ENGLISH HERITAGE
PRACTICAL BUILDING CONSERVATION

# MORTARS, RENDERS & PLASTERS

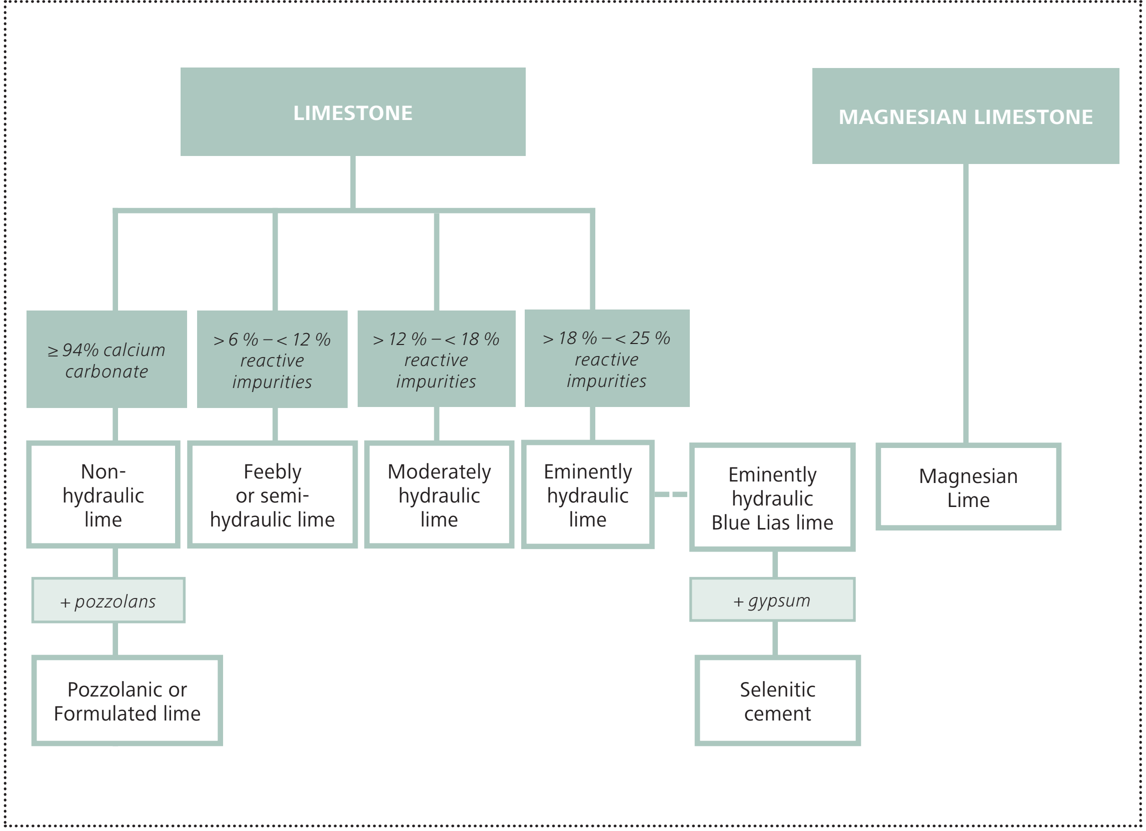
ENGLISH HERITAGE

ASHGATE

# LIME

Lime is of immeasurable importance in the long history of traditional building in England. Being an extremely versatile material it can be used as the binder in mortars for building, pointing, rendering, plastering and flooring, as well as in grouting and lime concrete. It can be mixed with other materials for various decorative applications or diluted with water to form a protective coating. Lime has variable physical properties, depending on the parent rock from which it is derived, which contribute to the nature of lime mortars. They are eminently compatible with traditional building materials and have good water vapour permeability, unlike cement mortars. Lime-based mortars are relatively flexible under stress and have limited autogenous healing properties, due to slight dissolution and redeposition of lime over time, which can fill minute hairline cracks. By contrast, cement mortars are brittle, prone to cracking, and are not self-healing. ➲STONE ➲CONCRETE

Lime for building is derived from calcium or magnesium carbonate minerals. In England, quarried limestone was the principal source, although seashells were exploited in some areas. There is a wide range of different types of lime, each with varying properties suitable for different applications. Whatever the type of lime, the first stage of production is burning the raw carbonate material in a kiln.



