Hot Mixed Mortars

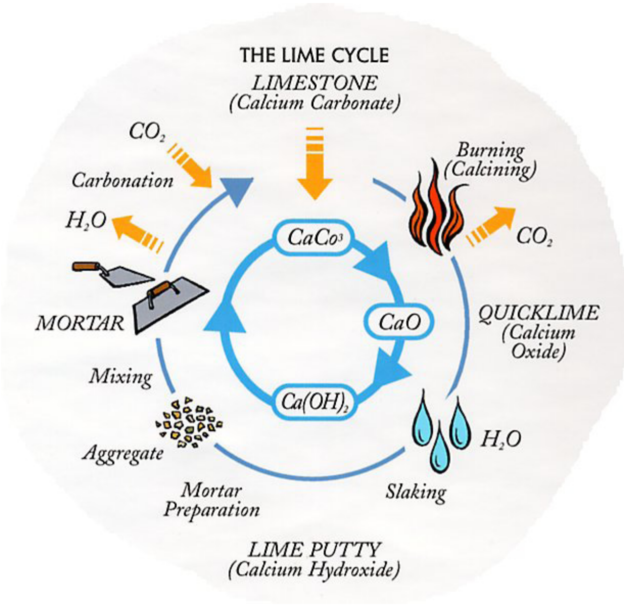
Advantages and limitations

'Hot mix', 'hot limes' and 'hot-mixed mortars' are all terms used more frequently within the conservation industry. But what exactly are they?

A hot-mixed lime mortar is one based on three components; quicklime, water and an aggregate such as sand. In a conventional mix, aggregate is mixed with lime which has previously been slaked. In this case, quicklime is mixed with the aggregate and then 'slaked' with water. The process generates heat, hence the terms. It may be used immediately as a hot mix or later when cool.

Quicklime

Quicklime is limestone (a rock rich in calcium carbonate) that has undergone a chemical change in a kiln, liberating it of all the carbon and water it holds ($CaCO^3$ 500-600°C} CaO + CO^2), creating a very unstable material (calcium oxide) which needs to hydrate. Quicklime will do so very energetically with any moisture it comes into contact with, resulting in a strong exothermic reaction and the production of lime (CaO + H^2O –} $Ca(OH)^2$), calcium hydroxide. The addition of water, slaking, has the potential to produce temperatures exceeding 250^0C very quickly. However, when creating a mortar the quicklime can reach these high temperatures as hot spots only, and the overall temperature of the mortar should not exceed 100^0C – the temperature at which the water turns to steam.



Sands

The general rule with mortars made with lime putty or naturally hydraulic lime (NHL) is that clean, washed sands and aggregates should be used. Dirtier sands tend to contain impurities such as clay minerals which absorb water and swell, so more water has to be added. This results in an increased risk of shrinkage in the mortar as it dries. With a hot mix, however, testing has shown that dirtier silica sands often work best as clean silica sands can make the mortar brittle. As the quicklime slakes it expands, so the original volume of lime increases significantly. A sand with a higher fines content (including clay minerals and other) can help combat the increase in binder due to the higher surface area of smaller particles. However, it is important that the fines content is not too high as excessive fines will still make the mortar prone to shrinkage.

Historic mortars

Before modern cements took over in the early 20th century, lime was the principal binder used for making mortars and renders. It was produced by burning limestone in a kiln at temperatures of 800°C. For the core of the limestone to reach the required temperatures in a reasonable time, the temperature in the kiln had to reach 950°C. In early kilns the temperature varied throughout, leaving lumps of lime unconverted and some sections over-burned.

The finished product could then be supplied to site as quicklime, or it could be slaked immediately and left to mature as lime putty, saturated with water. Today, it is generally accepted that lime putty was reserved for fine plasterwork, and that, for ordinary construction, mortars would have been hot-mixed on site with quicklime, water and sand/aggregate. Whether the material would have been used hot or stored and used cool is open for debate and various historic text refers to both applications.

Although a ratio of one part lime putty to three parts aggregate is widely specified for modern mixes, there is evidence that different mixes would have been used historically. This would have been down to several factors such as type of work, location, availability and cost.

