# Repointing mortar joints: some important points

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## REPOINTING MORTAR JOINTS: SOME IMPORTANT POINTS

### 1. Introduction

A new technical guide on mortars and repointing will soon be published by the heritage councils (or their agencies) of the six Australian States (Young, in prep). Preparation of the guide has identified some key points about materials and practice that should change the way most mortar joint repairs are specified and undertaken.

### 2. Traditional practice

Lime was the principal binding material in mortars until the late nineteenth and early twentieth centuries. Portland cement was imported into Australia from the 1850s (Lewis, n.d.) but its use was initially limited (because of cost) to more exposed parts of buildings such as rendered cornices and parapets. Cement began to be specified for mortars towards the end of the nineteenth century though its uptake was regionally variable. Lime mortars were used in domestic construction until the middle of the twentieth century. With major changes in industry after the second World War, cement became the dominant binder in all mortars, though lime was commonly used in composition with cement. With the change from lime to cement came a change from good quality sands to fine-grained sands that often contain clay, the clay providing the workability that was lost with the change to cement. Traditional knowledge about different limes and the practicalities of their use was largely lost.

### 3. Repair practice in the last 30 years

Many of us were incorrectly persuaded that, by itself, lime wouldn't work as a binder, and so conventional practice in the last thirty years has been to repair lime mortars with composition mortars such as 1:2:9 or 1:3:12 (cement, lime and sand), with white or off-white cements being used to match the colour of the lime. The theory was that the cement would add strength, while the lime provided elasticity and workability.

## 4. New understandings

In the last thirty years there have been considerable advances in understanding the behaviour and role of lime in mortars. Major laboratory research projects in the USA (Getty Conservation Institute, 2009) and across Europe, together with many conferences, some specifically on historic mortars, have resulted in a very large output of published material (e.g. Brocklebank, 2012, English Heritage, 2011, Vàlek et al., 2012, and other references in Young, in prep). Paralleling the academic research has been a re-learning of traditional practice, and the establishment of training organisations and professional bodies dedicated to advancing the application of the new knowledge and to developing practice. This paper summarises some of the key understandings as they apply to the repointing of lime mortar joints.

## 5. Walls breathe

Traditional walls of porous masonry are not just piles of stone and brick; they are systems in which permeable lime mortars allow the walls to dry rapidly after rain. That such walls 'breathe' through their joints is clearly shown in Figure 1. The longevity of walls made of low-fired bricks or soft porous stones is critically dependent on the maintenance of a permeable joint system.

Figure 1 Permeable mortar allows moisture transport and evaporation through the joints, here graphically illustrated by salt crystallising at the surface.

## 6. The lime–cement spectrum

Lime and cement binders can be understood as forming a continuous range, or spectrum, from pure (non-hydraulic) lime through hydraulic limes to cements, (Figure 2; Brocklebank, 2012). Along the spectrum there is a series of hydraulic limes of increasing strength and decreasing elasticity, porosity and permeability. We can choose a binder from across the spectrum depending on the properties that we want of the hardened mortar.