# Lime Burning

When heated, calcium and magnesium carbonate undergo a chemical change. At temperatures in excess of 800°C carbon dioxide is driven off, producing a material called quicklime. This process is known as calcining. In order for temperatures at the core of the limestone lumps to attain the required temperature in a reasonable length of time, the temperature in the kiln has to reach approximately 950°C. In many early kilns, temperatures varied throughout the kiln, and some limestone lumps did not achieve the critical temperature and remained fully or partially unconverted.

Archaeological evidence shows that lime burning in England dates from Roman times. Initially, stone was simply layered with fuel (usually wood, furze or brushwood) and burned in a pit or clamp, but by medieval times the use of kilns made of stone (and later of brick) was widespread. Early kilns burned intermittently, the stone and fuel being loaded, burned, then allowed to cool before being emptied and reloaded for the next batch.

By the mid-18th century, continuous draw kilns were developed, in which the charge burned in the middle of the kiln, quicklime was drawn off from the bottom, and more raw materials and fuel (coal was increasingly used) were loaded from the top.

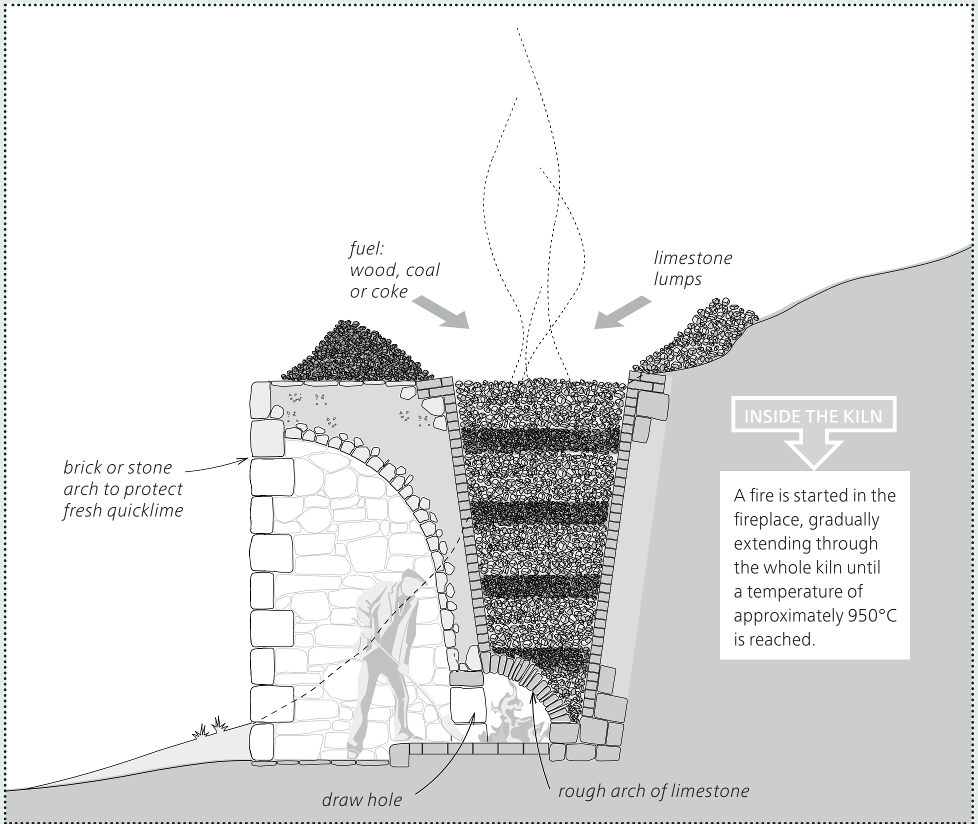



Diagram of a lime kiln in section. This is one form of continuous or draw kiln, built into a hillside.

Alternate layers of limestone and fuel are loaded from the top.

