THE USE OF LIME MORTAR IN HISTORIC STRUCTURES

Technical Conservation Note 2
April 2004

Cadw

1. Introduction

The making of quicklime by heating limestone in kilns, and preparing mortars, plasters and whitewash from it, is an ancient practice, mentioned in the Old Testament. Many ancient examples of its use — for example, lime plasters in the pyramids and Roman lime mortars — survive to this day.

This tradition continued until the patenting of Portland cement in 1824 heralded a steady decline in the use of lime for building. Today it is almost obsolete, apart from works on historic buildings.

2. What is lime?

Limestone (calcium carbonate), when burnt in a kiln, loses carbon dioxide and becomes quicklime (calcium oxide). On contact with water, it combines with it, producing great heat, to form slaked lime (calcium hydroxide), also called lime putty. This gradually takes up carbon dioxide again from the air and changes back to calcium carbonate. This 'setting' is called carbonation.

Lime putty mixed with sand makes mortar. This then hardens into an artificial stone made up of grains of sand embedded in a mass of calcium carbonate.

3. Why use lime?

Most pre-nineteenth-century buildings used lime mortars and plaster. Materials used to repair or replace original masonry should have similar properties so as not to disrupt the balance of interaction within the building.

Cement pointing is particularly detrimental if applied to soft stone or bricks. It is hard, non-resilient and comparatively non-absorbent. Nor does it respond to the variations in the atmosphere to the same extent as the surrounding stone or brickwork. Hard pointing can cause rapid weathering of the softer stone or brick. Many causes of stone decay have been traced to the use of impervious mortar with a porous stone. In such cases saturation and evaporation are confined to the stone whereas the process should be distributed evenly over stone and pointing. Where a particularly soft stone is employed then the mortar should sacrifice itself for the stone.

4. Types of lime

These notes assume the use of a non-hydraulic high calcium lime putty to prepare mortars etc. This should not be confused with other types of lime.

Hydrated lime

This is sold in most builders' merchants as bags of dry powder. Soaked in just enough clean water, for at least twenty-four hours, it makes a lime putty. This putty may be of a poor quality due to carbonation of the powder occurring in the bag before use and the inclusion of unburnt/unslaked particles from the manufacturing process.

Note: Only enough (ie not an excess) of water is used during the slaking stage so that the heat given off will result in the slaked powder containing lumps which are then crushed. In lime putty manufacture sieving takes place after slaking to remove any particles which have not reacted or are overburnt, as these will not carbonate properly.

Hydraulic lime

This is so called because of its ability to set under water without the presence of air. Some of these limes can set as hard as Portland cement. However, there are a few 'feebly hydraulic' limes available that, if used soon after slaking, can give good service in mortars.

5. Is the work really necessary?

If the joints are only weathered back to a rough finish or if the mortar appears soft compared to modern mortars then repointing may be unnecessary. If the joints do not allow rain to penetrate or to rest in them it may be best to leave them alone. However, if they have weathered back by more than the joint thickness, or are partly or wholly open, then they probably require repointing.

It is not necessary to point every open joint in a wall. The mortar, although weathered back, may still be sound. Unless recessed more than 12mm there should be no need to fill the joints.

6. Matching the mortar

The new mortar should match the original in colour and texture as closely as possible. This is especially important if only partly repointing the wall. Mortar analysis can help achieve this. However a highly detailed chemical analysis is rarely necessary.

A simple mortar analysis can carried out as follows:

1 Remove a piece of mortar from the wall.
2 Closely examine the sample, noting the texture, colour, etc. Note whether there are any bits of ash, charcoal, coal, lumps of lime etc. A 10x magnifying glass is useful for this.
3 Lightly crush it.
4 Mix it with water in a calibrated flask (a jam jar and a ruler will do) and stir thoroughly.
5 Allow it to stand and settle for approximately twelve hours.
6 Measure and calculate proportions.
7 Assess aggregate sizes and colours.

A more detailed analysis, which is to be recommended, involves dissolving the lime in hydrochloric acid (dilute 10%, which can be bought as brick and cement cleaner.) The aggregates can then be identified by eye and comparisons made with known aggregate samples (after washing and drying). It can also be useful to grade the aggregate by using a set of British Standard sieves. By accurately weighing samples before and after dissolving the lime the approximate ratio of lime to aggregate can also be calculated.

Note: care should be taken in areas of limestone, as sometimes this was crushed and used in the aggregate; thus the aggregate may also dissolve.

The mortar's suitability for the stones or bricks and the location should also be considered. Bear in mind that the mortar should always be weaker than the materials it bonds but strong enough to resist weathering.

7. Aggregates

When matching the aggregate of an historic mortar it may be necessary to mix several sands and/or gravels. Therefore it is essential to have a good knowledge of the sands available in a particular region.

Take particular care about the grading of the replacement mortar's aggregate. It should be clean and well graded, ranging from fine to coarse, and gritty in texture. This produces a stronger mortar with less risk of shrinkage. Beware of artificially crushed stone dusts (especially limestone). These cause shrinkage problems, are weak and have poor adhesion.

The size of aggregate will depend upon the thickness of the mortar joint. Fine joints will not be able to accommodate large particles.

When buying ready mixed lime:sand mortar specify the aggregates required and make sure they are supplied.

8. Mixes

Even if lime:aggregate ratio has been calculated by mortar analysis, this may not be the ideal mix in a certain situation. For example, the mix may be too weak to survive in an exposed location; this may be the reason it failed in the first place.

A good general mix comprises 1 part lime to 3 parts aggregate. It can be increased up to a maximum of 1 part lime to 4 parts aggregate in sheltered locations or decreased to a minimum of 1 part lime to 2 parts aggregate in exposed locations. On finely jointed stone or brick a suitable mix would be 1 part lime to 1 part aggregate.