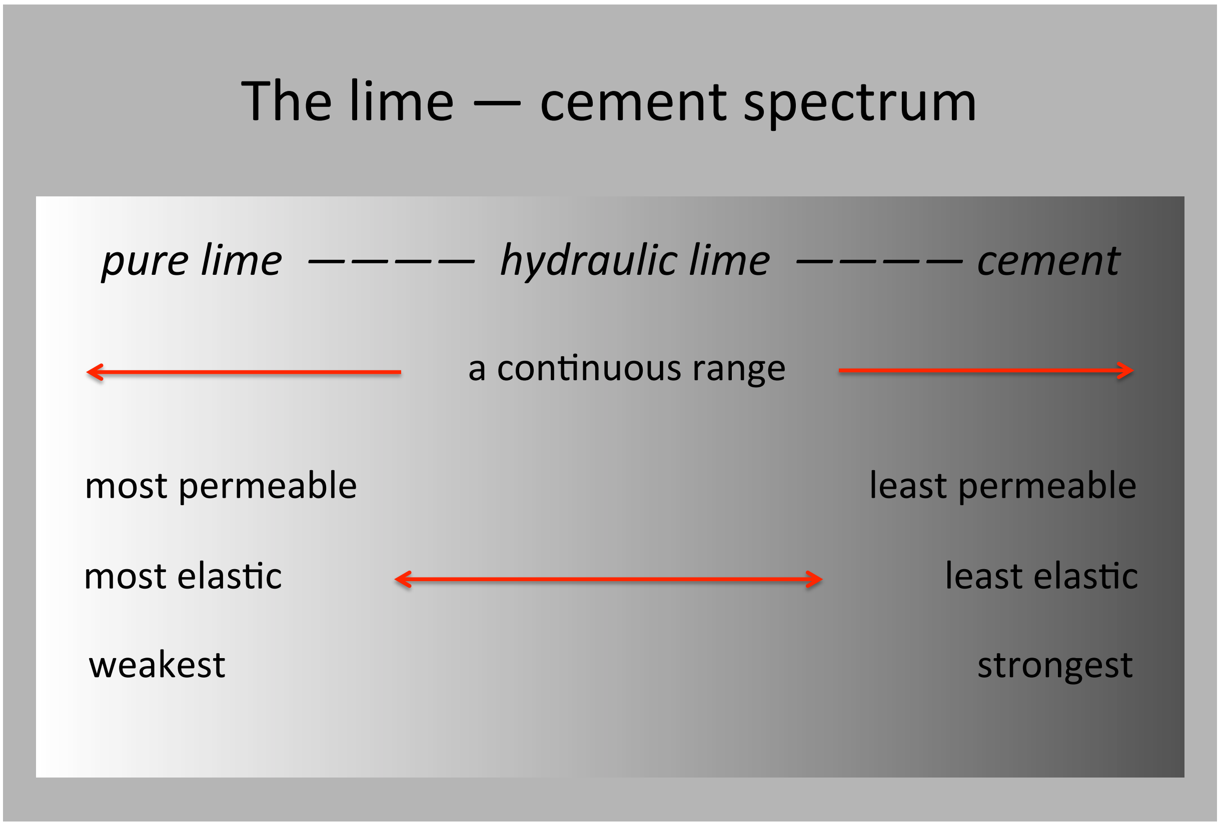


Figure 2 The lime–cement spectrum, a continuous range from pure lime through a series of hydraulic limes to cements (See Brocklebank, 2012).

## 7. Natural hydraulic limes

Natural hydraulic limes (NHLs) are made by burning a single raw material, an impure limestone, that naturally contains the right proportions of silica or clay to produce a binder with hydraulic properties, i.e. one that will react with water as part of its hardening process. In contrast, pure (non-hydraulic) limes harden by reacting with carbon dioxide from the air. While we can think of hydraulic limes as a cross between pure lime and cement, a natural hydraulic lime will be a much better binder for our purposes than one made by mixing lime and cement together as we do when we make a composition mortar. For the same compressive strength, a mortar made from a natural hydraulic lime will have equal or greater flexural strength, greater elasticity, much greater permeability, much lower salt content, and better thermal expansion compatibility with stone and brick masonry units.

Traditionally, hydraulic limes were classified into three grades: feebly, moderately and eminently hydraulic, for limes of increasing rate of hardening. Contemporary classification is based on measurement of compressive strength and these are set out in European Norm (standard) EN 459. Importantly, the three modern grades are not direct equivalents to the traditional ones (Brocklebank, 2012). Figure 3 shows the relationship between the gradings. That the lowest modern grade (NHL 2) is roughly equivalent to the moderately hydraulic limes of the late nineteenth century is an important understanding.

Classification of natural hydraulic limes

| Traditional classification | Strength | EN 459 classification |
|---|---|---|
| Natural cements | | NHL 5 |
| Eminently (strongly) hydraulic | | NHL 3.5 |
| Moderately hydraulic | | NHL 2 |
| Feebly (slightly) hydraulic | | * |
| Non-hydraulic (pure) lime | | CL 90 |

Modern hydraulic limes are stronger and out of step with the traditional classification

* An NHL 1 category has been proposed to equate with slightly hydraulic lime

Figure 3 Classification of natural hydraulic limes. The three grades of the modern EN 459 classification are not directly comparable to those of the traditional classification.

