part of the wall, working downwards, to avoid damaging finished work when dampening-down subsequent areas. Deep joints and voids should first be backfilled with mortar to within 25 mm of the surface, and allowed to stiffen before pointing.

Joint filling

These photographs show the three basic stages in placing mortar and finishing a joint where the aim is to create a slightly recessed and weathered appearance. Where the intention is to match a particular joint profile, the pointing technique will have to be adapted accordingly.

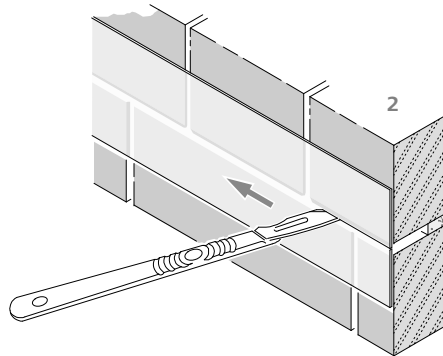
1. Placing mortar in the prepared joints using a pointing iron with a blade narrow enough to fit into the joint. Mortar prepared to the correct consistency will adhere readily to the blade of the pointing iron. The joints are filled to excess and no attempt is made at this stage to smooth the surface.

2. Once the mortar has stiffened to a ‘leather-hard’ consistency it is further compressed with the pointing iron, then trimmed back to leave the weathered arrises of the bricks clean and clear of mortar.

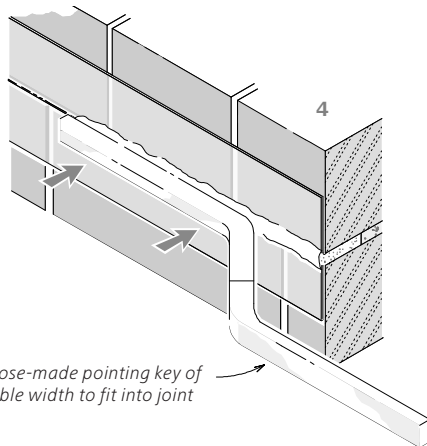
3. Finally, the surface of the joint is firmly stippled with a churn brush. This further compacts the mortar in the joint and gives an open-textured, weathered appearance.



METHOD FOR CUTTING OUT & FILLING FINE JOINTS

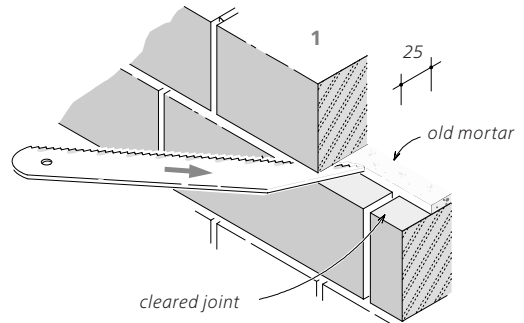


50-mm wide heavy duty adhesive tape (carpet type) applied over joint. Tape slit with sharp knife along centre of joint.

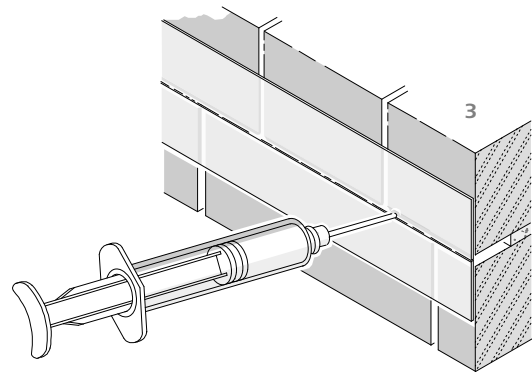


purpose-made pointing key of suitable width to fit into joint

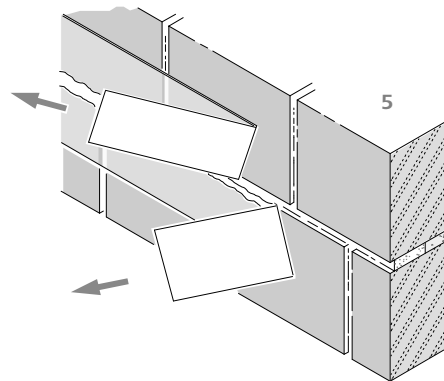
Mortar introduced into damp joint and compressed with pointing key through slit in tape.



