ALISON HENRY

Hot-mixed mortars: the new lime revival

Appreciation of the limitations of lime putty mortars and concerns about the strength of natural hydraulic limes have triggered renewed interest in traditional mortars, and in hot mixing.

When non-hydraulic lime-putty mortars are used in exposed locations or, as here, for demanding applications such as on wall tops, failure due to frost damage is not uncommon.

Quicklime made in traditional kilns often contained under- or over-burned limestone which did not slake when the mortar was made, and remained in the mix as rounded whitish particles, often referred to as 'lime lumps'. Fragments of black fuel ash from the lime kiln sometimes found their way into the mortar too. These are clearly visible in many hot-mixed mortars. However, for very high-quality work, quicklime was 'BHP' – 'best hand-picked' – and did not contain lime lumps or ash.

The last five years or so have seen a revival in use of hot-mixed mortar. While many people have welcomed this as a way of making more authentic mortars for conservation, others are sceptical or even hostile to what they see as a new fad. Before exploring the pros and cons of hot-mixed mortars, it is worth reflecting on the past 40 years of lime use and how we have arrived at the current situation.

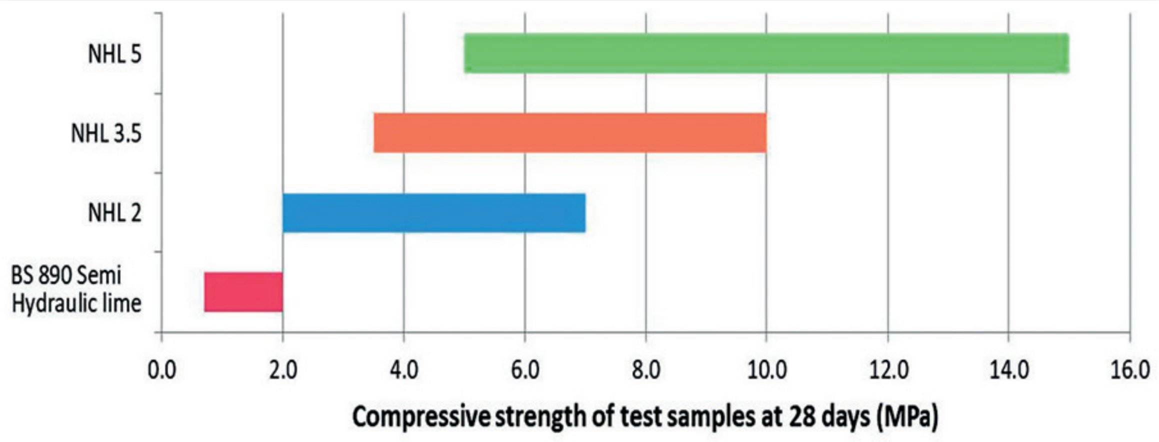
The lime revival

As the damage caused by hard, impervious cement mortars became apparent from the mid- 20th century, the revival in use of lime from the 1970s was naturally welcomed by conservation practitioners. Emerging practice borrowed from materials and methods used in various stonework conservation programmes, particularly the restoration of the west front at Wells Cathedral from 1974.

Here non-hydraulic lime putty, typically blended in a ratio of 1:3 with aggregates, was used to make sacrificial mortars for conservation of fragile limestone sculpture; pozzolans were added where additional strength was needed. Mortar design was based on practical experiment, and ignored historic source materials. While such mortars were eminently suitable for this specialist application, and proved durable for re-pointing and rendering in sheltered locations, there were some failures when they were used in more exposed locations.

During the 1990s attention began to shift towards hydraulic lime, which it was hoped would prove more durable. Hydraulic lime began to be imported from the continent and there was a brief renaissance of production in the UK. Mixes generally comprised 1 part powdered lime to 2 or 2½ parts aggregate.

These mortars were indeed faster-setting and more resistant to salt and frost damage than ones made with lime putty. However, by the early 21st century alarm bells were ringing in some quarters. Many practitioners were concerned that the new breeds of hydraulic limes (termed natural hydraulic limes [NHLs] under the



The hydraulic lime most widely used in the past for general building work was termed 'feebly hydraulic' in the 19th century, and later (in a British Standard of 1966) 'semi-hydraulic lime'. The maximum strength of semi-hydraulic lime equals the minimum strength of NHL2, and most NHLs are very much stronger than this. This demonstrates the disparity between lime binders commonly used in the past and those in widespread use today for much conservation work.

relevant standard) were much stronger than their historic counterparts, and were perhaps too strong for many conservation applications.