## SLAKING WITH AGGREGATE

For making larger quantities of mortar for building, rendering or plaster base coats, a different method was often used. Written accounts dating to the early 18th century describe a process of 'dry slaking', in which lumps of quicklime (either non-hydraulic or hydraulic, depending on local availability) were lightly dampened to initiate slaking, and layered or covered with damp sand. The moisture in the sand contributed to continued slaking, whilst the heat generated ensured that any excess water was driven off. The result was a mixture of powdered hydrated lime and dry sand. Non-hydraulic lime would slake within a couple of hours at the most, whereas hydraulic lime could take much longer (12–48 hours). However, a major advantage of slaking hydraulic lime this way was that the heat of slaking was retained by the sand, which speeded up what would otherwise be a very slow reaction. Adding the right amount of water was critical: too much and any hydraulic components would start to hydrate, too little and the lime would not slake properly.

A late 19th-century description of the process is provided by Wray and Smith (1879): *"A convenient quantity of the quicklime is measured out on to a wooden or stone floor under cover, and water enough to slake it is sprinkled over it. The heap of lime is then covered over with the exact quantity of sand required to be mixed with the mortar; this keeps in the heat and moisture, and renders the slaking more rapid and thorough. In a short time – varying according to the nature of the lime – it will be found thoroughly slaked to a dry powder."*

The process of dry slaking

*Top left:* Quicklime is placed within a circle of damp sand.

*Top right*: The sand is drawn over the quicklime. The moisture in the sand initiates slaking. The heat produced by slaking drives off some of the moisture from the sand in the form of steam.

*Bottom left*: As the quicklime slakes it expands, forming fissures in the sand, which is by now almost dry.

*Bottom right*: The quicklime is slaked to a dry hydrate, which is easily mixed with the dried sand. This can be passed through a screen to remove lumps of unslaked lime. However, unscreened material, containing both unslaked lime and under-burned limestone, was often used, imparting a particular character to many historic mortars, such as those often found in wall cores.

*"Hydraulic limes should be left (after being wetted and covered up) for a period varying from twelve to forty-eight hours, according to the extent of the hydraulic properties they possess; the greater these are, the longer will they be in slaking... Only so much should be slaked at once as can be worked off within the next eight or ten days."*

Once slaking was deemed to be complete, the dry sand and powdered hydrate were shovelled through a large inclined mesh screen to remove lumps of unburnt, overburnt or unslaked lime, although rough mortars for some vernacular buildings or for core work were unscreened and often contain such lumps. As late as 1927, Cowper described the dry slaking of hydraulic quicklime and sand, and recommended that any material that will not pass a IMM [British Institute of Minerals and Metals] Standard No. 5 sieve should be removed by screening, unless the mortar is subsequently worked in a mortar mill that would crush the lumps.

If non-hydraulic or feebly hydraulic lime was employed, the screened mixture could be stored for a few days either in its dry form, or wetted and mixed to form mortar, known as coarse stuff. Non-hydraulic or very weakly hydraulic coarse stuff could be stored indefinitely as the water in the mix inhibited carbonation, and (as for lime putty) storage allows time for any remaining particles of quicklime to slake and for the lime to fatten up, rendering the mortar more workable. Coarse stuff stiffens during storage, but plasticity can be restored by vigorous beating or knocking up. Even feebly or moderately hydraulic coarse stuff was often stored overnight or over the weekend, before being knocked up for use on the next working day.

Eminently hydraulic lime would start to stiffen quickly once wetted, and had to be used soon after mixing, so additional precautions were required, as described by Wray and Smith (1879): *"With strong hydraulic limes, or with others that are known to contain overburnt particles, it is advisable to slake the lime separately, and to screen out all dangerous lumps, etc., before adding the sand, or the safest plan is to have the lime ground before using it."*