## 8. Pozzolanic materials

The use of pozzolanic materials in combination with pure limes is an alternative way of making a binder that, when hardened, is similar to a natural hydraulic lime. Pozzolans are materials that have no binding power of their own, but when combined with pure lime make a portion of it hydraulic. All pozzolanic materials contain finely-divided reactive silica. They may be natural materials, such as volcanic ash from Pozzuoli near Naples in Italy (hence the name, pozzolan); or deliberately manufactured materials, such as metakaolin; or by-products of other processes, such as fly ash from coal-fired power stations, and ground granulated blast-furnace slag (GGBFS) from iron blast-furnaces. Pozzolanic materials are widely used in blended cements and are key targets of research into cements and concretes that have smaller carbon footprints than current materials.

## 9. Portland cement

As well as having a large carbon footprint, Portland cement is no longer ideal for masonry, particularly the more porous materials that we find in historic buildings. Portland cement is too strong, too brittle, too impermeable, too thermally expansive and too high in soluble salts to be a suitable material for use in the repair of porous masonry. A key understanding is the change in the properties of Portland cement over time; for example, its compressive strength has increased by a factor of ten, from 6 MPa to 60 MPa since 1840 (Figure 4). This means that we cannot reproduce an 1880s specification for say, a 1:3 cement and sand mix, and get the same results. Instead, we may need to use alternative materials including NHLs and lime and pozzolan mixes.

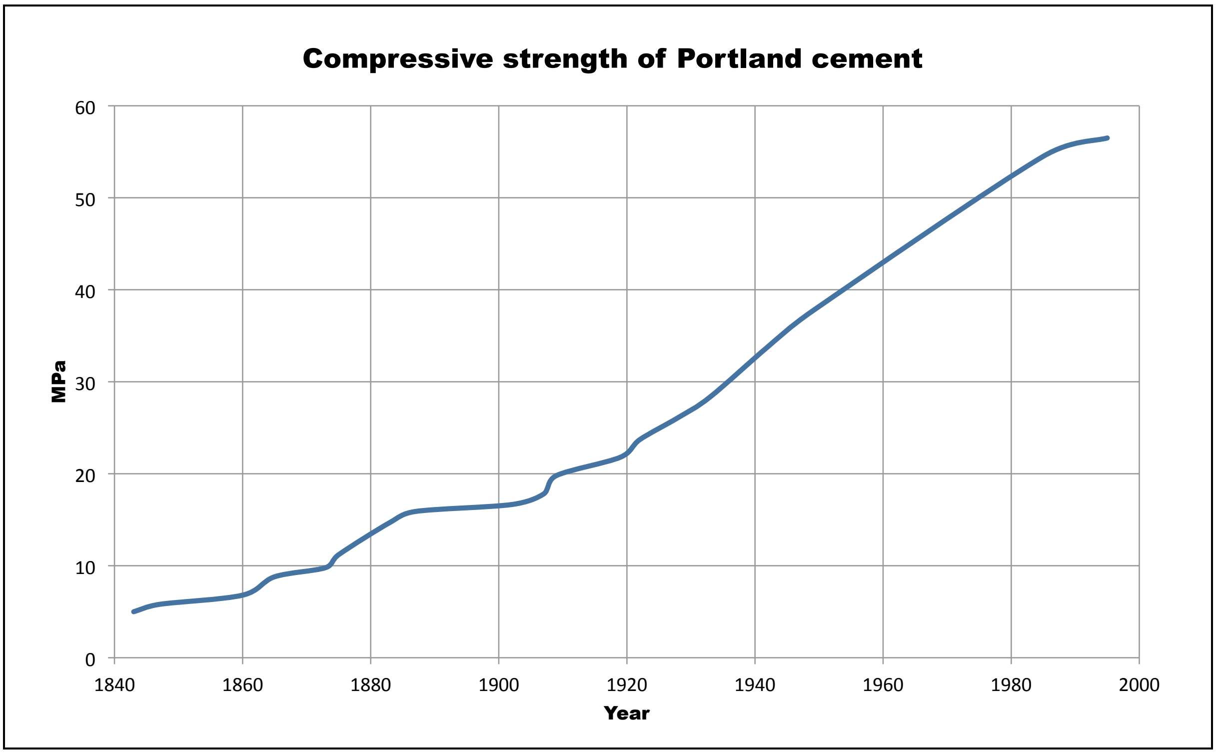


Figure 4 Progressive increase in the compressive strength of Portland cement from the 1840s (after Livesey, 2003).

