Heritage Building Conservation Technical Advice Sheet 4

Limestone walls need lime mortars

Relatively soft and porous materials like Fremantle limestone need mortars that are also soft and porous — lime mortars!

This technical advice sheet follows on from **Sheet 3 *Looking after limestone walls*** which should be read first. This sheet explains the traditional use of lime in Fremantle buildings, why lime is preferred over cement, the range of available limes, and those that should be used in repairs to limestone walls.

What is lime mortar?

Mortars and plasters consist of a binder, such as lime, and an aggregate, such as sand, that are mixed together with water to form a plastic (workable) material, which then hardens as it dries out in a wall. The lime binders that built Fremantle's older buildings were made by burning the local limestone in kilns to produce quicklime. The lumps of quicklime were then mixed with sand, and water was added to slake the lime to a fine powder, a process that gave off a lot of heat. Once slaked the mix was sieved if needed to remove any large lumps, wet again and mixed to the desired consistency and then left for a period of days to mature before use as mortar for laying stones and bricks. The same mortar was used for the base coats of internal plasters and external renders.

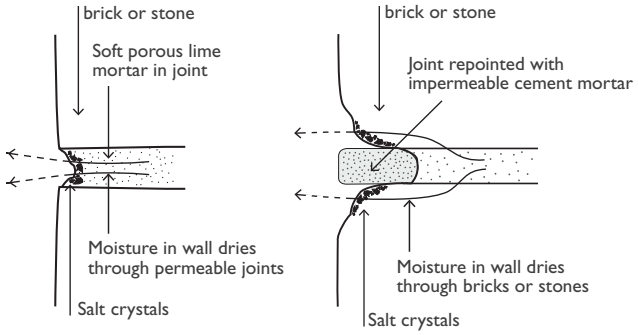
Traditional lime mortars are generally off white in colour though they may be light grey because of ash and also contain pieces of charcoal as residue from the wood-fired kilns. Small lumps of underburnt limestone are common in old mortars and are evidence that the quicklime was slaked with the sand (known as sand-slaking) in the way described.

What limes are available?

Pure limes — Today most lime is used in the dry powder form known as hydrated lime (or builders lime) that is widely available in hardware stores. Lime is also available as a directly slaked wet putty (lime putty). There are local producers of lime putty which is sealed in heavy duty plastic bags. Because of its finer particle size and greater workability, lime putty is often specified for conservation and repair work.

Hydraulic limes — Natural Hydraulic Limes, which are imported from Europe, can be thought of as a cross between pure limes (like lime putty and hydrated lime) on the one hand, and cements on the other; they make stronger binders than pure lime, but with significant permeability and elasticity advantages over cement. Natural Hydraulic Limes (NHLs) are widely used in Europe in new build and in the repair of older buildings. Formulated Limes (FLs), which are also imported from Europe, are pre-packaged mixes of lime and pozzolans.

Pozzolans — Pozzolans are fine-grained, glassy materials that when added to pure lime make a portion of it hydraulic, producing similar binders to natural hydraulic limes. It's possible to make your own lime and pozzolan mixes by adding small proportions of waste materials like fly ash and ground granulated blast-furnace slag (GGBFS) (which are both pozzolanic) to lime putty or hydrated lime.



Behaviour of mortar joints in limestone: left diagram shows a traditional permeable lime mortar, and the right diagram shows after repointing with an impermeable cement mortar. Salts crystallise where the moisture evaporates from the wall, decaying the lime mortar at left and the stones at right. It's much cheaper and easier to replace mortar than it is to replace stones. Repointing mortars should always be more permeable than the stones (or bricks).

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Which lime should I use?

Most of Fremantle's older buildings will have been constructed with relatively pure limes, and so it is appropriate to use pure limes like lime putty in repairs such as repointing of mortar joints (repointing is the process of replacing the outer part of a mortar joint with new mortar). Pure limes should be used whenever there are serious damp problems and salts that need to be managed (see Technical Advice Sheet 5 *Dealing with dampness in old walls*). This is because pure limes provide maximum permeability (breathability) which is so important to successfully dealing with damp issues. It may be appropriate to add a small percentage (5%) of pozzolan, such as fly ash or ground granulated blast-furnace slag (GGBFS) to pure limes for repointing more exposed walls with damp problems.

For more exposed walls generally, repointing mortars might be made of lime putty with 5–10% pozzolan, or of the lower grades of natural hydraulic lime (NHL 1 or NHL 2). NHL 2 mortars can be made more permeable and more workable by adding 10% of lime putty. The higher grades of natural hydraulic lime (NHL 3.5 and NHL 5) are too strong and not appropriate for repointing the mortar joints of most older buildings in Fremantle. Equally inappropriate, are limes with too much pozzolan, which is too reactive, as these will tend to block pores and so restrict the all-important breathing that enables traditional walls to work in the way they were intended (see Advice Sheet 3 *Looking after limestone walls*).

Why not cement?