Slaking quicklime with sand in this way persisted into the 20th century; a number of veteran practitioners recalled making mortar, particularly hydraulic lime mortar, by this method. Procedures for the preparation of Blue Lias lime mortar for use in the conservation of ancient monuments in the care of HM Office of Works (later known as the Ministry of Public Building Works) were set out in 1911 by Frank Baines, Architect in Charge. Baines recommended a standard mix of two parts hydraulic quicklime to five parts of well-graded aggregate. Blending with aggregate and slaking were carried out together, in a pit or metal bin, by alternating layers of sand (5 inches thick) and ground hydraulic quicklime (2 inches), watering the sand each time, and finally cutting through and mixing it by hand with a little additional water. The blended material was then heaped on a boarded platform, polished with the back of a shovel, and left overnight or for at least 12 hours until it was 'cool'. Slight expansion of the slaking material took place during this time. Any mortar which had begun to stiffen was rejected. This practice continued until the demise of hydraulic lime production in the UK in the early 1970s.

Evolution of decorative plaster style over three centuries

*Top left*: High-relief and richly-modelled Baroque ceiling of the late 17th century.

*Top right*: High-style hand-modelled plasterwork with characteristic strapwork design of the mid-17th century.

*Middle*: Hand-modelled provincial work of the early 17th century, with pressed elements set within diamond patterns.

*Bottom left*: Extremely fine and subtle relief of mid-18th-century lime plasterwork.

*Bottom right*: Late 19th-century plasterwork in the Adam revival style, typically of cast gypsum.

## FREEHAND MODELLING

Until the 1770s, freehand modelling of plaster *in situ* was used to create free-flowing and curvaceous high relief work to individual designs, often in conjunction with elements such as leaves and flowers formed by press moulding. Thereafter, the use of cast ornament became more common.

Plasterers and pargeters both executed freehand-modelled internal ornamental plasterwork in lime mortar. Plasterers worked on a variety of buildings including those of high status, and some were itinerant. Pargeters were primarily engaged in local vernacular buildings (both exterior and interior). Interior pargeting was particularly prominent in vernacular buildings in the 17th century. In the mid-16th and early 18th centuries, plasterers were complemented by Italian *stuccatori*, who created even more refined interior work in lime-based plaster.

Freehand modelling of lime plaster is an additive process in which progressively finer plasters are gradually built up from the surface by the craftsman. Until the late 18th century, this consisted of three-coat work in lime and sand, with each successive coat finer than the proceeding one. Base coats also contained animal hair. This individual hand working of each element enabled the deep undercut and layering that enriches so many buildings of the late 17th and 18th centuries, and distinguishes it from the later technically precise mechanical repetition of cast gypsum plaster.

Large projections such as limbs, foliage or instruments required reinforcement with an armature until the plaster was adequately carbonated. These were either of metal (typically iron wire, nails or lead), organic materials (such as wood and bone), or indeed anything capable of providing suitable support. They often became significant factors in later deterioration. Lighter ornament was set directly into the wet mortar of the flat work.

## CASTING

From the late 18th century, the rapid setting time of gypsum – around 15 minutes from mixing with clean water – enabled large quantities of repetitive low-relief ornament to be churned out in a fraction of the time taken to model lime *in situ*. It was also applied to the skilled casting of models ‘in the round’, initially using interlocking piece moulds. By the mid-19th century, flexible gelatine moulding materials allowed a degree of undercut to be achieved in a single cast. However, reverse-carved timber or well-hardened plaster master moulds were sufficient for gypsum-poured models without undercut.

Casts could be large or small, plain faced or decorative. Suspended ceiling sections might be made up of several smaller items if a large degree of undercutting of the enrichment was required. Finished cast sections were then affixed to a latticework of timber joists or metal struts, and all joints and gaps filled with plaster and made good.

# RENDER & PLASTER ON SOLID BACKGROUND

The most typical problems encountered with renders and plaster applied to solid backgrounds are cracking and detachment, but surface deterioration and inappropriate repairs are also common.