When using a hot-mixed mortar today, a mix ratio of 1:3 quicklime and aggregate will, after expansion, produce a mortar that is 1:1.4 or even 1:1. Many historic mortar samples that have been analysed show a similar ratio with a high binder content. Making such a rich mix with a lime putty would have been impractical as the mortar would have been sloppy.

As our acceptance of their historic authenticity has gathered pace, more and more claims are being made about the benefits of using hot-mixed mortars and about the detrimental impacts of NHLs. While these claims may have been made with the best intentions, they are largely unsubstantiated by any scientific and real life data.

Benefits of Hot-mixed Mortars

A hot-mixed mortar offers a very workable material. Due to its high lime content, it is very sticky and this can help stop the mortar being washed out. It offers good water retention that can be controlled during the mixing process. And it can be a cost-effective option; the purchase price of quicklime is usually less than putty or NHL and cheaper, dirtier sands can be used.

From testing it has also been proven that hot-mixed mortars offer extremely high vapour permeability. Under lab conditions a hot-mixed mortar at 1:3 can offer vapour permeability up to 1.36kg/m^{2}sPa, whereas a comparable NHL 3.5 mortar at 1:3 will be around 0.69kg/m^{2}sPa. This has yet to be proven in the field or over long enough periods as carbonation is a very slow process. Nevertheless, it seems likely that a hot-mixed mortar could be twice as breathable as an NHL3.5 mortar, offering significant advantages to historic fabrics in many situations.

Which type of quicklime will work best?

Quicklime is available in two forms; 'kibbled' which is granular, containing particles from 1mm up, and finely powdered. Both of these are chemically identical, but kibbled is more dense than an equal volume of powder, and as mortars are usually mixed by volume not weight, mix proportions should be varied accordingly. (Kibbled expands to approximately 2.7 times its original volume, while powdered expands approximately 2.1 times.)

Powdered quicklime

- Reacts faster than kibbled – a quicker reaction can be harder to control and mix as it stiffens
- No hotspots – as a powder it is all of similar granulometry
- Plumes – powdered quicklime can be thrown into the air during mixing, posing significant health and safety issue (eyes, inhalation, skin)
- Limited pop outs – less prone to latent expansion after the mortar has been placed as almost all of it converts to lime.

Kibbled quicklime

- Reacts a little slower than powder
- Hotspots – larger pebbles can reach higher temperatures during slaking causing spitting
- No plumes – granules and pebbles are heavier and denser than the powder
- Pop outs – some larger pebbles can be slow to slake, causing delayed expansion which can disrupt the mortar face.

There are technical benefits and drawbacks to using either option. From a historic perspective, however, kibbled generally provides a better match for mortars which contain lime inclusions. These are particles of quicklime which have combined insufficiently during mixing.

Hot mixing mortar is not difficult, but it is more labour intensive than mixing putty or NHLs as the material is stiffer and stickier. While there are health and safety concerns due to the heat, with the adoption of appropriate measures on site the risks can easily be managed. The most significant risk is when mixing the powdered quicklime as it can plume into the air. If this is inhaled, able to dwell on skin, or comes into contact with the eye it can pose serious health risks.

Does it have to be used hot?

The short answer in no; hot mix is a term that has been coined due to the heat generated during the mixing phase, there are benefits to using the result immediately, while still hot.

Using it hot has the advantage that water content is easier to control, and the mortar is stickier and the work is quicker to finish. No storage facilities are required as the mortar is made in small batches. However, the mortar has to be made on site, close to the point of use, so work is slower. If used cold, large batches can be made either on site or by a commercial supplier, and pop-outs are less likely because the mortar has had more time to slake.

Is hot-mixed superior to NHL mortars?

One key argument for the use of hot-mixed mortars over NHL based mortars is that of strength. The problem is that the strength specified for an NHL at 28 days may have little bearing on its full strength, which may not be achieved for several years. As an example; the two-year compressive strength of a St Astier NHL3.5 mortar at 1:3 is approximately 4N. This is too high for soft masonry units as the compressive strength of the mortar could cause disruption to the host fabric, however most common building stone will be much harder than this (typically a poor sandstone has a compressive strength of 25N), so strength is not usually an issue.