As well as the conservation principle of matching like with like, there are good technical reasons for not using cement. Portland cement is very strong and ideal for making reinforced concrete, but it is not suitable for repairing old walls that were built with porous materials such as old bricks, limestone and lime mortar. This is because Portland cement is too strong, too brittle, too thermally expansive, relatively impermeable and it contains salts. While each of these factors are reasons for not using cement, impermeability is a key one. By blocking pores in the mortar and so forcing moisture in a wall to dry (i.e. to breathe) through the stones, salts will be concentrated in the stones leading to their early decay.

This effect can be seen in many walls that have been repaired with the best of intentions, but using the wrong materials. The new cement mortar stands proud while the stones erode (or fret) back from the surface leaving deep cavities. Eventually the stones will need replacement, which will be much more costly than replacing the mortar.

Two examples of the decay caused by impermeable cement mortar, which forces the limestone walls to dry through the stones. Salts accumulate in the stones which erode away, leaving the mortar standing proud. It's much cheaper and easier to replace mortar (repointing) than it is to replace stone.

One response might be to consider a composition mortar, such as a 1:2:9 mix of cement, lime and sand, thereby reducing the cement content and gaining some of the workability advantages of lime. But even mixes such as this are still too impermeable for use in old walls. Where there's a need for greater strength than pure limes can provide, then the addition of small percentages of pozzolans to pure lime, or the use of the lower grades of natural hydraulic lime are the appropriate response. However, it's important to be aware that strength is not often an issue when it comes to repointing thick stone walls. More important are good permeability, elasticity and compatible thermal expansion properties.

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Which sand?

Early mortars were made of fine-grained sands from the site or from nearby coastal areas with some variation in colours including white, pale cream, light grey and pale pink. Matching the colour and texture of the original mortar is one aim of good repair practice. Equally important is use of a sand that will work well with the lime binder. Some bricklaying sands, intended for use with cement, contain too much clay, which blocks pores and reduces bond strength. Clay-rich sands are not suitable for use with lime binders. Sands that are suitable will be washed free of clay, salts and any organic matter; have angular surface textures that feel 'sharp' when rubbed in the hand; and be well-graded, meaning that they will contain a range of grain sizes, including coarse, medium and fine, that 'fit' together in a mix.

Washed concrete sands are often suitable materials, though they may need screening to remove the coarsest particles. Sometimes an otherwise good sand isn't quite the right colour, in which case blending it with another sand can be a way of achieving an acceptable outcome. It is the finer particles in a sand that provide much of the colour. Each building should be carefully investigated to establish the colour and texture of the original mortar. Sample 'biscuits' made with different blends should be used to select the right repair mix.

What mix?

The standard mix of 1:3, one part lime to three parts sand, has been known for millennia. However, there are several reasons why this mix might be unsatisfactory and this Advice Sheet recommends that 1:2½ be the starting point for most mixes. This is partly because many sands are not as well-graded as we would like, and also because of the nature of the locally-available lime putties and hydrated limes. Because they contain a proportion of inert material, 1:2½ is also an appropriate mix for natural hydraulic limes.

Mixes will need to be made richer as the grain size of the sand becomes progressively finer, so instead of 1:2½, the mix may need to be 1:2, 1:1½, or even 1:1 for very fine sands.

Any pozzolans are added as a percentage of the lime content (not of the overall mix) so that a 1:2½ mix with 5% pozzolan will be one part lime putty, two and a half parts sand, and one-twentieth part of pozzolan, such as fly ash or GGBFS.

How to use?

One of the most common tasks in repairing limestone walls is repointing of their mortar joints and this work is explained in Technical Advice Sheet 6 *Repointing lime mortar joints*. Whether repointing joints or re-laying stones or bricks, the successful use of lime mortars involves getting some key things right. These include:

- drain liquids from lime putty and use only stiff putty that's like feta cheese, not ricotta;
- do not add water to lime putty, there's already enough, even in a well-drained putty;
- forced action (screed) mixers make better mortars than conventional rotary mixers;
- thoroughly pre-wet the existing masonry and new stones to control their suction;
- use relatively stiff dryish mixes for repointing;
- use tools that fit within the joints (caulking or finger trowels) for repointing;
- protect (cover) the new work from wind, rain and sun; and
- thoroughly cure it by spraying and maintaining damp conditions around the new work.

See further reading for more details.

Important notes

Application – This technical advice sheet is about repairs to existing buildings, which may have heritage value. It is not about new buildings for which the *National Construction Code (Building Code of Australia)* is the appropriate reference.

Safety – Limes (and cement) are very caustic materials. They can cause irritation and chemical burns to the skin, and serious eye damage (potentially blindness) if not treated quickly. Always wear goggles and gloves when working with limes, have an eyewash bottle to hand, and seek urgent medical attention should any lime be inhaled or lodge in the eyes.

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Further reading

Young, David. 2015. 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.

Other technical advice sheets in this series

City of Fremantle Technical Advice Sheet 1
Introduction to good conservation practice.

City of Fremantle Technical Advice Sheet 2
Checklist for inspections.

City of Fremantle Technical Advice Sheet 3
Looking after limestone walls.

Coming in 2016

City of Fremantle Technical Advice Sheet 5
Dealing with dampness in old walls.

City of Fremantle Technical Advice Sheet 6
Repointing lime mortar joints.

These sheets can be downloaded from...

www.fremantle.wa.gov.au/cityservices/planning/conservationandcareofheritagebuilding

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