ENGINEERS AUSTRALIA	PRACTICE NOTE NO: M1				Version: R4	April	2026
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	General	Buildings and structures	Museum artefact	Operating object	Material specific	Intangible heritage	Sustainability
	Mortars for Historical Masonry -Part 1						

Many of the concepts in this document are best illustrated by graphics. These graphics are included for reference in Mortars for Historical Masonry -Part 2

1. Introduction and Background

For thousands of years, most masonry was built using mortars containing lime, except for drystone work. Historically, lime mortars were used for bedding the masonry units and, in many cases, giving the masonry substantial flexural properties.

Mortars also paid a significant part in controlling moisture in the masonry, especially in its ability to "breathe" and shed moisture externally in solid masonry construction.

"Cements" started to be developed in the late 18th century and some of their advantages led to them becoming the major or sole cementitious component in most mortars in the late 20th century. The disadvantages of using Ordinary Portland cement (OPC) or its derivatives in historical masonry have become increasingly obvious in recent decades, as historical masonry has been badly damaged or destroyed by its use.

Historical lime mortars, and successful modern lime mortars, have been successful because they had some hydraulic properties, that is they use a chemical reaction with water, forming minerals which give strength and durability. Many historical mortars were "contaminated" with minerals which gave hydraulic properties, but the Romans discovered how to give hydraulic properties deliberately by added volcanic ash from Pozzuoli, hence our term "pozzolan".

2. Purpose

This Practice note explains the elements of lime mortar design, mixing and use. It attempts to help practitioners understand the basic science and the range of practical problems encountered.

3. Scope and Applicability

Whilst this document has been principally written for use in heritage engineering practice, most of its principles are applicable to new construction, even using when using OPC mortars.

4. Content and Guidance

Mortar Components

- simply, aggregate (sand) + binder (+ additives sometimes);
- ordinary Portland cement should not be used in any proportions in normal historical masonry (banned in some European countries); some use permitted for below-ground etc.;
- mixing best in a "mortar mill" or by hand.

Sand

- sand used by most of the industry in Australia is NOT satisfactory.
- grading is important to achieve workability and clay fines take up space meant for binder, weakening masonry.
- sand grading is not in current AS 3700 (unfortunately) so BS 1200 should be followed.
- some historical specifications called for maximum sand particle size to be 1⁄3 to 1⁄2 joint thickness; (see grading in Mortars for Historical Masonry -Part 2).

Binder, General

- historically, a form of lime, but (the clay in) loam sometimes found for buildings before 1850 with little or no lime.
- "hydraulic" lime (cures partly by hydration) is traditional, giving best end result, but "air" lime, which relies purely on carbonation, often found on earliest buildings where lime came from a pure source.
- the essential difference between Portland cement, and its derivatives, and hydraulic lime is that Portland cement relies on hydration of tricalcium silicates and aluminates and hydraulic lime on dicalcium silicates and aluminates.

Lime

In Australia, *lime* is usually calcium lime derived from calcium carbonate (CaCO3) from limestone.

It is "burnt" to form calcium oxide or "quicklime" (CaO) which is then hydrated to become Ca(OH)2. Dolomitic lime from limestone with high magnesium proportion is rare in Australia but common in USA.

An important characteristic of lime is its **reactivity**, that is how quickly it will react with water. Lime that is lightly burned (underburnt) reacts more rapidly with water; lime that is overburnt (hard lime), reacts more slowly.

The temperature of burning therefore has a marked effect on reactivity and quality: 850°C to 1100°C is optimum.

Much of the industry uses old horizontal cement kilns with poor temperature control along the length, giving hot zones and "hard" burning. **Vertical kilns designed for lime are best.** Vertical wood- fired kilns have the advantage of producing some hydraulic properties from the wood ash. The "lime cycle" is found in many publications. As usually seen, it implies that CO2 acts without water being present: this is not the case. If mortar is not wet cured, it desiccates rather than cures. (refer graphic in Mortars for Historical Masonry -Part 2).

The current Australian standard for building limes, *AS 1672.1–1997 Part 1: Limes for building,* is referenced poorly in Australian Standard *AS 3700-2018 Masonry Structures*. AS 1672.1 recognises reactivity but AS 3700 ignores this property and assumes that any lime from the standard can be used in volume batching with no adjustments for available lime.