Closely allied to this is the issue of permeability. For a mortar the general rule is that the higher the strength, the lower the vapour permeability, and it is claimed that NHL mortars can trap moisture within historic fabric. However, mortars made with NHL3.5 or weaker have been proven over many years that they have sufficient vapour permeability not to trap moisture.

There are claims that hot-mixed mortars do not need protecting in the same way as putty or NHLs, but this is not the case. All limes require babysitting in their infancy especially during winter months as a compressive strength of around 2N is required before they can cope with the impacts of frost. While NHLs may achieve this rapidly through a hydraulic set, non-hydraulic limes rely solely on carbonation. For this to occur at any depth, carbon dioxide must dissolve within the pore structure of the mortar, so a hot-mixed mortar must be kept damp. In cold temperatures moisture can hold less carbon dioxide and reactions occur more slowly. Even when warm, this is a very slow process, so the mortar is vulnerable to the effects of rain and frost for several months and it can take several years before full strength is fully achieved.

With very high binder content and relatively low strength, a hot mix will therefore be more prone to failure as a result of frost. During rain spells it will also be more likely to exhibit lime bleed due to the high binder content.

Hot-mixed mortars also have a high rate of absorbency. Under laboratory testing, a hot-mixed mortar at 1:3 became fully saturated in under 15 minutes. As a comparison, a typical putty mortar at 1:3 will take around 30 to 35 minutes and an NHL3.5 mortar at 1:3 around 60 to 80 minutes. Whilst vapour permeability is a significant factor in mortar selection, as its ability to wick moisture out of a wall, in exposed locations absorbency cannot be ignored.

Historic Precedent?

A point often raised is that hot-mixed mortars were used originally. However, we are now using very pure limes (CL90) which have no traces of hydraulic components. This type of lime cannot accurately be compared to historic limes, as most would have contained impurities which resulted in some hydraulic element, and aggregates were often used which would have had some pozzolanic effect.

We cannot claim to be using the material of our forefathers unless we revert back to the traditional methods of producing quicklime, and given the time and costs involved this would not be viable.

Conclusion

This article is not intended to deter anyone from using hot-mixed mortars. There is most certainly a place for their use within conservation, especially for mass wall building; they make fantastic bedding and pointing mortars. It really comes down to selection and location; the same factors we use to decide if putty or NHL is best suited. A pure hot-mixed mortar used in a location that is not subject to wind driven rains should work very well. And its high absorption and vapour permeability characteristics can be used to help wick moisture from a wall in many situations.

For more exposed situations, given that the majority of historic hot-mixed mortars analysed contained some hydraulic element, should we not be adding this back into the mix through the addition of a pozzolan or NHL? This is a practice that is carried out today and has been extensively used for the last 20 years in Scotland. A form of gauged hot mix will often be closer to the original than a pure lime hot mix.

There has been a consistent cycle within the lime movement of changing binders. It started with lime putty, which through improper use or inadequate specification resulted in some failures. We then moved towards NHL mixes to try to overcome these, which worked well for many applications. Now we are moving towards hot-mixed mortars. All of these binders were at some point hailed as 'the solution', and while our knowledge of these materials has significantly increased we are still constantly learning. Ultimately anyone aware of the virtues of lime and using or specifying the material is looking for the most appropriate mortar to conserve, enhance and protect a building. Hot mixes most definitely have a place within conservation and they offer another choice, but selection is critical and they should only be used where appropriate.

We cannot adopt a one-size-fits-all approach.

This article was written by Adam Brown BSc (Hons) is a qualified building surveyor who works for Cornish Lime, which supplies a full range of lime products including hot-mixed mortars, and offers technical consultancy. This article is based on a dissertation he prepared for his degree. The article can be found on page 37-38 of The Building Conservation Directory 2017.

The information given in this document is for guidance purposes only and is not intended to be a specification.