## 10. Changes in availability of materials

NHLs and pozzolans are now reasonably readily available and so we no longer need to use any cement in the repair of buildings made with lime mortars. The change in availability of these materials is well documented in the 2003 second edition of John Ashurst's seminal work, *Mortars, plasters and renders in conservation*. Unfortunately, too many practitioners in Australia are still specifying and using cement and lime composition mortars, such as those recommended in the 1983 edition of this work.

## 11. The importance of compatibility

Irrespective of whether we are building anew or doing repairs, the mortars we use must be compatible with the masonry units. Repair of traditional porous masonry requires mortars that are: weaker than the units, to prevent cracking through them; more permeable, to promote drying through the joints; of negligible salt content; and of similar thermal expansion coefficient, so that stresses are not transferred to the masonry units.

**12. Don’t use too high a grade of binder**

One of the risks of the adoption of natural hydraulic limes is that it will lead to the uninformed selection of the middle grade (NHL 3.5) ‘because it’s not too strong and not too weak’. For most projects involving conservation of lime-mortared buildings in Australia, NHL 3.5 will be too strong and too impermeable. Even NHL 2 will be too strong in many circumstances.

Similar concerns apply to the use pozzolans. The most highly-reactive ones, such as metakaolin and silica fume, are good for concrete but not for mortars as they will lead to blocking of pores. Even fly ash and GGBFS are quite reactive, and should be used sparingly; generally at only 5–10% of the lime content when used with weak and porous masonry. Less reactive pozzolans, such as trass and pozzuolana, can be used at higher proportions (10–20%) with similar masonry.

**13. Don’t overlook pure limes**

In the enthusiasm for NHLs and pozzolans, there is a risk that pure limes will be overlooked, yet this is what most Australian lime mortars were made of. Many would have had some degree of hydraulicity, but in most cases it would have been too small to produce any noticeable effect. In the right circumstances and with good practice, pure limes can make durable mortars. Pure lime mortars can be made from lime putty or from quicklime that is slaked with the sand in the traditional process known as sand-slaking. This method is not commonly used in Australia, but should be for important projects, as it produces better mortars that more closely resemble the originals. For less important projects lime putty mortars will be quite adequate, provided they are made with good sands.

### 14. Maturing putties and mixes

Lime putties should be matured for a minimum of four months before use in repointing. During this time the lime particles become smaller and their shape changes to become plate-like, both factors making them more workable and more reactive. During maturation the putty settles and becomes denser; only the denser material (minimum 1.35 kg/l) should be used. Provided they are non-hydraulic, mortar mixes can also be matured and doing so will make them stronger and more workable than if the lime putty is matured separately. Sand-slaked quicklime mixes will also benefit from maturing.

### 15. Mortar sands

Much consideration is given to the binder in mortars; the same level of effort should be put into selecting suitable sands and other components of the aggregate. Key properties of sands are that they should be: free of impurities such as salt, soil and organic matter; angular (i.e. ‘sharp’) rather than rounded; washed to remove clay and fine silt; and well-graded, meaning that they should have a wide range of particle sizes. There are no Australian standards for mortar sands and so the forthcoming technical guide sets out the key criteria.

### 16. Size-grading

Size-grading (or particle size distribution) is the most important property of mortar sands. Well-graded sands have a wide range of particle sizes, from coarse through medium, fine and very fine grain sizes, whereas poorly-graded (uniform) sands have a narrow range of sizes, making their mixes ‘hungry’ and difficult to work unless considerably more binder is added.

Figure 5 shows cumulative plots of a well-graded and a poorly-graded sand. Developing familiarity with the use of these size-grading plots will improve sand selection.