The above mixes can be gauged with a pozzolanic additive to give a more rapid set. This may be important if the work cannot be carried out in the spring or summer (the ideal times of year).

9. Pozzolanic Additives

Pozzolana is a volcanic dust first found at Pozzuoli, near Naples, that when mixed with lime mortar causes it to set more quickly even in the presence of water.

'Pozzolan' is the term now used for any material that performs the same task as pozzolana.

Pulverized fuel ash (PFA):
Ash extracted from power station flue gases, also known as 'fly ash'. It is variable in colour, grading and pozzolanic ability. It may also contain significant amounts of sulphate, and therefore a low sulphate content should be specified.

High temperature insulation (HTI) powder:
Fireclay used to withstand high temperatures that has been finely ground. It can be purchased as such, or refractory bricks can be crushed.

Brick dust
Nothing more complicated than fired clay bricks that have been crushed. There is evidence that this has been used in the past so it may be found in the original mortar during analysis.

Trass
Volcanic ash found particularly in the region of Andernach, on the Rhine; thus a true pozzolan.

White cement and Portland cement (OPC)
Not pozzolans but true cements; ie they will set on their own in the presence of water.

OPC is the grey cement that everybody is familiar with. It can have high strength and be rather impermeable. Soluble salts may migrate out of OPC into the masonry, possibly causing further damage.

White cement is made from chalk and china clay. It is not as strong as OPC and is more expensive.

In the past it has been common practice to gauge lime mortars with a small amount of cement, typically 1:2:9 and 1:1:6 (lime:cement:sand). However, recent research suggests that adding cement in small quantities weakens a mortar considerably and lowers its durability.

10. Mixing the mortar

Coarse stuff is best mixed in advance of works and left to mature. This is easily done by storing in plastic sacks or tubs to exclude air. Mixing is best done by hand, mortar mill or pan mixer. A drum mixer can be used but as it relies on gravity it tends to just roll the lime putty around taking a long time to mix it with the aggregate.

Thorough mixing is essential. Turning it over with a shovel is not enough. In times past the practice was to chop, beat and ram the mortar, and this was certainly the best way. This can be achieved by ramming and beating with a timber and turning over and chopping with a shovel, giving increased contact between lime and aggregate and reducing water content. Mixing in this manner will give good workabilty and performance of the mortar.

Knock up the coarse stuff in the same fashion before using, adding pozzolan if required in the following proportions (which may vary):

Brick dust	a minimum of 1 part brick dust to 20 parts coarse stuff
HTI	a minimum of 1 part HTI to 20 parts coarse stuff
Trass	a minimum of 1 part trass to 20 parts coarse stuff
PFA	1 part PFA to 40 parts coarse stuff

11. Cutting out joints

Rake joints out to a depth of at least twice the thickness of the joint, usually 25–50mm. If the mortar is soft, this may be accomplished using a bent spike or a knife blade. If hard, cut out using a quirk, plugging chisel or similar with a small club hammer. Never cut out joints with a disc cutter or chisels that could wedge in the joint and spall the masonry. On thin joints, a hacksaw or masonry saw can be used to good effect. Remove root growth in the wall at this stage. Brush joints out and thoroughly wash with a hose or, preferably, a garden sprayer. It is also essential that masonry and brickwork are well wetted just before pointing.

12. Filling joints

Fill joints with mortar using pointing irons, made from steel bar, approximately 250mm long, flattened and curved at the ends to form blades of different widths to suit joints. Plasterers' small tools can also be used, as can stainless steel spatulas that come in various sizes (obtainable from scientific suppliers). Even wood or pieces of small broken branch can be used and are very good for pushing in the mortar after initial shrinkage. A joint can be filled fully and evenly only with an implement that fits the said joint. No voids should remain.

Deeper voids can be filled and tamped in with a slightly stronger mortar kept about 50mm back from the finished face of the pointing. Finish the joint slightly recessed, or struck and lined as required, copying any original pointing that remains.

Medieval masons usually struck the pointing off flush with the face of the masonry. In the course of time the mortar has weathered back and the edges of the stone have become rounded off. Therefore to obtain a tight joint, the surface of the pointing should be slightly recessed so that the mortar does not spread over the rounded edges of the stone. If it is brought out to the surface of the stone a thin skin spreads over the edges of the stone. This skin will, in time, weather off, leaving a pocket enlarged by wind erosion. This will hold moisture, which will accelerate deterioration of the stonework through frost etc.

After the initial set the mortar face may be 'weathered' to match the existing pointing in one of the following ways.

- lightly spray with water and possibly brush with a soft paint brush to show the aggregate;
- stipple with a stiff bristle brush;
- dab with coarse sacking.

This also removes the lime particles that migrate to the surface of the joint; this is necessary to allow carbon dioxide to penetrate the full depth of the joint and facilitate full carbonation. Initial (surface) set of a lime:sand mortar usually takes approximately 24–36 hours and of a lime:sand:cement mortar approximately 12–24 hours, depending on temperature.

In hot weather the pointing must be kept damp. This is achieved by lightly spraying, or by draping sacking which must be kept wet over the work.

Pointing should not be carried out in frosty weather. If it is unavoidable then the work must be thoroughly protected. Concreting quilts are ideal for this, but expensive. Old carpet is a good alternative.

13. Filling fine joints

Various methods have been employed over the years to accomplish this difficult task. Probably the simplest is to stick a strip of adhesive carpet tape over the joint. Cut the tape with a sharp knife and press the edges into the joint. The joint can then be filled with mortar and compacted using a pointing iron of suitable width, and the tape peeled away.

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15. Further information

If you would like further information on this subject, please contact us.

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