Decayed mortar raked out with hacksaw blade. Care must be taken not to damage arrises. Joints flushed out with clean water from hypodermic syringe.



Joint pre-wetted with clean water from hypodermic syringe.



Adhesive tape carefully peeled away.

Salt efflorescence and associated flaking is evident on the surface of this terracotta. There are planted troughs above, and it is possible that water from these containers has overflowed onto the terracotta below, either introducing additional salts or mobilising those within the terracotta.



FROST

When water present in the pore system of masonry units freezes, the formation of ice (which has a volume around 9 % greater than liquid water) causes stresses within the pores. The repetition of these stresses, through freeze-thaw cycles, will eventually weaken materials, and may cause spalling or crumbling of the surface. This can result in a surface that is more open and absorbent. Frost damage is most severe where the masonry is exposed to large amounts of water and low temperatures; for example, parapets, free-standing walls, cornices or chimneys. Blocks are also vulnerable if water becomes trapped in voids between the terracotta walls and infill material and there are no drainage holes. **ENVIRONMENT**

The susceptibility to frost failure depends on the clay type and manufacturing process; terracotta units with very different characteristics may be equally resistant, though for different reasons. For example, a dense block with a high compressive strength will be resistant because it absorbs little water; whereas a weak, highly absorbent block can still be resistant, because in this case the open pore system both dries quickly and allows space for the ice to expand. Low-strength or underfired terracotta tends to be the most susceptible.

SALTS

Salts may crystallise on the surface of terracotta, appearing as a white bloom. In the case of well-fired terracotta, this damage will be purely aesthetic. However, in underfired material, the crystallisation of salts is a major cause of deterioration and breakdown. Salts crystallising under a glaze can cause it to fail.

Salts can enter terracotta from mortars, pollution and adjacent building elements (such as chimney flues), driven by moisture ingress. Staining can occur if moisture migrating to the surface from the body of the terracotta brings with it various minerals, particularly brown iron stains from corroded fixings.

TEMPERATURE

Terracotta expands and contracts slightly with variations in temperature. The dimensional change of a single unit can be small. But across very large façades without expansion joints to absorb the change, the collective movement can cause stress, cracking and buckling of the units at the edges. This tends to occur at higher levels such as parapets where the temperatures fluctuate more widely, and there is less structural weight to prevent thermal expansion and contraction. This also occurs where mortar joints are of cement and there is little flexibility.

Differential thermal movements may also occur between the frame and terracotta cladding, but in reality, unless the metalwork is close to the surface, it will not be affected by temperature fluctuations.

POLLUTION

Research has shown that much surface soiling on terracotta is due to smoke, vehicular traffic pollution and acid rain. The latter can cause calcium carbonate in kaolinitic clays to convert to calcium sulphate (gypsum), forming black crusts, which will blister and exfoliate. Soiling analysis reveals that much of it comprises calcium sulphate and calcium sulphide compounds. In coastal locations, sea spray is also present, but there is little evidence that this causes excessive problems for terracotta or faience. **ENVIRONMENT**



A heavy crust of calcium sulphate has developed over centuries: this element of the building has not been cleaned since it was built in 1821.

MORTAR SELECTION

The mortar selection tables below suggest possible mortar mixes, taking into account terracotta type, condition and degree of exposure. As a general rule, mortars for pointing should be weaker and no less permeable than the host material. Aggregates should be carefully selected to ensure the colour and texture of the replacement mortar is as required; where needed, alkali-resistant pigments can be used to achieve a depth of colour. Detailed information about the formulation of repair mortars can be found in the *Mortars, Renders & Plasters* volume in this series. [☞ MORTARS](#)