**COMMON DEFECTS IN RENDER & PLASTER ON SOLID BACKGROUND**

| SYMPTOM DESCRIPTION | POSSIBLE CAUSES |
|---|---|
| STAINING & DISCOLOURATION | |
| Surface staining | Organic growth<br>Soluble salts migrating from backing or introduced in aggregate<br>Black soiling from carbon deposits<br>Water penetration |
| Dark soiling in sheltered areas on external renders | Sulphation |
| Surface streaking | Irregular water channelling on wall face (for example, through open joints and copings) |
| Staining, powdering and flaking internally | Water penetration, typically from parapet gutters at high level, or from rising damp at ground level and around openings<br>Local heat source |
| White surface crust (laitance) | Rapid drying of mortar or excessive working of wet mortar drawing lime to the surface, possibly restricting carbonation of the mortar at depth |
| CRACKING | |
| Fine crazing | Overworking of surface |
| Cracking: wandering, multi-directional lines | Mortar used too wet resulting in shrinkage on drying<br>Too many fines in the aggregate resulting in shrinkage<br>Lack of scouring and compaction as the mortar firmed up<br>Poor bonding, inadequate key to background<br>Excessive coat strength for the background |
| Cracking: accompanied by light coloured zones around the crack lines | Rapid drying shrinkage, followed by migration of lime binder to the drying zone formed around the crack line |
| Cracking: with lime leaching | Longer term development of the condition above in external renders |
| Cracking: directional lines | Differential movement of concealed elements such as timber lintels (horizontal), differential movement around blocked openings (vertical and horizontal)<br>Sulphate attack (especially ettringite, mainly horizontal)<br>Shrinkage stresses (typically diagonal from sills)<br>Stepped cracking (structural movement, typically subsidence)<br>Accompanied by rust staining: rusting hoop iron in bed joints behind, or from rusting of armatures supporting modelling |

| COMMON DEFECTS IN RENDER & PLASTER ON SOLID BACKGROUND | |
|---|---|
| **SYMPTOM DESCRIPTION** | **POSSIBLE CAUSES** |
| DETACHMENT | |
| Hollowness in small areas, with no cracking | Drying shrinkage<br>Poor adhesion due to low suction of backing, poor keying of smooth surfaces or application onto dry substrate<br>High strength of finish coat compared to backing coat(s), resulting in differential thermal movement<br>Salt crystallisation at interface of render/plaster and substrate, or between render/plaster coats<br>Use of impermeable coating on external render |
| Hollowness: accompanied by cracking and displacement | Further development of conditions described above, particularly in hard, brittle renders<br>Settlement or movement in the structure |
| Detachment between coats (delamination) | Undercoat too weak to support finish coat<br>Finish coat too thick for backing (typically modelled detail)<br>Lack of adequate keying between coats<br>Salt crystallisation at interface between render/plaster coats |
| FRIABILITY, CRUMBLING & FLAKING | |
| Crumbling and powdering | Insufficient binder in the mortar<br>Use of powdered lime that has (partially) carbonated before being used<br>Lack of carbonation of lime binder due to rapid drying of mortar<br>Action of acid rain on external render<br>Slaking *in situ* of over-burnt dolomitic lime, particularly in external renders<br>Internally, and more rarely externally, indicates presence of gypsum and the softening effects of water<br>Salt crystallisation |
| FRIABILITY, CRUMBLING & FLAKING | |
| Surface loss | Effect of acid rain on lime binders<br>Crystallisation of soluble salts in surface pores<br>Abrasion by climbing plants, tree branches, furniture<br>Loss of laitance crust (formed by over-working)<br>Frost damage |
| Loss of render/plaster with spalling of masonry behind | Excessively strong, impermeable material applied to a weaker background |
| Loss of render associated with water repellence of substrate | Usually indicative of oil priming of background and presence of oil mastics |
| Surface pitting | Late slaking of particles of unslaked lime<br>Abrasion, possibly due to abrasive cleaning<br>Penetration by climbing plants |

Ideally, all the remaining render or plaster surrounding the damaged area should be firmly adhered to the backing; if there is separation from the substrate this will result in a very slight bulge around the damaged area, making it almost impossible to achieve an 'invisible' repair without cutting out additional material, particularly on smooth, flat internal plasters. However, in practice, limited areas of detachment, particularly in plasters or renders reinforced with hair, may be quite stable, and not at risk from further deterioration, so the desire for an invisible repair must be weighed against the otherwise unnecessary loss of further historic fabric.