Comparison of the compressive strength of mortars made with NHLs with that of the limes most widely used historically (non-hydraulic and 'feebly hydraulic' lime) reveals clear differences, and suggests that concern about excessive strength of NHL mortars might be well-founded. Further concerns about long-term strength gain were raised by recent research commissioned by Historic England[1].

Furthermore, historic records and analysis of mortars indicate that in the past the stronger grades of hydraulic lime (termed 'moderately' and 'eminently hydraulic'), which compare closely in strength to the modern NHLs, were reserved for high-strength applications such as military and civil works, and for work underwater or in persistently wet environments. Yet by the early 21st century NHL mortars were being widely specified for many conservation applications, sometimes even for internal plastering.

Learning from the past

Recognition that NHLs were not the hoped-for panacea forced a rethink. Why do modern conservation mortars fail to replicate the balance between durability and sacrificial behaviour seen in so many traditional mortars?

The answer lies in the evidence presented by historical mortars; analysis of thousands of samples has shown that a large majority were very lime-rich – often in the region of 1 part of lime to 1½ parts aggregate – compared to the 1:3 proportions of typical modern lime-putty mortars. Furthermore, with the exceptions mentioned above, most historical mortars were non-hydraulic or only slightly hydraulic – certainly nowhere near the strength of even the weakest NHL mortars. So, durability in traditional mortars seems to derive from a comparatively weak binder but used in larger quantities than in most modern lime-putty mortars.

However, it is almost impossible to make very lime-rich mortars using lime putty because one volume of putty contains too much water for 1½ volumes of aggregate, so the resultant mix is very sloppy. So, how were such mortars made in the past? Historical sources show that in many cases sand was mixed with lime in the form of

A common way of making mortar in the past was to place a ring of damp sand on the ground, pour the quicklime into the centre, add water and draw the sand over the quicklime to cover it. During slaking steam would be driven off as the heat dried the sand. After slaking it was an easy matter to mix the dry sand and the slaked lime, before adding more water to make mortar of the desired consistency.

Reference

1 Figueiredo, C, Henry, A, Holmes, S (2018) 'Hydraulic lime production: coming full circle?' in *Building Conservation Directory 2018*, Cathedral Communications, Tisbury

quicklime, not putty. Quicklime expands (by variable amounts depending on its composition) on slaking. So if a recipe called for, say, 1 part of lime to 3 parts of sand, after slaking this could be equivalent to 2 parts of lime putty to 3 parts of sand (or 1:1½).

There were various methods of making mortar with quicklime, depending on its intended application, but broadly speaking the process involves either layering or covering quicklime with sand and sprinkling it with water to initiate slaking. Slaking is an exothermic reaction (hence the modern term 'hot-mixed mortar' for mortars made this way) and, depending on the hydraulicity of the quicklime, it might be almost immediate or take up to a couple of days.

Once slaking was complete (or nearly so), additional water was added to bring the mortar to the desired consistency. Sometimes mortar might be used while it was still hot or warm, but in other cases it was allowed to cool. Non-hydraulic mortar could be stored as 'coarse stuff' and knocked up for use when needed. Some suppliers are doing this today – hot mixing non-hydraulic mortars and selling them in bags, tubs or dumpy bags in the same way as ready-mixed lime putty mortars are sold.

Before mechanisation, hot mixing was without a doubt the easiest way of mixing mortar, as it is much easier to combine sand with quicklime than with lime putty. But, even after mechanisation, mortars were still generally made with quicklime well into the 20th century. However, there were exceptions, particularly for fine plasterwork and some gauged brickwork, when lime was often run to putty before mixing with aggregate.