KEY TO TABLE					
TYPE OF TERRACOTTA		CONDITION OF TERRACOTTA		EXPOSURE	
ROBUST	Modern (20th & 21st century) High-temperature fired Faience	GOOD	Sound condition, with no significant evidence of decay or surface erosion Glazes are intact with minimal crazing	SHELTERED	Undemanding locations, including internal and sheltered external environments, such as cloisters and courtyards
MODERATE	Hard-fired clay Medium-temperature fired Faience	MODERATE	Moderate condition, with some surface losses, blisters and scaling Glaze is heavily pitted or crazed, with small losses	MODERATELY EXPOSED	The majority of external exposure, including masonry at low to medium level, but exposed to all orientations
WEAK	Soft, low-temperature fired Poorly manufactured (that is, poorly mixed)	POOR	Poor condition, with loss of surface crusts and weak, powdery surfaces Loss of the majority of glazed surface	VERY EXPOSED	High-level situations, such as church towers, paving and copings, exposed marine locations and exposed upland locations, and other sites subject to high winds and driving rain
				WET CONDITIONS	Masonry permanently or regularly in contact with standing water

MORTAR SELECTION TABLE

TERRACOTTA TYPE	CONDITION	EXPOSURE			
		SHELTERED	MODERATELY EXPOSED	VERY EXPOSED	WET CONDITIONS
ROBUST	Good	A1, A2 B1, B2, B3 C1	B1, B2, B3 C2	B1, ¹ B2, ¹ B3 C2, C3	C3
	Moderate	A1, A2 B1, B2, B3 C1	B1, B2, B3 C1, C2	B1, ¹ B2, ¹ B3 C2	C3
	Poor	A1, A2 B1, B2, B3	B1, B2, B3 C1	B1, B2, B3 C2	C2
MODERATE	Good	A1, A2 B1, B2, B3 C1	B1, B2, B3 C1	B1, ¹ B2, ¹ B3 C1, C2	C2
	Moderate	A1, A2 B1, B2, B3	B1, B2, B3	B1, B2, B3 C1	C2
	Poor	A1, A2	B1, B2, B3	B1, B2, B3 C1	C1
WEAK	Good	A1, A2 B1, B2, B3	A1, A2 B1, B2, B3	A1, A2 B1, B2, B3	B1, B2, B3
	Moderate	A1, A2	A1, A2	A1, A2 B1, B2, B3	B1, B2, B3
	Poor	A1, A2	A1, A2	A1, A2	B1, B2, B3

¹ For robust or moderately durable terracotta in good condition in very exposed locations, the proportion of pozzolan may need to be increased (see Table: Type B Mortars)

INDENTING & PLATING

Insufficient use is made of indent and plate repairs of terracotta. These processes involve cutting out and replacing part of a unit with new or reclaimed material. Indenting is the replacement of a segment of a unit. Plating is the replacement of the whole or a section of the face of the unit with a replacement 'tile'. The new material can be fitted with considerable precision through the use of diamond cutting saws. Nevertheless, both operations can be even more difficult than the removal of a whole unit, but may be attractive, as the repair area will weather and soil in the same way as the parent unit. They may be cost-effective too, as the inserted piece can sometimes be made from a damaged unit removed from elsewhere in the building. Using salvage material often gives the best visual match. Plates or indents may need to be secured using stainless-steel fixings or dowels bedded in a thermosetting resin.



Left: The damaged area of terracotta has been cut out to receive a plate repair. The original infill can be seen. Plating is also feasible in the centre of terracotta units.

Right: A section cut from a salvaged piece of original terracotta has been indented. The colour and patination of the indent closely matches that of the terracotta block.