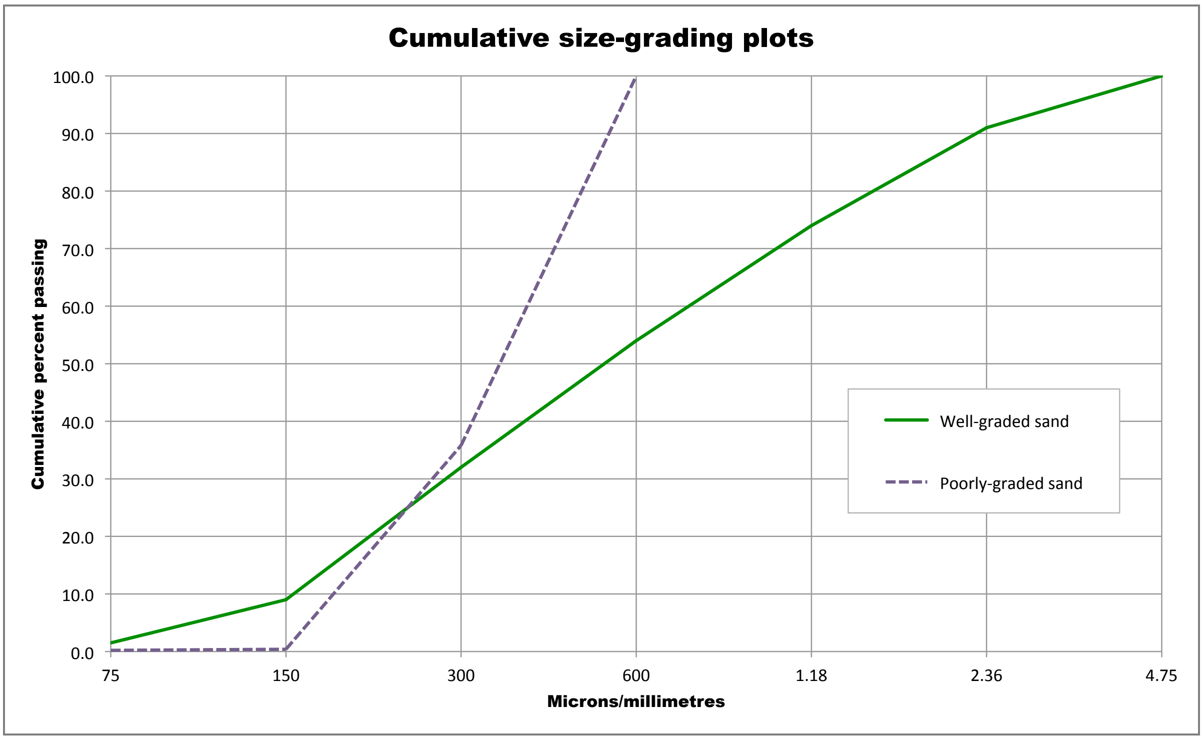


Figure 5 Cumulative size-grading plots produced by screening sands through a series of standard sieves. That shown by the dashed line is poorly-graded (i.e. relatively uniform) as 64% lies in one interval and 35% in another. In contrast, the well-graded sand has 15–25% in each of four main intervals.

## 17. Adding fillers

It is common for more-uniform sands to lack very-fine sand-size particles (75–150 µm), yet having some is important for workability (see, for example, the poorly-graded sand in Figure 5). Instead of adding more binder to make the mix workable, a small proportion of ground limestone (or marble) filler can usefully be added. As well as contributing workability, the filler provides limestone (carbonate) chemistry which improves hardening of the lime. Using such fillers eliminates the need for the all-too-common bad practice of adding clay or loam to make uniform sands workable.

### 18. Clays are bad

Clays are very fine, platy particles which have been shown to severely reduce bond strength in masonry, and also to reduce pore sizes with implications for reduced breathing characteristics. Their very high surface areas means they will not be fully-coated with binder, resulting in weak mixes. Despite this, clay-rich sands are widely used in contemporary bricklaying, because they make mixes ‘fatty’ or ‘buttery’. Sands for lime mortars should be washed free of clay.

### 19. Porous particulates

Replacing about a half part of the sand (in a mix of two or three parts) with crushed porous limestone or porous brick can be beneficial, particularly where deliberately sacrificial mixes are needed to control high salt contents and/or to promote good drying of a wall. Porous particles retain mixing water, which aids the hardening or curing of the lime; and also contribute greater porosity to the hardened mortar, improving its breathing characteristics and resistance to salt crystallisation. As with fillers, the use of crushed limestone particles adds similar chemistry to the mix and improves the hardening of lime binders.