The new lime revival

Appreciation of the limitations of lime putty mortars and concerns about the strength of NHL mortars have triggered renewed interest in traditional mortars, and particularly a revival in hot mixing. This enables the creation of lime-rich mortars that match some historic mortars more closely, both in terms of appearance and performance. Furthermore, such mortars are sticky and bond well, even to dense stone. When mixing, the water content can be controlled so that the final consistency is never too wet, reducing the risks of drying shrinkage and of frost damage when working in winter.

Many claims have been made regarding superior performance of hot-mixed mortars. Most of the evidence for this derives from historical mortars – after all, many thousands of hot-mixed non-hydraulic or feebly hydraulic lime mortars have survived and performed well for centuries. Historic Environment Scotland recently commissioned a review of 24 hot-mixed lime harling projects carried out between 1990 and 2015. These demonstrated good performance, with the only unacceptable deterioration being directly attributable to poor detailing.

However, our understanding of why hot-mixed mortars perform so well is currently limited. Research carried out at the University of Dundee suggested that the high calcite content of such mortars imparts a beneficial pore structure that is salt- and frost-resistant'[2],[3]. Initial research carried out by Historic England has shown clear differences in pore structure between hot-mixed mortars and samples made with the same amount of lime in the form of lime putty. There were even differences depending on which hot-mixing method was used. Such differences could certainly affect how mortars handle moisture and salts, which is the key to durability. Historic England is planning more research to better understand the properties and performance of hot mixed mortars.

Mortar selection

Many suppliers and contractors have embraced the new lime revival, and are making and using hot-mixed mortars. However, there is currently no agreed standard for the materials or methods, so practices vary according to individual experience, leaving the door open for misunderstanding and failure.

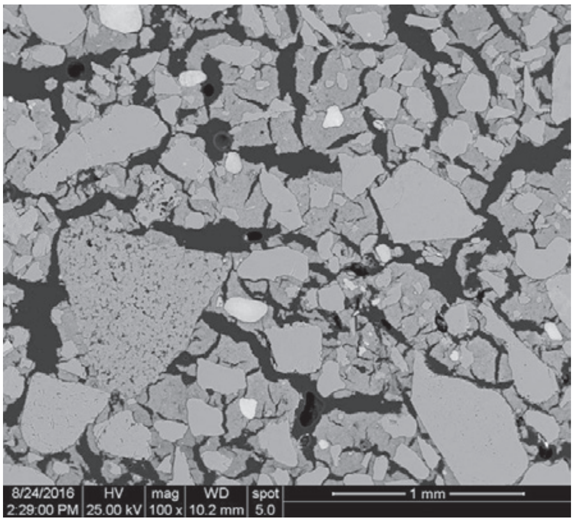
It is important to remember that hot-mixing is simply a method of making mortar, and that the properties of the mortar can, and should, be varied for different applications. As there is currently no readily available source of hydraulic quicklime in the UK, the focus of the hot-mixing revival has been on mortars made

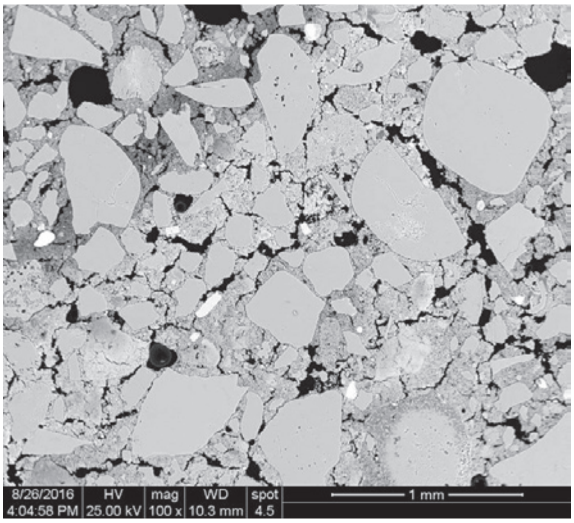
References

[2] Wiggins, D (2017) 'Traditional lime mortars and masonry preservation' in *Journal of the Building Limes Forum 2017*, Building Limes Forum

[3] Wiggins, D (2018) *Historic Environment Scotland Technical Paper 27: Hot-Mixed Lime Mortars: microstructure and functional performance,* Historic Environment Scotland

Small batches of hot mixed mortar can be mixed by hand or using a hand-held paddle mixer. Larger volumes can be made in a forced-action mixer or roller-pan mixer.