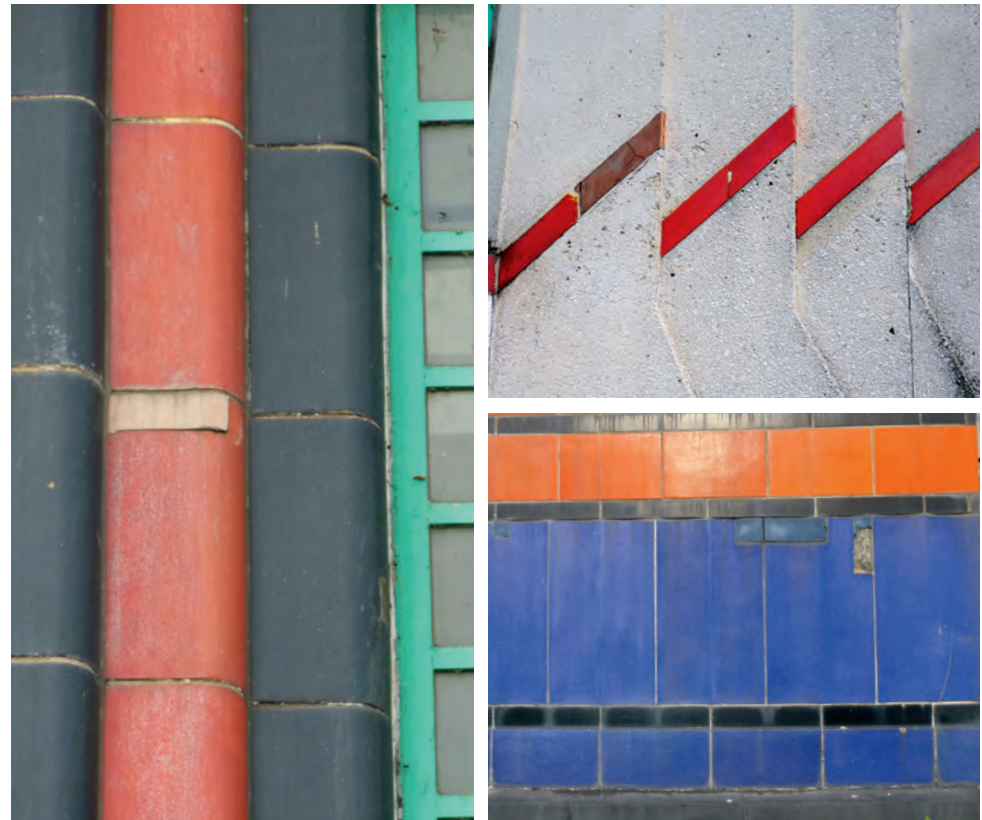


GLAZE REPAIRS

Applying a glaze to a patch repair or repairing a glazed surface is difficult, and the long-term performance of such finishes in England is anecdotal and yet to be comprehensively established. Studies in the United States have reported that some repair materials (such as those mentioned in the following table) perform well, although these have only been assessed after around 20 years. Materials used to replicate the colour and sheen of glazes often have very low water vapour transmission, which can cause problems and failure. It is inadvisable to apply them to damp surfaces; soluble salts may emerge later if moisture is moving into the terracotta system from behind. Some of these materials can also be used on unglazed terracotta, to disguise uneven surface appearance from staining.

Faience glaze can be cut with a glass cutter so the glaze repair can be applied. Good colour matches have been obtained using potassium silicate paints. This can be followed by a polyurethane resin-based varnish to provide the sheen.

Acrylic paints and polymer resins have been found to perform well. If required, polymer resins can provide a high gloss, but are only suitable for interior locations.



These examples of faience repairs on the Hoover Building, Perivale (1938) were carried out in 1980s. Although they are beginning to fail, the repairs have performed well and allowed for maximum original material to be retained. They can be repeated as part of an ongoing maintenance programme at a fraction of the cost of replacement.

CLEANING TECHNIQUES

MECHANICAL CLEANING

Mechanical cleaning removes soiling by breaking the physical bonds between the soiling particulates and the surface.

ABRASIVE CLEANING (WET & DRY)

If done incorrectly, abrasive cleaning can irreversibly damage terracotta, eroding the surface. This erosion can affect the appearance of the terracotta or faience by altering the way light is reflected off it: changing the colour and lustre of the surface finish, or making the glaze appear dull. Abrasive cleaning can also blur arrises of corners and decorative details. Furthermore, if the surface is broken through, exposing a more porous underbody, it may be vulnerable to weathering and decay. It should only be carried out by experienced specialists. **STONE**

Health & Safety

ABRASIVE CLEANING

Abrasive cleaning is hazardous and the onus is on the employer or contractor to assess the risk posed by using abrasives, and to implement appropriate controls in accordance with current legislation. **STONE**

NOISE & DUST

To protect operators from harmful noise and dust, personal protective equipment will be required for all abrasive cleaning systems. For dry abrasive cleaning, respiratory protective equipment may also be needed. Dust may need to be controlled using sheeting or extraction systems to prevent nuisance to the surrounding area. The noise impact on the wider environment should also be considered.