### 20. Mixing mortars

Mixing lime mortars requires considerable force to push the lime and sand together, so as to overcome minute water layers that are tightly bound to damp sand (dry sands are much preferred). Conventional rotary cement mixers do not make good lime mortars as they turn a mix over, rather than forcing it together. They can be improved by adding heavy stones or steel balls to provide the impact, but purpose-designed mixers such as forced-action (screed) mixers are much better. Also suitable are roller pan mixers, heavy-duty hand-held helical-bladed mixers, as well as manual methods such as pounding the mix in a heavy bucket with end of a mattock handle, or using a mason's hoe (larry) in a trough. Prolonged mixing improves workability and reduces the amount of water required, an important objective.

As noted earlier non-hydraulic mortars can be pre-mixed, matured in sealed pails and then turned out and knocked up to regain their workability. No water should be added. If pozzolans, pigments or admixtures are to be included, they should be added (during knocking up) in the form of a slurry made from the liquid material drained from lime putty.

**21. Raking and cutting out joints**

Joints should be raked out to 2.5 times the joint width with the ends left square. Clean surfaces on both sides are critical to achieving a good bond with the masonry units. Lime mortars can be cut out with modern oscillating blade tools which, if used carefully, produce good results. Hard cement repointing is more difficult to deal with. It should first be cut down the centre of the joint with a small diameter disc cutter, which must cut through the full depth of the cement repointing. Sharp tungsten-tipped masons chisels are then used to chisel the mortar, small sections at a time, away from the brick or stone on either side, working always towards the free space created by the cut. It's slow painstaking work, but it can be quite successful at removing hard repointing, while minimising damage to bricks or stones.

**22. Pre-wetting**

When walls were first built they were saturated with water which played an important role in the hardening of lime mortars. When we come to repoint old walls they are generally much drier and so we have to add water (and lots of it) to control the suction of the substrate and prevent premature drying of the new mortar, which would leave it weak and imperfectly cured. Old porous walls should be thoroughly hosed the day before repointing, and then several times on the day, the last just before applying the new mortar. Surfaces should be thoroughly damp, but not glistening with water.

### 23. Repointing — use the correct tools

A relatively stiff, dryish mortar is much better than one that is too wet; the latter cannot be compacted tightly into the joint, which is a critical aspect of good repointing. To make this possible it is essential to have the correct tools: caulking or finger trowels that fit neatly into the joints (Figure 6). As joints vary, several trowels with different blade widths are needed. This stage of repointing cannot be undertaken with a triangular pointing trowel; mortar will either be pushed onto the face of the masonry or insufficiently compacted into the joint. With care, the correct tools, and a stiff mix, joints can be filled without smearing mortar onto the face of the surrounding masonry. The joints should be slightly overfilled, and as soon as they will take it, sprayed with a fine water spray to keep them damp.

Figure 6 Placing mortar with trowels that fit within the joints means that no mortar need be smeared on the face of the brickwork, and no acid clean-up is required.

**24. Finishing joints — tamping**

As the mortar begins to stiffen, any ‘crumbs’ can be trimmed off with a pointing trowel or plasterer’s small tool and the joint profile finished to match the original. Where the original cannot be found anywhere on the building, a plain flush-finish should be used. It is important not to overwork the joints by too much drawing of the trowel across the face, for this brings too much lime to the surface leading to a skin or laitance, which inhibits curing and reduces the breathing capacity of the mortar. Where it is appropriate to produce a weathered appearance, this can achieved by tamping the surface with a stiff bristle brush. The action is not one of brushing, but a direct end-on tamping using considerable force. Tamping, which can be light or heavy to suit the required appearance, removes any laitance, compacts the mortar, preventing any shrinkage cracking, exposes the colour and texture of the sand grains, and increases the effective surface area of the joint, thus improving its breathing capacity. Joints should be sprayed with water as soon as tamping is complete.

## 25. Protection and curing

Good curing and protection are essential aspects of making durable lime mortars. Although the hardening of pure lime is a reaction with carbon dioxide from the air, it will only do this in the presence of water. In fact the lime dissolves into the water and then precipitates out as calcium carbonate. If there is no water, there is no hardening, and this why premature drying must be avoided at all costs. New lime mortars (whether hydraulic or non-hydraulic) need protection from rain, frost, sun and particularly wind (to avoid rapid drying) for a minimum of four weeks after placement.