SEM images showing the difference in structure of two mortar samples. Both contain the same amount of lime (after slaking) and both were mixed to the same consistency. The sample above left was made with lime putty and exhibits considerable drying shrinkage, whereas the sample below left was made using quicklime and a dry-slaking process, and is much denser and has shrunk much less. (Images: Lucie Fusade)

with non-hydraulic quicklime. While these may have superior performance to, say, a 1:3 lime putty mortar for certain applications, they can not work miracles and may fail if used for some applications, particularly in exposed locations.

All mortars must be fit for purpose. When deciding what mortar to use, the first question should never be 'should I use a hot-mixed mortar?' That is a bit like saying 'should I steam or boil the vegetables?' without first deciding which vegetables you want to eat.

Sometimes the driving force behind mortar selection will be like-for-like replication of historical mortar. If it can be shown that the original mortar is lime-rich and was likely to have been made by hot mixing, it would make sense to replicate both the materials and method of mixing when making replacement mortar. However, the form and purity of quicklime available today is different to that used historically, so direct replication of historical mortars in every sense is not always possible.

If there is no historical mortar to copy (such as when replacing later cement pointing) or where the historical mortar is not performing appropriately, the primary driver behind mortar selection will be the required performance in the given context. This should take into account masonry type, condition, degree of exposure, and the proposed application (such as repointing or rendering). Guidance on this is provided in Historic England's Practical Building Conservation volume *Mortars, Renders and Plasters*. Once mortar performance requirements have been defined, the appropriate materials to impart those properties can be selected. There is a wide range of binders, aggregates and additives to choose from, and specialist advice may be needed to select the right ones. Only once this has been done should you consider whether the best way to make the mortar is by hot mixing.

For non-hydraulic mortars, hot-mixing may be a good method of production. For some applications it may be beneficial to use the mortar hot, but this is not always essential, which means that hot-mixed mortars do not necessarily have to be mixed on site. Ready-mixed mortars that have been prepared by hot-mixing are available from a number of lime mortar suppliers.

And the fact that most quicklime available today is non-hydraulic does not mean that hot-mixed mortars can not have hydraulic properties. If additional strength is needed, mortar can be gauged with a pozzolan or NHL. This is a particularly good way to make mortar with feebly hydraulic properties, but specialist advice may be needed to select the right additives. When strongly hydraulic mortar is needed for a severe environment or high-strength application, an NHL mortar may well be the most appropriate material.

Health and safety

Anyone who has seen quicklime being slaked in water will be well aware that slaking can generate very high temperatures. However, when hot-mixing, much of that heat is absorbed by the sand, and temperatures typically reach between 120 and 140°C – much lower than the temperatures that we encounter when taking a casserole or pizza out of the oven. This is not to say that hot-mixing is not hazardous, but the hazards can be managed by wearing appropriate personal protective equipment (gloves, mask, goggles).

The right context

Our historic buildings demonstrate the wide range of mortar types used in the past, from earthen mortar through non-hydraulic, feebly hydraulic, and stronger hydraulic limes to natural and early Portland cements. Where these mortars have proved fit for purpose, the objective in most conservation interventions will be to match them like-for-like. We therefore need a wide range of binders and mortars with varying properties. While hot-mixed mortars are a good match for many historical mortars and undoubtedly have many benefits, particularly in terms of authenticity and compatibility, it is essential that the current wave of enthusiasm does not lead to non-hydraulic mortar being used in contexts where it is unlikely to succeed.

When this happens is the material really to blame, or does responsibility lie with the specifier? Focusing on the performance requirements of mortar should reduce the risk of failure and help ensure that hot-mixed mortars are used appropriately, and make a major contribution to the conservation of historic buildings.

Further reading

Henry, A, Stewart, J (eds) (2012) *Practical Building Conservation: Mortars, Renders and Plasters*, Ashgate

Artis, R (2018) *Historic Environment Scotland Technical Paper 28: Specifying Hot-Mixed Lime Mortars*, Historic Environment Scotland

Alison Henry is senior architectural conservator, and head of the building conservation and research team, at Historic England.