SILICEOUS ABRASIVES

The use of siliceous aggregate (sand) for abrasive cleaning has been linked to silicosis. It is therefore banned for most blast cleaning, and although a loophole in the legislation permits its use as an abrasive for cleaning buildings, bridges and other similar structures, the Control of Substances Hazardous to Health [COSHH] Regulations regarding containment of the silica dust produced are so demanding as to be all-but-impossible to comply with; so, in effect, the use of siliceous abrasives for cleaning buildings is outlawed. Even when used with water for wet abrasive cleaning, the risk of dust inhalation when cleaning up spent abrasive makes its use impracticable. There are a number of alternatives to silica sand that can be successfully used for abrasive cleaning.

British Standards

PRESSURE CLEANING

BS 8221-1:2000 Code of practice for cleaning and surface repair of buildings. Cleaning of natural stones, brick, terracotta and concrete

Reference is often made to 'low', 'medium' and 'high' pressures; these refer to the indications on the pump gauge.

BS 8221-1:2000 defines the pressures ranges as:

- low pressure: 17 bar or less
- medium to high pressure: 17–69 bar.

Even small devices for the do-it-yourself market operate at pump pressures in the range of 80 to 100 bar, at flow rates of 10–30 litres per minute. These are more than capable of causing damage.

For conservation work the lowest effective pressures should always be used.


Dry or wet abrasive systems should employ minimal pressures (7–40 bar) and soft (less than 3 Mohs), round aggregates. Vortex abrasive systems have added 'swirling action', which lessens the amount of water and pressures required to clean the surface. For interiors, minimal amounts of water should be used and, instead of rinsing, the abrasive powder can be left to dry, and then brushed and vacuumed off. Manual abrasive methods such as phosphor-bronze bristle brushes, and abrasive (such as plastic or carborundum) pads and carborundum wheels, may be used in heavily soiled, localised areas.

Dry ice cleaning exploits the sublimation of frozen carbon dioxide, which expands in volume as it changes rapidly from a solid to a gas. The special equipment provides a stream of compacted pellets of dry ice that are each about 3 mm across as they leave the unit, but break apart to be a millimetre or so in diameter by the time they reach the surface. Particles of dry ice, embedded in the pores and cracks of surface deposits, will break the deposits apart as they sublime.

Abrasives can also be embedded in water-based polyurethane foam, which will rebound off the surface, modifying the impact; the porosity of the foam can also be exploited. Many parameters can be varied, including the embedded abrasives and the sponge. Sponge materials can be recovered and re-used, providing the soiling being cleaned is not hazardous.

WATER-BASED CLEANING

Water-pressure washing is an effective way of cleaning lightly soiled, smooth surfaces. At pressures of 17–100 bar, these machines deliver around eight litres of water per minute. Surface spraying with a hose at standard mains pressure, delivering water at around 3–5 bar and 9–16 litres of water per minute, and agitation with natural or nylon bristle brushes or plastic scourers, can also be effective on more detailed or vulnerable terracotta.

Steam cleaning that delivers far smaller quantities of water (typically one litre per hour) at high temperatures (vapour at temperatures of up to 160°C and pressures of less than 50 bar) is highly effective, particularly for removing greasy deposits. The temperature and water pressure can be adjusted to achieve the required result. 

More cautious recent practice has favoured cleaning with hot water or steam, followed by scrubbing with soft bristle brushes or plastic scourers, the application of non-ionic detergent, and then high-temperature steam, to remove the residue of the detergent and the loosened dirt. If the terracotta is still soiled after this procedure, stronger cleaning methods may be needed.

Hardened substances on the surface of the tile, such as paint splashes, may be removed with mechanical methods, such as a scalpel or small blade. On unglazed tile, paint strippers and solvents can soften and spread the paint, although they may be effective for removing slight residues.

With glazed wall tiles, pH neutral detergents are recommended. Initial trials are important as some acid- or alkali-based products can affect blue or red-lead glazes adversely.