Where loss is due to inadequate key between coats or with the substrate, measures such as roughening, applying a spatterdash coat or using a mesh support will be needed to increase the key for the repair (see **Using Lime Mortar: Good Practice**).

Preparation for patching is similar to that for crack filling: removing loose dust and, if lime mortar is to be used for repair, thoroughly dampening down the substrate and surrounding render or plaster. To control suction and improve adhesion, some of the mortar can be diluted with water to form a slurry, and painted onto the backing; the repair mortar should be applied once excess water in the slurry has been absorbed into the backing, but whilst the slurry is still damp.

## APPLICATION

The tools for applying the repair mix will depend on the size of the repair; for minor patches, plasterers' small tools (such as a leaf and square, or a trowel and square) are ideal; gauging trowels are suitable for slightly larger repairs, and for extensive areas, a steel laying-on trowel can be used. For repair of large areas, the base coats may be cast on with a casting trowel.

Mortar should be applied by casting (making sure surrounding surfaces are protected) or firmly trowelling on, ensuring good contact with the substrate. It is also important to form a good contact with the edges of surviving render or plaster, but care must be taken not to force new mortar into any undercut, as this can cause detachment.

Small surface repairs in lime mortar should be built up in layers no more than 25 mm thick, although very small areas up to roughly 20 mm diameter can often be filled in just one operation, provided the total depth of the repair is no more than about 30 mm. Areas larger than roughly 400 mm square are best repaired in the same number of coats of the same thickness as the original work.

Lime plaster patch repair

1. Plaster damaged by the removal of fixings.

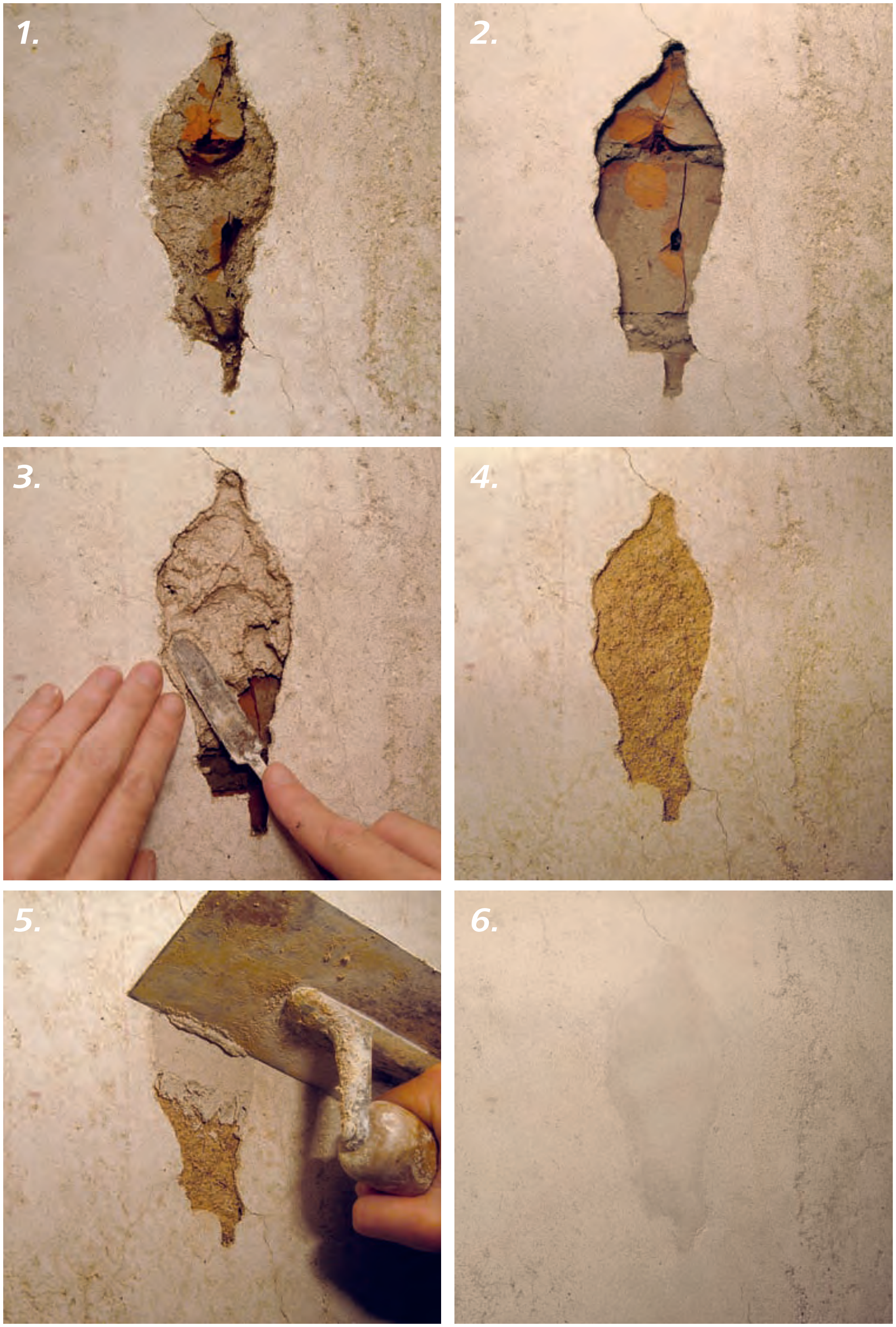
2. The damaged area is cleaned back to the substrate and the edges of the area to be repaired are slightly undercut, using a sharp craft knife, to help provide a key for the repair.