For a selection of Australian limes where the data could be found, available lime can be summarised:

Type	Prop^{n} CaO by Weight	Density (kg/m^3)		1m^3 – wt of CaO	
		Low	High	Low	High
Quicklime	1	950	1100	950	1100
Lime Putty	0.61	1220	1320	744	805
Hydrated	0.76	400	600	304	456

This means that even if powdered hydrated lime were reactive, three times as much by volume would be required to replace quicklime, the basis of the traditional 1:3 mix.

Lime is marketed as quicklime (CaO) and hydrated lime (CaOH2) as powder or putty. **Agricultural lime is powdered limestone or chalk and has no role in mortar.**

Most bagged powdered hydrated lime is unsuitable for mortar, except as a filler (although it is better than fire clay) because it is frequently burnt at too high a temperature in old cement kilns and has little or no reactivity.

The complex chemistries of lime and cements, plotted against burning temperature are included in a graphic in Mortars for Historical Masonry -Part 2.

Cement

The term "cement" in this context refers to Portland cement and its many derivatives. Few are suitable for use with historical masonry, except some for early 20th century "compo" mortar, and even then not modern OPC. Referring to the term "hydraulic lime", OPC and its derivates are described by Standards as "hydraulic cement".

Often the architectural specification will specify "white" cement (in which Iron and manganese are removed during production) for historical masonry, based simply on appearance. White cement is as problematic as OPC.

Another problem found frequently in conservation is where the original specification used Portland cement, the difficulty being that Portland cement has changed markedly over the past 150+ years. (refer graphic in Mortars for Historical Masonry -Part 2)

The term "cement" in this context refers to Portland cement and its many derivatives. Few are suitable for use with historical masonry, except some for early 20th century "compo" mortar, and then not modern OPC. The "compo" mortar mix, also known as composition mortar, was a blend of lime and cement used in the early 20th century. This mix was created by combining lime putty and Portland cement in equal parts, which was a significant innovation in masonry construction. The composition of the mortar mix allowed for a quicker setting time and improved workability, making it suitable for various masonry applications.

A diagram showing the properties of various limes and cements, from the original Vicat classification, those to the modern European standards which are imported into Australia (NHLs or natural hydraulic limes) to historical and modern cements. NHL2 is generally the most suited to historical masonry as the others cure to too high a strength.

Breathability

Historical solid masonry relies on breathability for control of moisture, with evaporating moisture being expelled to the exterior. If this is prevented, either by impermeable mortar or paint layers, moisture will preferentially be evaporated internally.

Recent research referenced below (*) in the UK has elucidated the mechanism and materials needed for effectively expelling wall moisture externally. Decreasing pore size from the wall mass to the external surface promotes capillary action moving outwards and this has been shown to be best accomplished using lime plaster (or "harling") coated with limewash.

Best Practice

European and UK practice is now, increasingly, using "hot lime" mixes in which quicklime is mixed with the sand, and possibly some pozzolan, and it is slaked in the mix. This can be suitable to use immediately, depending on amount of pozzolan, but is often "knocked up" and used the following day. One advantage of hot mixing is that lime attacks silica at >70°C, giving the mix some hydraulic properties. Another advantage is that so much sand reduces the risks from lime slaking. WHS requirements for the use of quicklime cause some problems in Australia, but these can be overcome.

5. References

In recent years two UK-based organisations, in particular, have been predominant in masonry and lime mortar research:

The Building Limes Forum, of which there is an Australian Chapter — https://www.buildinglimesforum.org.uk; the BLF has an annual gathering, usually in the UK

The Scottish Lime Centre Trust — https://www.scotlime.org, which provides training, analysis services and has an extensive publication list.

Standards

AS 1672.1–1997 *Part 1: Limes for building*

EN 459-1:2015, *Building lime - Part 1: Definitions, specifications and conformity criteria*

AS 3700 -2018 *Masonry structures* (with extreme caution for historical masonry)

Research (*)

Wiggins, David (2020), How traditional lime coatings work, The Journal of the Building Limes Forum, Volume 27.

Guides

Mortars: materials, mixes and methods, A guide to repointing mortar joints in older buildings by David Young; published jointly by Heritage Council of Victoria, Heritage Council of New South Wales, Heritage South Australia, Heritage Council of Western Australia, Tasmanian Heritage Council and Queensland Heritage Council, 2021.

'***Practical Building Conservation'* guides** by Historic England (formerly English Heritage). As most Australian practice came from the UK, they are quire relevant. In particular, the three volumes: ***Mortars, Plasters & Renders, Earth, Brick & Terracotta (2 volumes)***