Removing Paint from Glazed Tiles



Paint removal from glazed tiles is a relatively straightforward process. Dichloromethane-based paint strippers have now largely been superseded. Most products are non-corrosive, but those which are sodium hydroxide-based are corrosive and the surface of the ceramic must be neutralised following the removal of the paint layer. Otherwise, alkaline salts can penetrate and later cause salt crystallisation. Products which work on the two-part system of paste application covered by laminated paper can be very useful if the surface is intricately modelled. Some products carry health-and-safety implications for use in confined areas, so manufacturers' instructions need to be observed.

Products which are non-toxic to both the environment and the conservator are available; these are non-methylene chloride-based and non-caustic. Several applications of this type of product may be required to soften layers of hardened paint, or to effectively remove it from the grout lines. All products should be used according to the manufacturer's instructions.

Plastic or wooden spatula tools can be employed to scrape away the softened paint. Wire wool, wire brushes or metal scrapers should not be used, as they will scratch or scour the surface and permanently damage the glaze.

The tiles should be thoroughly washed down with clean water (preferably distilled) after all of the paint has been removed. The surface of the tiles may be tested for pH levels after washing, if necessary, with indicator strips.

CLEANING PRODUCTS USED IN THE CONSERVATION OF TILES

These are all specialist materials and methods, used by tile conservators with a knowledge of their properties and risks

TYPE	SUITABLE FOR	METHODS & COMMENTS
Abrasive	NONE	Abrasive cleaners are not recommended for historic tiles
Acid-based	Industrial tiles	Can remove coatings or stains from lime or cement Can damage silicates in a glaze Can etch the surface of a glaze Can attack certain colours such as orange/red in a glaze The tile should be pre-wetted; this saturates the porous body of the tile and prevents cleaning agents from penetrating further 5 % hydrochloric acid in water can remove encrustations (calcium or magnesium carbonates) A chelating agent solution in water can be effective for encrustations such as hard water deposits (calcium carbonate, magnesium hydroxide and calcium sulphate),
Alkaline	Delft tiles Industrial tiles	Alkaline cleaners can attack certain colours such as blue in a glaze The tile should be pre-wetted; this saturates the porous body of the tile and prevents cleaning agents from penetrating further One conservation-grade liquid soap is based on potassium methyl cyclohexyl oleate, and is generally used 1:6 in water or 1:10 in mineral spirits; and should be fully cleared afterwards with same diluent (this material does more than simple detergent action; it is effective for soot and greasy and fatty deposits, as well as for paint removal)
Ammonia-based	Industrial tiles	Ammonia can remove stubborn asphalt, oil stains or scuff marks but these must be used with caution The tile should be pre-wetted; this saturates the porous body of the tile and prevents cleaning agents from penetrating further
Mechanical (e.g. soft brushes)	Medieval tiles Delft tiles Industrial tiles	Slow but effective Useful for cleaning grout
Mechanical (polypropylene fibre pads; more abrasive methods)	Industrial tiles	Danger of abrading the surface of the tiles; generally not recommended Abrasive pads on mechanical equipment and abrasive powders are generally not recommended Sponges are the least invasive, but still must be used by an experienced practitioner
Mechanical (scalpels and blades)	Medieval tiles Delft tiles Industrial tiles	Used to remove hard substances and encrustations Danger of damaging the surface of the tiles; must be used by an experienced practitioner
Paint strippers	Delft tiles Industrial tiles	Often left on the surface for a few seconds before removal to swell and soften the coating; however, can soften and spread the paint, making the removal more difficult Some non-corrosive strippers are based on ethanol; needs several applications to be effective
Steam Wet or dry vacuum	Delft tiles Industrial tiles	These are gentle cleaning methods, but must only be used by an experienced practitioner Steam cleaning can help soften encrustations or greasy deposits, but often leaves a residue which must be removed by hand Wet or dry vacuum methods are recommended after cleaning and before any sealing
Solvents	Industrial tiles	The tile should be pre-wetted; this saturates the porous body of the tile and prevents cleaning agents from penetrating further; however, if left on the surface solvents can discolour it
Synthetic detergents (pH neutral)	Delft tiles Industrial tiles	The tile should be pre-wetted; this saturates the porous body of the tile and prevents cleaning agents from penetrating further A mild detergent is made of alcohol ethoxylates; also used as a wetting agent

Note: Chloride bleach should not be used on historic ceramics, as it can encourage salt crystallisation under the glaze.