Protection may be in the form of tightly enclosed scaffolds with misting systems to control humidity, or, for smaller jobs, wrapping or draping the new work with well-wetted removalist's blankets or carpet. Hessian sheeting has commonly been specified for this purpose, but is too thin and dries out too rapidly.

The curing procedure is one of alternate weeks of wetting and drying. For the first week the new work should be kept quite damp (but not running with water) with the relative humidity (RH) kept over 90%. This may mean continuous light spraying by hand or from a misting system. The second week is a period of 'damp drying' in which the RH should be maintained in the range 60–70%. It is common in Australia for the humidity to drop well below this range, particularly in the afternoons, and so light sprays may be required to maintain humidity and to add some water to the wall at a time when it is 'breathing in'. The third week is a period of wetting, in which the walls are thoroughly sprayed at least three times daily, while maintaining the background RH in the range 60–70%. The fourth week is back to 'damp drying' with light afternoon sprays if needed. At the end of the works the walls should be thoroughly wetted down as the scaffolding is being removed. Exposed sites in dry weather may warrant an additional two weeks of protected curing.

Many contractors will be unfamiliar with these curing requirements and may underestimate the costs involved. To overcome this, protection and curing should be a separate cost item on the form of tender, not only so that contractors will be forced to take account of it, but also so that they will know that they will be paid for the work.

## 26. Specifying repointing

Not may years ago specifications for repointing were often a one line: 'Repoint the mortar joints in a lime mortar to match the existing'. Nowadays one or two pages will be required to adequately spell out the materials and works required. Specifications should cover:

- materials — grade and qualities of binders, aggregates, admixtures, fillers;
- mixes and batching — mix proportions and batching procedures;
- mixing and knocking up — mixing equipment, maturing mixes, knocking up;
- raking and cutting out joints — depths of raking, tools and methods, flushing out;
- pre-wetting to control suction — methods, frequency and timing;
- repointing — tools to be used, building up in layers if dealing with deep voids;
- finishing the joints — profile to be reproduced, tamping if required;
- curing and protection — nature of protection, curing regime;
- site practices — dry storage of materials, logging of admixtures;
- samples, trials and reference panels — for approval and subsequent matching;
- compliance — tests to assess compliance, replacement of non-compliant work;
- training — of works crew and requirements for maintaining trained workers on site.

## 27. Conclusion

The last thirty years have seen extensive international research and field trials on most aspects of traditional mortars, including work on lime putties, sand-slaked quicklime mixes, natural hydraulic limes and pozzolans. There is still much to learn about traditional lime practice and about the properties of the materials available to us. There is even more to be done passing it on to those who will use it. The need for training extends across the industry, from specifiers to estimators, project managers, builders, contractors and tradespeople. All of us, specifiers and doers included, must drive changes to practice if our masonry heritage is to be well-conserved.

## 28. References


Ashurst, J. 2003. *Mortars, plasters and renders in conservation*. 2nd edn, Ecclesiastical Architects' and Surveyors' Association, London.

Brocklebank, I. (ed) 2012. *Building limes in conservation*. Donhead, Shaftesbury, UK.

English Heritage. 2011. *Practical building conservation: mortars, renders and plasters*. Ashgate Publishing, Farnham, UK.

EN 459:2015. *Building lime — Part 1: Definitions, specifications and conformity criteria; Part 2: Test methods; Part 3: Conformity evaluation*.

Getty Conservation Institute. 2009. *Lime mortars and plasters*. Research project. (http://www.getty.edu/conservation/science/mortars/)

Lewis, M.B. n.d. *Australian building: a cultural investigation*. Section 7.04 Portland cement. (http://www.mileslewis.net/australian-building/ accessed 26 May 2008)

Livesey, P. 2003. "Portland cement strengths through the ages". *Journal of the Building Limes Forum,* Volume 10, 76-79.

Válek, J. Groot, C, & Hughes, J.J. (eds) 2012. *Historic mortars: characterisation, assessment and repair*. RILEM Bookseries 7, Springer, Dordrecht.

Young, D.A. (in prep) *Mortars: materials, mixes and methods: a guide to repointing mortar joints in older buildings*. Heritage Councils of New South Wales, Queensland, South Australia, Tasmania, Western Australia and Victoria, Melbourne.