3. The area is thoroughly dampened, and lime mortar pressed onto the backing. The undercut edges are supported whilst mortar is gently pressed into the recess. When working on solid substrates, it is not essential to include hair in the mix, but it helps reduce the risk of shrinkage.

4. The mortar is finished a couple of millimetres below the finished level, and lightly keyed by scratching and allowed to dry.

5. The base coat is dampened and fine setting stuff applied. It is important that the repair is not feathered over the edge of the adjacent plaster, but is butted up against it. A straight edge or the edge of a trowel is run over the repair to strike off excess material and finish the repair flush with the existing surface. If need be, the repair can then be wetted and polished with a trowel to create the desired surface finish.

6. The finished repair, ready for painting.



Paint is an opaque dispersion of small insoluble pigment particles in a liquid binding medium which sets or dries, adhering the particles to each other and to the substrate. Paints enliven building surfaces with colour or decorative design, and provide protection to vulnerable masonry, plasters, renders, timber and metalwork. When applied to a building, paint is part of a dynamic system comprising the building structure (the support of masonry, timber, metal, concrete and so forth), an intermediate layer (the substrate, generally of plaster or render) and the paint itself. Paint has the potential to influence the condition of these other components, both beneficially and detrimentally.

This section provides an overview of architectural paints and their use from past to present. It does not cover materials and techniques for specialist decorative techniques, such as egg tempera and fresco, which are the preserve of the wall paintings conservator. Nor is it a definitive technical text. Instead, it offers guidance on materials and best practice.

## HISTORY

Evidence of wall protection and decoration with simple paint exists from the earliest times. Paint technology evolved slowly until the Industrial Revolution. During the 19th century, the invention of artificial pigments and other paint additives improved the range of products available. Until the 20th century, when mass production became the norm, painters made their own paints, although ready-ground pigments in oil were available from colourmen from the middle of the 18th century.

*Facing page*:

Redecoration of Carlton House Terrace, London ,1898. The monumental effect of the structure depends on its design, scale and maintenance of its painted render in a pristine state. In the polluted environment of Victorian cities, such buildings were soon covered with grime, as evidenced in the colonnade. Consequently, buildings on private estates were required by lease to redecorate on a regular basis; for example, every four years. Here, surveyors, foremen and painters pose to commemorate the progress of their prodigious task (see also **Treatment & Repair: Access**).

*Right*: Wroxeter Roman Baths. The earliest surviving architectural painting on plaster in England dates from the Roman period, normally as plain fields of colour, simple linear patterns or, rarely, more elaborate schemes, such as this. These were painted in the 'true fresco' method.

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