REPAIR OF TILES

MORTARS FOR TILE CONSERVATION

The standard repair material for tiles is mortar, used to grout voids under tiles, fill surface joints and re-bed tiles. Grouts and re-bedding mortars need to be both compatible with the cladding (that is, not excessively strong), but bond securely with the substrate as well, which is often of Portland cement mortar or concrete. Significantly different mortars can produce tensile stresses as a result of differential expansion or contraction.

Mortars for new substrates, or bedding and grouting voids, need to have hydraulic properties (the ability to harden in part by reaction with water). Pure 'air' or non-hydraulic limes, which require air for setting by reaction with carbon dioxide, will not do so under dense, impervious tiles. Speed of set is also significant: fixing of wall tiles requires adherent mortar that attains sufficient tensile strength; bedding mortars for floor tiles need to gain compressive strength quickly to carry loads.

⇒ MORTARS

Late 19th- and early 20th-century bedding mixes for tiles were very often 1:1 Portland cement and sand. Their modern equivalents are too strong for conservation purposes, as they have strengths far in excess of historic ones. The challenge is to find a mortar which has comparative tensile strength and moisture absorption properties as any extant historic cement mortar. If this is not achieved, there will be failure at the junctures of the patch repairs in the future.

Natural hydraulic limes come in three classes, according to *BS EN 459-1: 2000 Building lime*, as NHL 2, NHL 3.5 and NHL 5; the numeric designation is compressive strength in MPa at 28 days. These need be specified with caution, as they are likely to attain strengths (which are related more importantly to adhesion and coefficient of expansion) greater than the needs of the application (see **General Introduction and Appendix**).

These are too strong to be used as bedding mortars for weak medieval or Delft tiles. Instead, pozzolanic mortars are appropriate, based on non-hydraulic lime with additives that contribute a reliable hydraulic set (as metakaolin, or pulverised fuel ash). However, weak lime mortar is not suitable for 19th- and 20th-century work, largely because of potential leaching and staining, the lack of good adhesive power, and the tendency towards slumping.

A useful mix, particularly for 19th- and 20th-century floor work, is the traditional 1:2:9 or 1:1:6 'compo' of hydrated lime gauged with cement and sand. This has been used successfully in the past. Mixes which are too hard and do not allow any moisture permeability will result in moisture from ground level migrating into walls, sometimes with serious consequences.

It is always necessary to carry out test fixings before finalising the required mix.

CHOOSING THE CORRECT REPLACEMENT MORTAR

Typical examples of mortar mixes for new bedding and substrates are provided below. However, mortar tables can never be fully comprehensive or inclusive for every situation; the mixes suggested are intended to be used as a starting point for the development of appropriate mortars for individual projects. The experience and competence of the specifier must always be an important factor in the specification process. In order to select an appropriate mortar for a specific project, the tile type, condition and degree of exposure must all be taken into account, as referred to in the following mortar selection tables.

In the following tables, bedding and substrate mortars are defined as a system of compatible materials that need to bond tiles to the structure. Tiles require bedding and substrate mortars with hydraulic properties if they are to harden in a reasonable period of time. Therefore, mortars of non-hydraulic lime (described in other mortar tables in this book as 'Type A' mortars) are not suitable for structural applications.

TYPE B MORTAR SYSTEM: BASED ON NON-HYDRAULIC LIME PUTTY + POZZOLAN + NHL

	APPLICATION	MATURE LIME PUTTY	NHL 2	WELL-GRADED SAND ¹	BINDER:AGGREGATE PROPORTIONS	POZZOLAN EITHER A OR B (% by volume of coarse stuff)	
						A	B
						PFA	METAKAOLIN
B1	BEDDING	1		2¾	1:2¾	10	5
	SUBSTRATE		1	2½	1:2½		
B2	BEDDING	1		2	1:2	15	8
	SUBSTRATE		1	2½	1:2½		

All proportions are by volume

¹ For details, see corresponding TYPE B mortar tables in the Brick section of this volume

TYPE C MORTAR SYSTEM: BASED ON NATURAL HYDRAULIC LIME

	APPLICATION	NHL 2 ¹	NHL 3.5 ¹	NHL 5 ¹	WELL-GRADED AGGREGATE	BINDER:AGGREGATE PROPORTIONS
C1	BEDDING	1			2½	1:2½
	SUBSTRATE		1		2½	1:2½
C2	BEDDING		1		2½	1:2½
	SUBSTRATE			1	2½	1:2½
C3	BEDDING		1		2	1:2
	SUBSTRATE			1	2	1:2

All proportions are by volume

¹ These tables are for guidance only: manufacturers' advice regarding proportions and batching for the specific natural hydraulic lime used should always be followed

CONSERVATION PLANNING

A *Conservation Plan* had been prepared for the Abbey in 2000. This characterised the Refectory pavement as being of ‘European importance’ comparable “*with the Chapter House pavement of Westminster Abbey and the Byland Abbey pavements for fineness, extent, state of preservation, original context and visibility to the public*”.

In tandem with the diagnostic monitoring programme, a conservation options appraisal was undertaken to guide the decision process at the end of the research project. It identified the following options, with an appraisal of each:

- protecting the pavement with a permanent cover structure
- lifting the pavement, with a view to relaying and exhibiting it under cover either at Cleeve Abbey or elsewhere
- presenting the pavement exposed to the elements in the summer and covering it with protection during the winter (as prior to the erection of the marquee in 2005)
- reburying the pavement.



Solar radiation on the pavement contributes to environmental instability. These areas were specifically monitored to compare conditions with those constantly in shaded conditions.

At the time of excavation in the 1950s, the risks of exposure and the issues of deterioration of exposed glazed tiles appear to have been little understood. The Ministry of Works took the conventional approach to its presentation and repair. Progressive loss of the glaze over the latter half of the 20th century was undoubtedly one consequence of exposing the pavement to a highly dynamic environment each summer. This jeopardised the very fine slip decoration and the inherent decorative significance of the tiles themselves. Due to the lack of good historical documentation, the amount of loss since 1951 cannot be quantified; however, there is no doubt that all decorative slip would eventually be lost if summer exposure continued.

Today, conservation is driven by a preventive approach. This aims to create a more benign environment, where possible, to reduce the rate of deterioration and the need for repair, thereby preserving the authenticity of cultural material. At Cleeve, a protective building or reburial are the two distinct preventive conservation options that can satisfy the ethical imperative to preserve the pavement for future generations. A new cover building or shelter was ultimately chosen to protect the pavement, while continuing to allow public access. This was being designed and built at the time of writing.

SHELTER DESIGN

The creation of a new shelter on an archaeological site is always an imposition, in conflict with the intrinsic historical and natural character of the site. However, the protective function of the shelter must be paramount, meaning inevitable compromises in aesthetic design (see box on **Medieval Tiles on Archaeological Sites** earlier in this chapter).

The diagnostic research and monitoring informed the design of the new protective cover building over the pavement. The refined functional model of the tent is also reflected in the shelter design. In this respect, the marquee has been of immeasurable importance, providing an opportunity to assess its impact, with modifications, and ultimately mimic the environment of a permanent structure. Consequently, this instils confidence in the future performance of the shelter, which could not be afforded either by computer modelling or by the conventional design-and-build process. Testing and modelling of this kind is relatively rare on archaeological sites but is beneficial in developing a system that works and reduces remedial conservation treatment.

The specific environmental strategy to protect the pavement requires management of rainfall, temperature, relative humidity, ventilation, solar gain and drainage, by passive means and with no mechanical control. This will be achieved by the shelter's cladding materials and its design. The main components are of timber, which being naturally hygroscopic will help to buffer fluctuations in relative humidity. Ventilation is provided by fixed louvres on the east and west elevations; this can be reduced with retrofitted internal blinds if required. As the site will not be open to the public in the winter, the pavement will continue to be protected with a winter cover.

The diagnostic programme will be resumed after construction (both environmental monitoring and condition monitoring), to confirm the performance of the new building and prompt a response to any unforeseen consequences.